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Emerging economies – potentials, pledges and fair shares of greenhouse gas reductions

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Emerging economies – potentials, pledges and fair shares of greenhouse gas reduction

by

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Abstract

Greenhouse gas emissions need to decrease substantially to limit global average temperature to a maximum of2°C warming above the preindustrial level in 2100. Emerging economies are of increasing importance in this global effort. In this report we assess how ambitious emission reduction pledges of emerging economies are compared to business as usual emissions, the countries' mitigation potential and respective efforts based on different equity principles. We also compare the pledges and the identified mitigation potential of emerging economies to a global emissions pathway needed to limit global temperature increase to 2°C. Our assessment includes Brazil, China, India, Mexico, South Africa and South Korea.

We find that emerging economies have a substantial impact on future global emission levels. This is due to high current levels and high projected growth rates. Also, in most of the countries a large emission reduction potential is available. Action needs to be taken soon to enable the full use of the potential until 2020 and most emerging economies will need significant support from developed countries to implement those.

Kurzzusammenfassung

Globale Treibhausgasemissionen müssen drastisch sinken, um den durchschnittlichen globalen Temperaturanstieg im Jahr 2100 auf 2°C gegenüber dem vorindustriellen Niveau zu begrenzen. Schwellenländern kommt eine wachsende Bedeutung in dieser globalen Anstrengung zu. In diesem Bericht untersuchen wir, wie ambitioniert Emissionsminderungszusagen von Schwellenländern im Vergleich zu Referenzszenarien, zum Minderungspotenzial der Länder und zu Ergebnissen sind, die sich aus auf Gerechtigkeitsprinzipien basierenden Verteilungsansätzen ergeben. Außerdem vergleichen wir, wie sich die Emissionsreduktionszusagen und Reduktionspotenziale zu einem globalen Emissionspfad verhalten, der nötig wäre um das 2°-Ziel zu erreichen. Wir untersuchen die Länder Brasilien, China, Indien, Mexiko, Südafrika und Südkorea.

Aus den Ergebnissen geht hervor, dass Schwellenländer einen großen Einfluss auf zukünftige Emissionen haben werden. Dies begründet sich aus ihren derzeitigen bereits hohen Emissionsniveaus, den hohen zu erwartenden Wachstumsraten sowie auf den hohen identifizierten Minderungspotenzialen. Die Länder müssen geeignete Maßnahmen sofort umsetzen, um das Potenzial bis 2020 auszuschöpfen. Die meisten Schwellenländer werden dafür erhebliche Unterstützung aus Industrieländern benötigen.

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List of Abbreviations

ADB	Asian Development Bank
AFOLU	Agriculture, Forestry and Land Use
BAU	Business as usual
BRT	Bus Rapid Transit
C&C	Contraction and Convergence
CCS	Carbon Capture and Storage
CDC	Common but Differentiated Convergence
CCS	Carbon capture and storage
CFBC	Circulating fluidized bed combustion
CNG	Compressed natural gas
CO2	Carbon dioxide
DoE	Department of Energy
EDGAR	Emission Database for Global Atmospheric Research
EREC	European Renewable Energy Council
EVOC	Evolution of Commitments Model
GDP	Gross Domestic Product
GDRs	Greenhouse Development Rights
GHG	Greenhouse gas
HDI	Human Development Index
IEA	International Energy Agency
ICCT	International Council on Clean Transportation
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied petroleum gas
LULUCF	Land Use, Land Use Change and Forestry
NAFTA	North American Free Trade Agreement
NAPCC	National Action Plan for Climate Change
NCCR	National Climate Change Response
OECD	Organisation for Economic Co-operation and Development
Pemex	Petróleos Mexicanos
PFBC	Pressurized Fluidized Bed Combustion
PPCD-Am	Plan for Prevention and Control of Deforestation in the Amazon
PPCerrado	Plan for Prevention and Control of Deforestation and Forest Fires in Cerrado

SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales
SENER	Secretaría de Energía
SN	South North approach
SWH	Solar Water Heaters
TERI	The Energy and Resources Institute
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
WEO	World Energy Outlook

Executive Summary

With the Copenhagen Accord, the international community has committed to the aim of limiting anthropogenic greenhouse gas (GHG) emissions to levels that would hold the global average temperature below 2°C (UNFCCC 2009). To achieve this objective, global emissions need to decrease from present levels of around 50 $GtCO_2e/a$ to 41 to 46 $GtCO_2e/a$ in 2020 in comparison to a business as usual (BAU) pathway of 55 to 59 $GtCO_2e/a$ (UNEP 2011).

According to Article 3.1 of the United Nations Framework Convention on Climate Change (UNFCCC), "parties should protect the climate system (...) on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities". This principle requires developed nations to take the lead in mitigation action. It also invites them to support developing countries in fighting climate change and adapting to its impacts.

Since the beginning of climate negotiations in the 1990s, emerging economies have gained importance in the international arena. This is reflected both in their increasing economic and in their rising GHG emissions. The countries that this report analyses - Brazil, China, India, Mexico, South Korea and South Africa - together emitted one-third of global GHG emissions in 2008 (EDGAR 2011).

This report focuses on two main questions:

- How ambitious are the pledges of the different emerging economies when compared to
    - baseline scenarios (BAU) of national emissions
    - the country's mitigation potential and
    - respective efforts based on different equity principles?
- How do the pledges and mitigation potential of the emerging economies relate to the global emissions pathway needed to limit global temperature increase to 2°C by the year 2100?

The assessment is aimed to provide insights from an international perspective. We do not evaluate national policies or specific barriers and instruments to implement the identified potentials at a national level.

Overview of methodology

We base the evaluation of pledges on literature research. Our analysis consists of three parts:

- The pledges and national climate strategies
- Mitigation potential as determined in public literature
- Results of different effort sharing approaches

We first collect existing baseline scenarios and assess the emission levels resulting from the pledges. Where countries have provided data clarifying the absolute levels of their pledge or the relevant baseline we use this data. If alternative baseline scenarios are publicly available we

show them to provide a better context for the analysis.[1] The second step is to collect mitigation potential identified in the literature and classify it into different cost categories:

- No-regret measures: no or negative costs.
- Measures with co-benefits: Measures come at moderate positive cost or at higher cost with significant co-benefits that lower overall cost to society.
- Ambitious measures: Measures are available at higher cost and potential co-benefits do not outweigh these costs in a societal view.

For each country assessed, we compare this potential to the pledged emission reductions.

We furthermore calculate the necessary emission reductions according to various effort sharing approaches using the Evolution of Commitments (EVOC) model. The results are again compared to mitigation potential and pledges.

The second part of the analysis in this report consists of looking at the impact of emerging economies' mitigation actions on global emission pathways. Here, we vary the actions of our target countries in the context of different global scenarios.

Using the reduced complexity coupled climate/carbon-cycle model MAGICC 6, we estimate the effects of these emission scenarios on global-mean temperature increase by 2100 and evaluate the probability of exceeding 2°C warming within the 21st century.

Key conclusions

Emerging economies have significant influence on future emission levels because of their present level of emissions and high expected growth rates. Our analysis has identified substantial mitigation potential in these countries. Only with ambitious actions in all countries by 2020 can global emissions be reduced most cost-efficiently to a level which would hold global temperature increase below 2°C.

Immediate action is necessary by both developed and emerging economies: With every year delay in action, we can achieve less of the reduction potential by 2020. Delay decreases the likelihood of reaching the pledges and means that reductions at a later time will need to occur more rapidly and will be more expensive. To ensure pledges are met, countries analysed in this report would have to implement at a minimum all available "no-regret" measures as soon as possible. The implementation of all required measures over the remaining eight years to achieve the pledges may seem more ambitious today than when the pledges were first discussed in 2009, as the time frame now available for technical implementation is much tighter.

The depth of reductions in emissions implied by the international pledges compared to BAU levels differs between the countries. China's and India's international pledges are close to or even above their estimated BAU emissions and hence there is a good chance they will achieve or even over-achieve their pledges. Mexico and South Korea have rather ambitious pledges, which will require substantial deviation from the BAU trajectory. South Africa's pledge of 34%

[1] We do not develop our own baselines or evaluate policies within the countries.

below BAU is a strong reduction, but South Africa has given a wide uncertainty range for both its pledge and BAU levels and thus does not allow a definite evaluation. Similar - even more severe - issues arise for Brazil, where the uncertainty associated with land use, land-use change and forestry (LULUCF) emissions is too high to allow us to determine whether reaching the pledged emission level would be a significant improvement relative to the BAU level.

Pledges of emerging economies make use of the countries' potential to different degrees. While South Africa and Mexico would need to exploit a large share of their identified potential, India's and China's pledges would need to tap only a share of the potential. South Korea and Brazil are difficult to evaluate in this context due to the lack or uncertainty of data.

Sharing the global reduction effort based on selected equity principles would for some of these principles require a more stringent pledge from China and potentially also from Brazil. Results from different effort sharing calculations vary significantly depending on the approach, but tend to show that the pledges of India, Mexico, South Africa and South Korea are within the range resulting from the effort sharing approaches, while China's efforts to reduce emissions could be higher than under the current pledge for some effort sharing approaches. Brazil should, according to most approaches, also increase the level of ambition of its pledge, but again high uncertainty around LULUCF and its impact on emissions in 2020 allows only an indicative assessment.

For some countries, there are effort-sharing approaches, which would require emission levels lower than what can be reached by implementing the full mitigation potential identified in this report. However, it is important to be clear that the mitigation potential included in this study is incomplete. First, the literature used as a basis may not have covered the complete mitigation potential and second, we analysed only the set of selected standard measures identified as most important.

Support from developed countries is needed: For some countries, the mitigation potential goes significantly beyond what the results of various effort sharing approaches imply. Of the countries assessed in this report, this holds especially for India, South Africa and Mexico. Furthermore some countries - like South Africa - will need to tap into higher cost potentials to be able to meet their pledge. We conclude that there is a need for more developed countries support for these countries to exploit their mitigation potential. A more precise formulation of support requirements on the part of emerging economies could help to ensure fast provision and timely implementation.

Data availability is low and uncertainty is high, making it difficult to evaluate and compare countries. Furthermore, pledges are generally not defined as absolute emission levels in 2020 but relative to baselines, which are often subject to changes in definition and the sectors covered, or depend on growth of Gross Domestic Product (GDP), for which forecasts are highly uncertain.

The absolute level of emissions resulting from a pledge depends on a variety of factors and interpretations require various assumptions. The table below gives an overview of some important parameters of the pledges and roughly indicates our overall evaluation of the pledge.

Tab. 1 Overview of information and evaluation for the countries analysed

	Brazil	China	India	Mexico	South Africa	South Korea
GHG inventory provided for a recent year	✓	✓*	✓	✓	✓	✓
Absolute level of pledge in 2020 is clarified and fixed	✓					✓
Absolute level of pledge in 2020 is variable		✓	✓	✓	✓	
Changes of pledge since December 2009	Less stringent: Baseline emissions corrected upwards				Less precise: Baseline modified from one value to a range	More stringent: Baseline emissions corrected downwards
Overall evaluation of the pledge	Level of ambition of pledge unclear due to high uncertainty of BAU and underlying assumptions on forestry	Pledge less ambitious than some effort sharing approaches; likely to be overachieved with national policies	Pledge close to BAU but in line with effort sharing approaches; likely to be overachieved	Pledge ambitious against potential and effort sharing approaches	Pledge ambitious against potential and effort sharing approaches, but uncertainty range limits evaluation	Pledge ambitious against most effort sharing approaches; limited information on potential

*: China submitted its Second National Communication in November 2012 (Government of China, 2012), which for the first time includes a recent GHG emission inventory and scenarios for future emissions. The Communication was published too late to be fully considered in this report.

Detailed results per country

Below, we describe the countries' results in more detail. For each country analysed, we display the range of emissions resulting from the BAU projections, the pledged emission reductions, the available mitigation potential distributed to cost categories and the results from different effort sharing approaches[2].

Brazil

The great uncertainty around Brazil's LULUCF emissions does not allow a precise evaluation of the pledge.

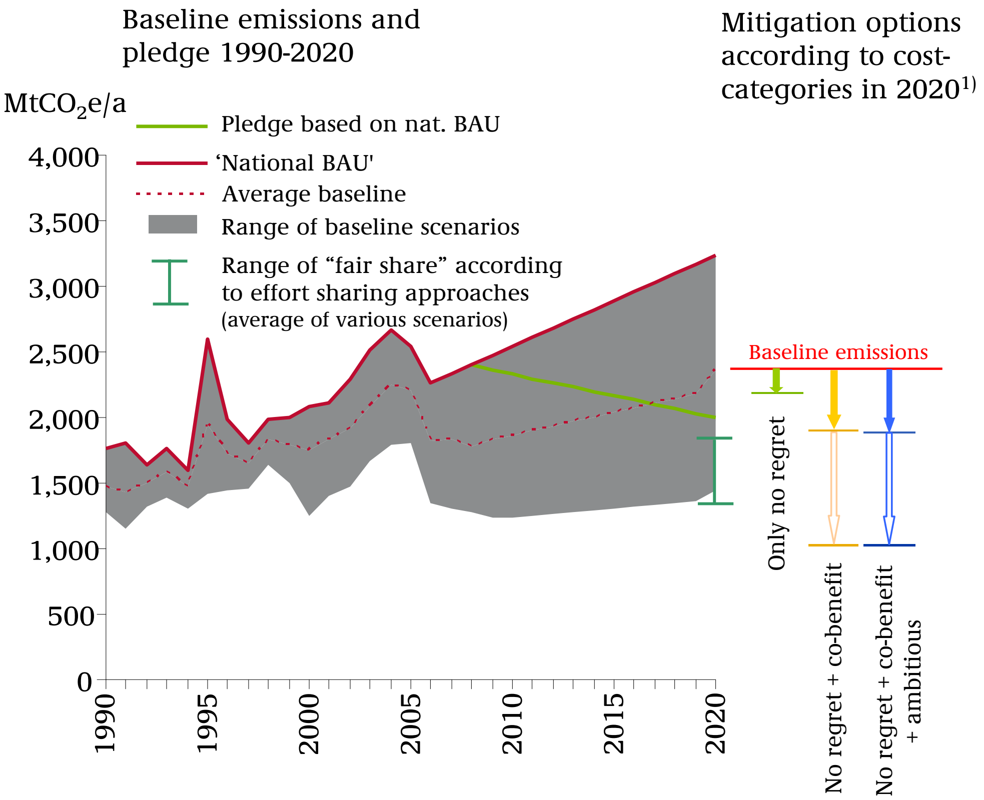
Huge uncertainties associated with LULUCF lead to a mixed picture

Given the large range in BAU emissions, the evaluation of the impact of the identified mitigation potential is difficult. While the pledge to reduce emissions by 36-39% below BAU levels by 2020 seems ambitious at first sight, there are immense uncertainties connected to the data situation.

Assuming the average of the different BAU scenarios is a realistic approximation, the identified low end of the no-regret and co-benefit potentials could already overachieve the target. However, Fig. 1 illustrates the difficulty in evaluation. The pledge relates to the BAU scenario defined by the Brazilian Government, which forms the upper boundary of the range. The World Bank report (Gouvello, 2010) calculates a BAU emissions level that is 454 $MtCO_2e/a$ below the high end of the pledge range.

[2] For a more detailed description of the figure, please see chapter 2.1.2.

Only a small share of the identified mitigation potential comes at negative cost; this is mainly from measures in re-/afforestation, agricultural soils and energy efficiency in industry. The largest potential, from reducing deforestation, comes at moderate cost and determines the overall picture. The high ambition potential identified in a fuel switch in the transport sector will not contribute an overall significant reduction.



1) Mitigation potential includes major measures with highest potential only. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 1: Brazil: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches[3]

Given the emissions profile of Brazil the most important political instrument for Brazil's mitigation trajectory is forest legislation. The Forest Law was established in 1965 to protect forest areas in Brazil. In April 2012 the Brazilian Congress passed a highly controversial amendment. Effects of this are estimated to make it harder for Brazil to meet its emissions reduction target as well as its reductions in deforestation rates (Höhne et al., 2012). The amendment was only partially approved by the President, Dilma Rousseff. At this moment it is unclear what the effects of the changes will be and how it will affect the ability of Brazil to tap the mitigation potential analysed in this study.

[3] Unless otherwise specified, all figures and tables in this report are the authors' own.

Separation of the pledge for LULUCF and non-LULUCF would improve transparency and increase incentives

Brazil has defined its pledge as a "range" of 36 to 39% below BAU emissions. The basis used for this reduction is at the high end of available BAU estimates and depends very much on assumptions made for the development of the LULUCF sector. Due to the high uncertainty of these assumptions we propose to differentiate the pledge to cover LULUCF and other emissions separately. This would allow for a more transparent tracking of success and provide better incentives to the non-LULUCF sectors. A revision of the LULUCF projections based on the latest findings may also be appropriate.

Pledged levels are not ambitious due to the high BAU level – effort sharing approaches ask for deeper reductions

We have used the average of several BAU emission scenarios as the best estimate for future development for all effort sharing calculations that are related to BAU emissions, i.e. all except the Contract & Convergence (C&C) approach. Under this assumption, the results show that all effort- sharing approaches require a more ambitious reduction than that pledged by Brazil. The pledge is largely in line with the C&C approach, where per capita emissions converge by 2050. The approach that would require the most stringent reduction from Brazil is the Greenhouse Development Rights (GDR) approach. This approach is a function of income, equity of distribution of income and responsibility.

LULUCF leads to large uncertainties in estimates of reduction potential

This assessment of Brazil's mitigation potential shows:

- Brazil's mitigation potential lies mainly in the land-use sector, reflecting its emissions profile. Both emission projections as well as reduction potentials in this area are characterised by a high level of uncertainty and estimates vary significantly depending on the assumptions made.
- The literature on Brazil identifies only limited potential for the energy sector. The main reduction potential outside the land-use sector is in the industrial sector and is based on improvements through increasing efficiency and on the use of sustainable biofuels, mainly replacing unsustainable biomass use.

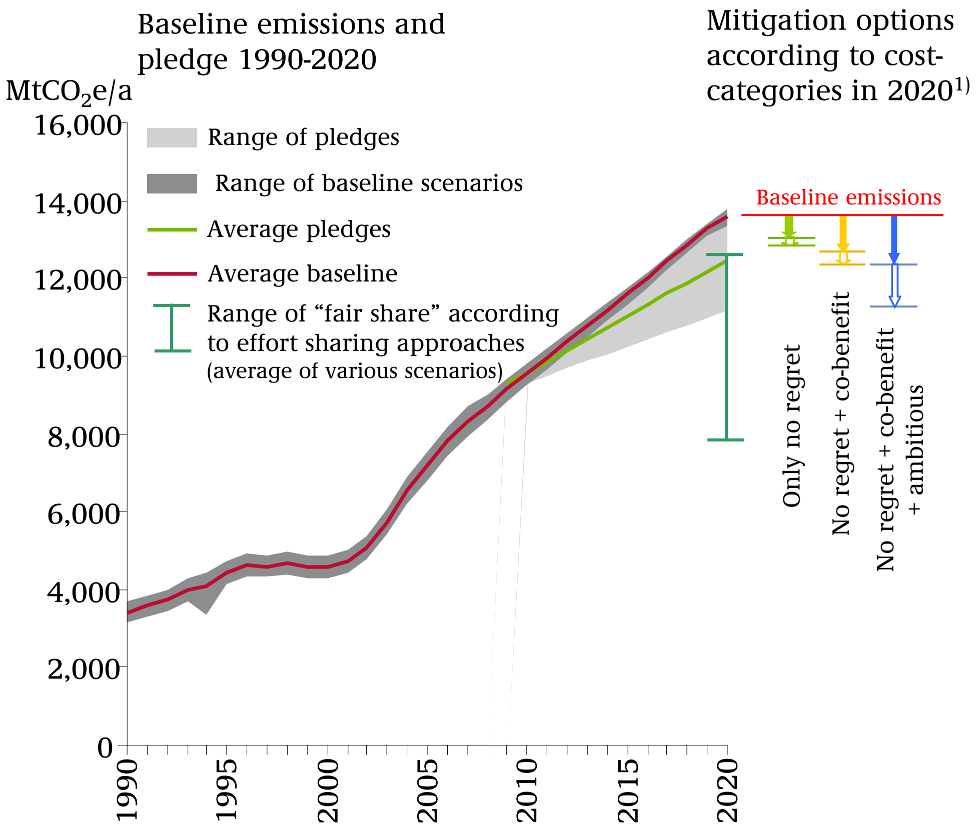
Considering the uncertainty related to estimating emission development until 2020, Brazil's pledge seems to be not very ambitious. The emission level resulting from some of the alternative BAU projections would be higher than the official pledge levels. But even assuming that the average BAU from the different projections is a realistic estimate of real development, the pledge delivers only a 14 to 16% reduction and could be implemented at moderate costs according to all studies reviewed.

China

China's international pledge leads to improvements compared to emission trends. Mitigation potential is likely to go beyond what is pledged. Effort sharing approaches based on per capita emissions suggest a more ambitious target could be warranted. National policies may be more ambitious, but their total effect was not evaluated here.

The mitigation potential identified in this report is larger than what China pledged internationally. Effort sharing approaches based on per capita emissions would suggest a more ambitious target. Meeting the pledge, China will increase its emissions to up to 14 $GtCO_2e$. National policies may be more ambitious but their total effect was not evaluated in detail here.

China submitted its Second National Communication in November 2012 (Government of China, 2012), which for the first time includes a recent GHG emission inventory and scenarios for future emissions. The Communication was published too late to be fully considered in this report. Our preliminary analysis confirms our conclusion, China's emissions would rise to 14 $GtCO_2e$ when meetings its pledge.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 2: China: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches

Meeting the pledge will slightly slow down but not stop China's emissions growth

Fig. 2 shows that the pledge can result in a range of emissions (from 11,200 to 13,700 $MtCO_2e/a$ in 2020), depending on different assumptions, mainly future GDP growth. The average of the pledge estimates (12,500 $MtCO_2e/a$ in 2020) is only 9% below the BAU trajectory and it is clear that making use of the mitigation potential, emission levels can be decreased further below the pledged level.

The range of pledged emissions overlaps with the range of BAU emissions. The pledge calculated based on IEA data is very close to BAU emissions based on the same information.

The IEA baseline already includes some of the Chinese policies and therefore is likely to be close to the pledge. The data from the Chinese Energy Research Institutes (ERI 2009) shows a larger difference between the pledged and BAU levels.

China has put forward an emission intensity target with the rationale that international climate change mitigation commitments should not constrain economic growth and development. This view does not necessarily reflect opportunities for growth in the area of climate change mitigation ("green growth"). With its dynamic growth, China can develop this area to make use of this concept and to reduce national emissions further. China already implements many national measures that could go beyond the international pledge. As such it is likely that the pledge will be achieved or overachieved.

China's dynamic growth can also be an opportunity for mitigation actions

The main possibilities for GHG mitigation in China lie in the energy supply sector, specifically in the area of renewable energy, and in the industrial sector, specifically in the area of energy efficiency. Another important area of improvement is the building sector, which is subject to rapid changes due to increasing economic wealth.

The total potential considered here takes us below the pledged emission level calculated based on IEA data. To reach the ambitious end of the pledge range, ambitious measures will have to be taken. With all the potential assessed, only the upper range of the potential including all three cost categories goes beyond the pledged emissions.

Effort sharing approaches based on per capita emissions would suggest a more ambitious target.

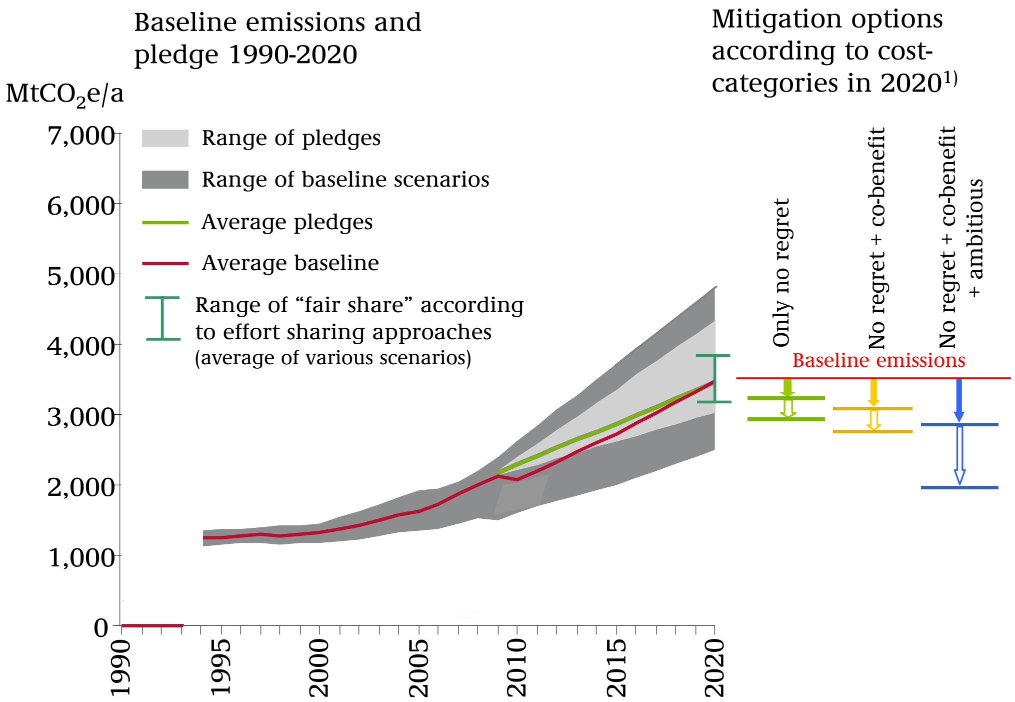
The results from different effort sharing approaches vary substantially across different approaches depending also on the assumed baseline development. The different approaches find emission reductions to be necessary between 6 and 41%[4] below BAU levels in 2020, generally more stringent than the pledged level of around 8% below BAU (the average of both data sources).

The most stringent approaches for China are common but differentiated convergence (CDC) and C&C (38% and 40% below BAU), which are both based on convergence of per capita emissions. As China already has relatively high per capita emissions in comparison to other non-Annex 1 countries, these approaches lead to higher reductions that need to start immediately. Less stringent are Triptych and the South North (SN) approaches (19% and 10% below BAU). Triptych, based on converging sectoral efficiency, allows for growth in production volumes, which will be significant in China. The SN approach judges China's capacities and responsibilities to be smaller than the other three approaches by putting it into a certain stage of development. The Greenhouse Development Rights (GDR) approach is the least stringent approach (6% below BAU in 2020), because major shares of the population are still below the defined threshold of 7 500 US$ income per capita in China.

[4] The percentage indicates the mean average of the scenarios calculated with the EVOC model. The complete range is shown in Fig. 20.

India

India's pledge does not exploit the full technical mitigation potential, but is in line with what some effort sharing approaches suggest. Our results thus reflect India's need for international support for additional GHG reductions.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 3: India: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches

India's pledge does not reveal an improvement on BAU

The average of the pledges lies at about the same level as the average BAU level, meaning that no reduction below BAU can be seen. Most sources expect the pledge to be overachieved in the BAU scenario. The mitigation potential can reduce emissions further than the pledge.

Vast potential seen in the area of renewable energy

India has large mitigation potential especially in the area of renewable energy. Other important areas are efficiency and alternative processes in industry and efficiency of appliances in the building sector.

If the most optimistic numbers for mitigation potential are considered, India is able to almost halve its emissions in 2020 by implementing the identified measures. About one third of the identified potential is covered by no-regret measures. About 50% has to be exploited by the use of measures in the "ambitious" cost-category.

International support needed to make use of India's mitigation potential

The results of the effort sharing approaches show a wide range, but many lie within the range of the pledge. At the same time, the maximum potential goes much further than the most stringent approach, taking as a reference the average BAU level for both.

The least stringent effort sharing approaches (which fall into the range of the pledged emissions) rely on convergence of per capita emissions. Because these are very low in India today, these two approaches allow a higher level of total emissions in 2020 than the others. The most stringent approach for India is Triptych, providing for global convergence of efficiencies on a sectoral level. This approach requires a major shift away from coal for all countries, which would affect India significantly.

Effort sharing approaches suggest reductions are need to, or slightly more than, the level of the pledge. Mitigation potential is available to a greater extent than that which would be required by the most stringent effort sharing approaches. This supports the need for international support for India to realise this mitigation potential.

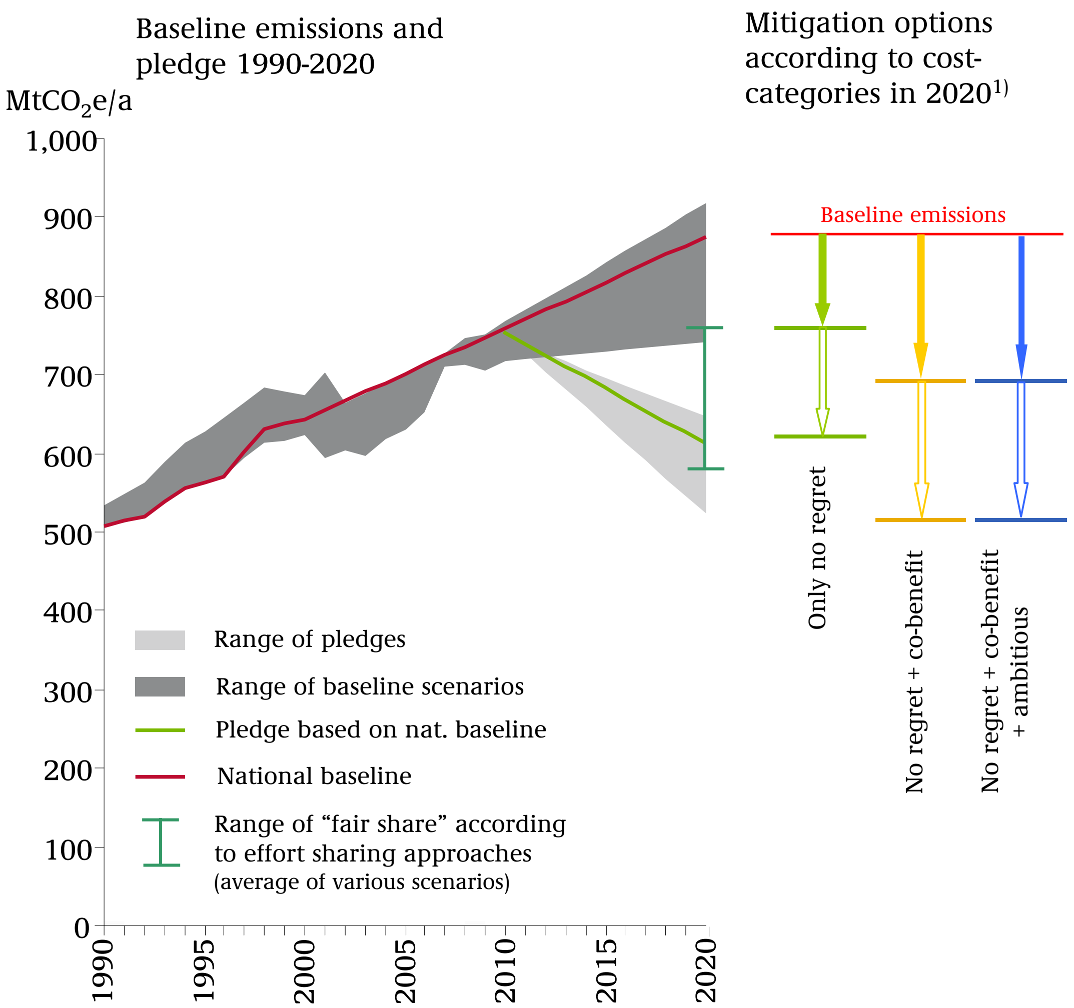
Mexico

Mexico could achieve its pledge at moderate cost if it fully implemented all measures assessed in the literature. The pledge is in line or more ambitious than expectations of most effort sharing approaches. This suggests that Mexico has grounds to call for international assistance to meet the moderate costs associated with realising its pledge.

Ambitious pledge based on conservative baseline could be achieved at no or moderate cost

According to the potential as identified in the studies Mexico could achieve its pledge at no or moderate cost if it fully implemented all measures.

Fig. 4shows that the baseline provided by Mexico is rather high compared to the range of projections and thus connected with a high level of uncertainty. Also the potential evaluated in the literature shows a high level of uncertainty. The total minimum potential represents the lowest common denominator between the studies and is across the categories up to 124 $MtCO_2e/a$ in 2020. The high end of the potential is given at 322 $MtCO_2e/a$. The total range is almost three times as large as the minimum potential.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 4: Mexico: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches

Mexico has been an active player in the international climate change arena over the last years, in the lead up to the Cancun meeting in 2010 as well as in the years since. At the national level a significant amount of legislation has paved the way for further action, including the General Law on Climate Change passed in April 2012. The institutional set-up as well as the availability of high quality national research in different sectors would allow rapid action. Since the elections in July it has not been clear how far the new government will utilise this positive starting point to implement policies and measures to tap the identified potentials.

Clarification of support requirements could speed up implementation of actions

Mexico has made the pledge conditional to international support. It has so far not specified how much funding and which types of other support would be required to achieve the pledge. As time is running out fast to implement measures that achieve substantial reductions by 2020, it would be useful to quantify the requirements for international funding.

The pledge is ambitious compared to results from effort sharing approaches

Fig. 4 shows the full ranges for the BAU scenario as well as the pledged level. The results from different effort sharing approaches are all within or above the pledge range. This means that the pledge is in line with or more ambitious than the reductions expected from the country under the different effort sharing approaches. The most ambitious effort sharing approach is the CDC, which requires a reduction to 568 $MtCO_2e$/a in 2020 (mean); lower than the official pledged level but still within the pledge range.

The approach requiring the least ambitious reduction from Mexico is C&C. With this approach Mexico could emit 707 $MtCO_2e$/a in 2020.

Overall it can be concluded that Mexico's pledge can be rated ambitious compared to the different effort sharing calculations. Furthermore it could likely be achieved at moderate cost to society if all measures identified in the studies are fully implemented. However, the potential as identified diminishes with each year of inaction and will make the achievement of the pledge more and more difficult and costly.

Assessment of Mexico's mitigation potential

The assessment of Mexico's mitigation potential shows:

- Mexico has a wide range of different mitigation potential in all sectors. There are some measures that draw immediate attention, like reducing deforestation and increasing renewable energy production, but no single measure has the potential to deliver the required reductions for Mexico to achieve their target.
- A wealth of information and thorough assessment from various sources exists on potential activities, technological choices and economic considerations to guide decision-making.
- Many of the potentials come at negative or very moderate cost and are connected with substantial co-benefits, for example in the transport sector, where measures could lead to improved air quality and thus reduced health problems as well as reduced time required for commuting to work, thus increasing quality of life and overall productivity.

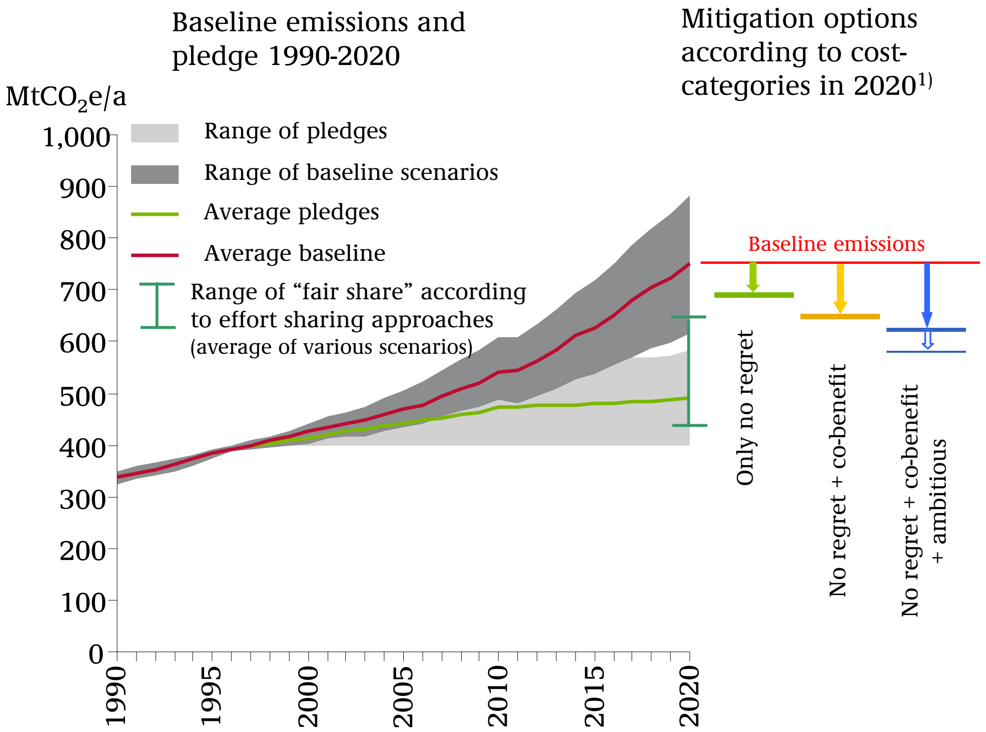
Our analysis only covers the most important measures. The total potential is therefore underestimated. Additionally some of the studies that form the basis of this exercise did explicitly exclude high cost options, leading to a further underestimation of the real potential. This enhances the analysis that Mexico has ample potential to not only meet its pledge, but to achieve additional reductions.

South Africa

While there is substantial potential in the mid-term, meeting the 2020 pledge will require immediate and strong actions, which need to be supported internationally.

Ambitious long-term vision for emission reductions – but not yet implemented

South Africa has developed a long-term vision for its low-carbon transformation: to peak emissions between 2025 and 2035 and decline thereafter. The National Climate Change Response (NCCR) White Paper, which was adopted in 2011, underpins the conditional pledge made by South Africa to reduce its emissions by 34% below BAU levels by 2020 (and 42% by 2025).



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 5: South Africa: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches.

The issue of climate change has gained political momentum in the country – and not only in the run-up to the COP 17 in Durban in 2011. Very much responsible for this is the Department of Environmental Affairs, which also drafted the NCCR strategy. The whole process is well grounded in sophisticated assessments of emission scenarios and mitigation potential (mainly by the Energy Research Center, University Cape Town). In the meantime, other ministries and players have taken up the challenge of reducing GHG emissions substantially (e.g. in the 'Integrated Resource Plan' for electricity generation by the Department of Energy (DoE 2011b)).

However, the latest development of South Africa's GHG emissions indicates that no substantial deviation from the BAU trajectory has been achieved so far (DEA 2011c). South Africa's average mitigation pledge for 2020 has already been overshot (see Fig. 5). The conclusion of this is quite dramatic: due to weak implementation of mitigation actions in the past, the country will have to strive towards absolute emission reductions in the future to reduce its emissions down to the level of its average pledge.

South Africa's absolute pledged emission level unclear

South Africa has defined its pledge to be 34% below BAU. As a result, the absolute level of the pledge in 2020 is variable, depending on the actual development of GHG emissions until then. The BAU scenario used as a basis for national policy implementation is defined as a range with lower and upper limits in the White Paper. Our analysis uses this range as a basis for determining the emissions resulting from the pledge.

Looking at historic data, the range in the White Paper rather underestimates emissions in South Africa. According to the 2nd National Communication, emissions in South Africa in 2000 were 461 $MtCO_2e$ (excl. LULUCF), while the White Paper's maximum is at 437 $MtCO_2e$. The actual expected emission level in 2020 implied by the pledge is thus rather unclear.

Pledge is in line with global mitigation responsibilities

South Africa's pledge is in line with or even more ambitious than mitigation responsibilities according to the effort sharing regimes of GDR, SN and Triptych (see Fig. 5), which are based on responsibility and capability criteria. However, South Africa has relatively high emissions per capita already (>9 tCO_2e/person in 2008). Consequently the pledge is not ambitious enough to meet the criteria of per capita based equity models. The upper margin of the pledge is hardly in line with the CDC model requirements. To meet the C&C requirements, South Africa would have to fulfil the average value of its pledge range.

Assessment of South Africa's mid-term mitigation potential – stronger short-term action needed

This assessment of South Africa's mitigation potentials shows:

- Huge mitigation potential exists in South Africa at negative cost (no-regret potential) or with substantial co-benefits (e.g. reducing local emissions and subsequent health risks or supporting other development goals in South Africa). Increasing energy efficiency in industry with a no-regret potential of 61 $MtCO_2e$in 2020 is a key example.
- South Africa's mitigation pledge is based on a thorough assessment of the country's development path and its mitigation potential (Winkler 2007a). Consequently, the sum of all mitigation measures provides sufficient potential to reach the country's pledge.
- However, we estimate that neither nuclear power nor Carbon Capture and Storage (CCS) (for both coal-fired power plants and synfuel coal to liquid plants) can make a significant contribution to South Africa's mitigation aspiration by 2020 – due to long planning horizons and uncertainties for nuclear power plants and lack of proven commercial scale technology for CCS. This assessment is irrespective of the long-term mitigation potential of these technologies in South Africa.

In conclusion, South Africa has a tremendous mid to long-term mitigation potential at moderate cost. However, meeting the country's 2020 target will require strong short-term action. South Africa will have to address all available mitigation options simultaneously, including more costly options. In this respect it needs to be noted that South Africa's pledge is conditional to international support. A large short-term mitigation potential exists specifically in the fields of energy efficiency, renewable energy, waste and land-use change. Immediate action is required to ensure its full deployment – not only to meet the countries 2020 target, but also to facilitate a cost-effective long-term mitigation pathway.

South Korea

South Korea's pledge is likely to be rather ambitious, although lack of data on mitigation potential makes an assessment difficult.

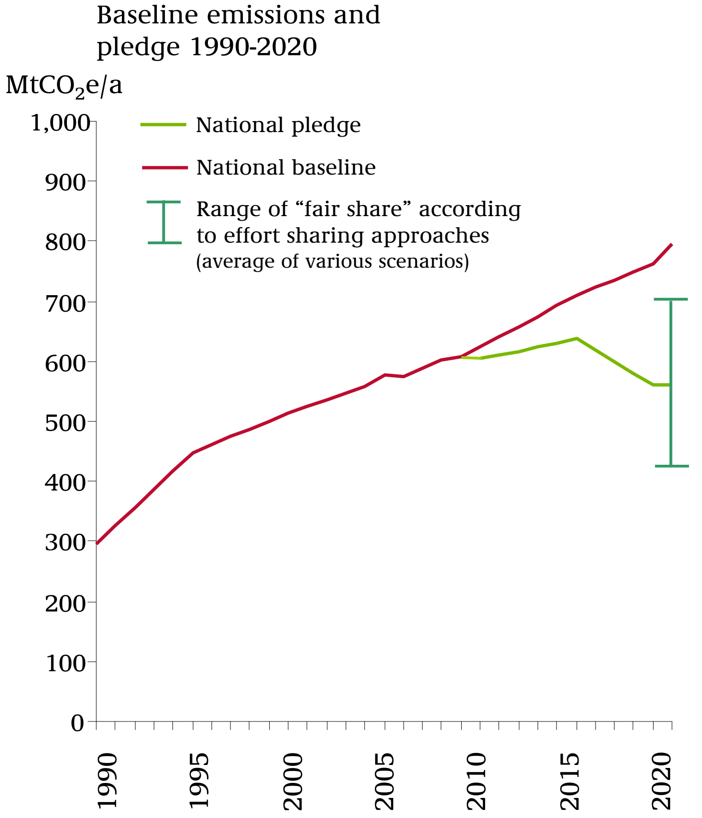


Fig. 6: South Korea: Projected BAU and pledged emissions compared to results from effort sharing approaches

Ambitious pledge - climate protection a high national priority

South Korea's pledge of 30% GHG reductions relative to BAU in 2020 is on the ambitious end of the range of effort sharing approaches we have assessed. Korea has a very fast-growing economy, and is now being classified as converging to the highest-income countries by the Organisation for Economic Co-operation and Development (OECD) (OECD 2012). The commitment was adopted by the Korean government in 2009 after an analysis of Korea's reduction capacity and the macroeconomic impacts of the reduction, despite the opposition of the industrial sector (R.S. Jones / B. Yoo 2011). Thus, the level of ambition South Korea is showing in its pledge seems to be fairly high. Climate protection ranks very high in the country's priorities, and is seen as an opportunity for economic expansion. The country has also adjusted its pledge accordingly as BAU projections have been lowered, making it unique amongst developing countries.

Lack of data prevents detailed analysis of full mitigation potential

An evaluation of this pledge against the country's potential is daunting as there is a distinct lack of data. If preliminary numbers of the Asian Development Bank (ADB) project are correct, South Korea's pledge can be interpreted as highly ambitious, as it could only be fulfilled in the highest carbon-price scenario. On the other hand, Greenpeace and EREC have identified a vast potential for renewable energy, which would even make a phase-out of Korea's nuclear energy program possible. Unfortunately, the limited availability of information makes it impossible to discern the feasibility and level of ambition of Korea's pledge. While there is a definite political commitment to green growth and climate-friendly development, the delayed implementation of South Korea's emissions trading system and its reduced ambition shows that there is still potential for more decisive action.

Wide variation in modelling of fair share

According to the CDC approach, South Korea's pledge does not fulfil its responsibility for a fair global effort sharing. On the other hand, for the SN approach even the BAU pathway falls within the range of a fair effort-sharing regime. According to the Triptych approach, South Korea's pledge correctly reflects the country's responsibility, with the median share almost exactly in line with Korea's pledge pathway in 2020.

Impact on global emissions pathways and temperature

A key issue that we turn to examine now is the potential overall role of the six emerging economies studied here in meeting the global goal of holding warming below 2°C. To quantify and illustrate the importance of the mitigation potential identified in this study in the global context we first compare an emission pathway 'Full potential, others IPCC ambition' where the full mitigation potential of these six countries is achieved and where all other countries meet the IPCC emissions reduction ranges for an approximate 2°C pathway, with three cases involving much less or no action – 'All Pledges', 'BAU all 2020', and 'BAU all'. In the 'All Pledges' scenario all countries meet their pledges for 2020, and beyond. In 'BAU all 2020' all countries follow BAU until 2020, and begin to reduce with global emissions peaking in 2030 at 57 $GtCO_2e/a$, and then reducing to low levels by 2100. In the 'BAU all' scenario, all countries follow BAU until 2100, reaching 60 $GtCO_2e/a$ in 2100 after peaking at 76 $GtCO_2e/a$ in 2050 (Fig. 7).

One important metric in evaluating which emissions pathways are consistent with 2 and 1.5°C is the 2020 emissions level. The United Nations Environement Programme (UNEP) (2011) and Rogelj et al. (2011) evaluated the long-term implication of 2020 emission levels in a large library of energy-economic scenarios from the scientific literature. The UNEP Bridging the Gap Report (2011) estimated that a global emissions level in 2020 of 44 $GtCO_2e/a$ is consistent with these goals. The emissions level in 2020 of the different pathways varies within the range of 44 $GtCO_2e/a$ for the 'Full potential, others IPCC ambition' scenario, the 'All Pledges' scenario is around 53$GtCO_2e/a$ and the BAU scenarios 57 $GtCO_2e/a$ for the BAU scenarios. It is clear from this that only the 'Full potential, others IPCC ambition' scenario has 2020 emissions consistent with the long-term global warming goal.

The rate of emission of emissions is an important metric to measure the level of effort and difficulty. We assume all scenarios (except BAU) lead to an equal emission level by 2100, which for this limited range of 2020 emissions would lead to roughly equal costs over the whole of the 21st century (e.g. van Vliet et al 2012). However, a scenario with high-2020 levels and equal 2100 end-point leads to higher total cumulative emissions and a higher probability that warming exceeds 2°C. If 2020 emissions are higher the probability to exceed 2°C can only stay the same by much steeper post-2020 reductions that fully compensate the too-high 2020 emissions by about 2050. Such a pathway would, however, lead to higher costs, reduce the opportunity for technological choices (IEA WEO 2011) and hence be associated with a higher risk of failure. Our analysis here is restricted to equal-cost scenarios, so that the price of a high 2020 level is paid in terms of stronger warming. Fig. 7 shows that for an equal 2100 end-point, the required reduction rates between 2020 and 2100 change depend on the 2020 emission levels, as well as the overshoot shape and duration.

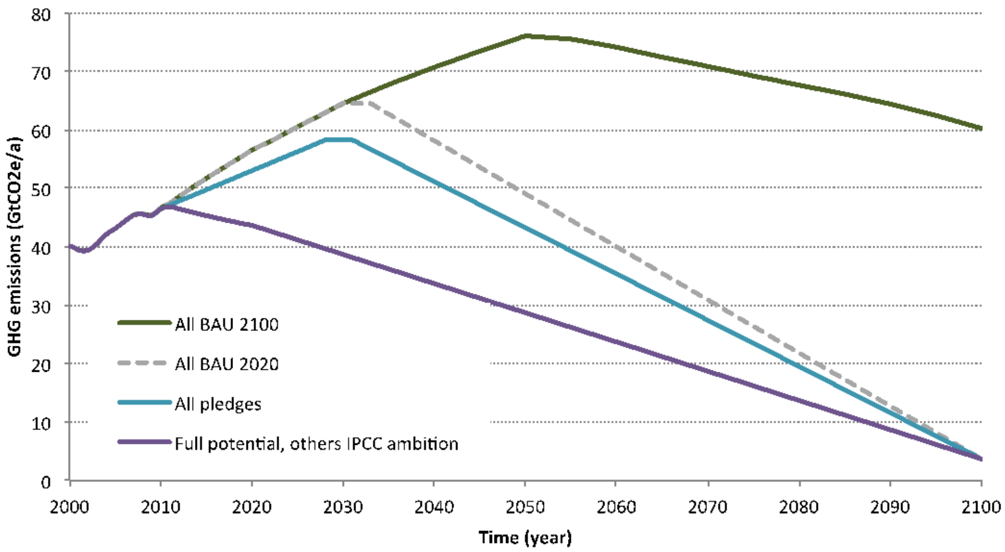


Fig. 7: Global total emissions pathways assuming the same ambition level for all countries.

To examine the implications of the levels of action in the six assessed countries on climate change, we have looked at additional scenarios as outlined in the table below, which quantifies emissions in 2020, the emissions gap, likely temperature in 2100 and the probability of exceeding 2°C. A probability of holding warming below 2°C or more than 50% is only achieved if the countries assessed in this report realise the full reduction potential by 2020 and all other countries achieve reductions in line with the Intergovernmental Panel on Climate Change (IPCC) range approximately consistent with GHG concentration levels ('IPCC ambition'). If all other countries achieve reductions in line with the IPCC range, but there is a lack of measures taken by the countries analysed in this report, the probability of exceeding 2°C could increase by a third (15 percentage points from 45% to 60%).

Tab. 2: Emissions level in 2020, median temperature increase in 2100 (and range) and probability of exceeding 2°C for the different pathways

Pathway	Emissions level in 2020 ($GtCO_2e/a$)	2020 "Emissions Gap" ($GtCO_2e/a$)	Median temperature in 2100 (16-84% range) (°C)	Probability of exceeding 2°C (%)
Six emerging economies exploit full potential, all other countries reduce compatible with 2°C*	44	0	2.0 (1.6-2.5)	45%
Six emerging economies meet their pledge, all other countries reduce compatible with 2°C *	46	2	2.1 (1.7-2.6)	55%
Six emerging economies exploit full potential, other countries meet their pledge	51	7	2.2 (1.8-2.8)	70%

All countries meet their pledges	53	9	2.4 (1.9-3.0)	80%
All countries follow BAU until 2020, then global emissions are decreased substantially	57	13	2.6 (2.1-3.3)	90%
All countries follow BAU through 2100	57	13	3.6 (3.0-4.7)	100%

*: 30% reduction below 1990 for Annex I countries, 12.5% reduction below BAU for developing countries, based on the ranges presented in the IPCC report.

These results can be illustrated graphically against likely 21st century warming levels. In Fig. 41 below we compare the 2020 emissions levels from the scenarios we have evaluated above with a large library of energy-economic scenarios from the scientific literature and the temperature increase associated with these scenarios. From this and the results in the table above it is clear that the level of action by the six assessed countries will have a significant effect on the emissions gap in 2020 and on our ability to hold warming below 2°C. These six countries alone cannot bring warming below 2°C but if they do not achieve their high potential nor can action consistent with the IPCC ranges by all others countries.

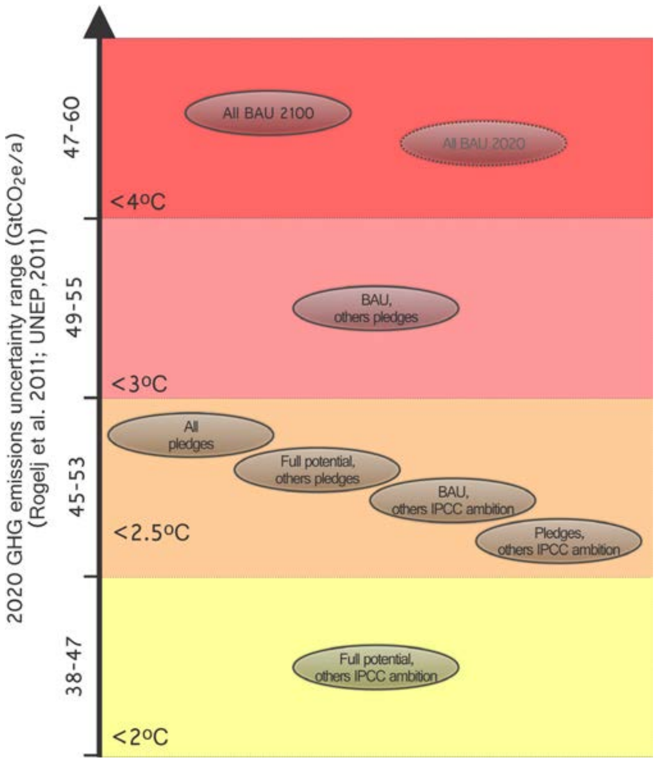


Fig. 8: 2020 global emission levels of pathways analysed in this report compared to the 2020 levels of typical scenarios from literature (15-85% uncertainty range) and associated with global average temperature change above pre-industrial levels (below 2, 2.5, 3 and 4°C).

Zusammenfassung (Deutsch)

Mit dem Copenhagen Accord (=Vereinbarung von Kopenhagen) hat sich die internationale Gemeinschaft zu dem Ziel verpflichtet, anthropogene Treibhausgase auf ein Niveau zu senken, das den durchschnittlichen globalen Temperaturanstieg auf 2°C begrenzt (UNFCCC 2009). Um dieses Ziel zu erreichen, müssen die globalen Emissionen von dem derzeitigen Niveau von etwa 50 $GtCO_2e/a$ auf 41 bis 46 $GtCO_2e/a$ im Jahr 2020 sinken, im Vergleich zum Referenzszenario von 55 bis 59 $GtCO_2e/a$ im Jahr 2020 (UNEP 2011).

Laut Artikel 3.1. der United Nations Framework Convention on Climate Change (UNFCCC) (=Klimarahmenkonvention der Vereinigten Nationen) sollten „die Vertragsstaatenauf Grundlage von Gerechtigkeit und entsprechend ihrer gemeinsamen, aber unterschiedlichen Verantwortlichkeiten und ihrer jeweiligen Fähigkeiten das Klimasystem (...) schützen." Dieses Prinzip verlangt von den entwickelten Nationen, eine führende Rolle bei den Minderungsmaßnahmen zu übernehmen. Zudem fordert es sie auf, die Entwicklungsländer bei der Bekämpfung des Klimawandels und dennoch notwendige Anpassungsmaßnahmen zu unterstützen.

Seit dem Beginn der Klimaverhandlungen in den 1990er Jahren haben Schwellenländer zunehmend an Bedeutung in der internationalen Arena gewonnen. Das zeigt sich sowohl in ihrem Wirtschaftswachstum als auch in ihren ansteigenden Treibhausgasemissionen. Die in diesem Bericht untersuchten Länder – Brasilien, China, Indien, Mexiko, Südafrika und Südkorea – verursachen zusammen heute etwa ein Drittel der globalen Treibhausgasemissionen (EDGAR 2011).

Dieser Bericht behandelt im Besonderen zwei Fragen:

- Wie ambitioniert sind die Emissionsminderungszusagen der verschiedenen Schwellenländer im Vergleich zu
- dem nationalen Emissionsreferenzszenario;
- dem Emissionsminderungspotenzial des Landes;
- den jeweiligen Bemühungen, die sich aus verschiedenen Gleichheitsprinzipien ergeben?
- Wie hängen die Zusagen und das Minderungspotenzial der Schwellenländer mit dem globalen Emissionspfad zusammen, der nötig ist, um die globale Klimaerwärmung auf 2°C im Jahr 2100 zu begrenzen?

Diese Untersuchung zielt darauf ab, Erkenntnisse in einer internationalen Perspektive darzustellen. Wir bewerten keine politischen Maßnahmen oder spezifischen Hindernisse, die die Umsetzung der identifizierten Minderungspotenziale auf nationaler Ebene verhindern oder erschweren.

Übersicht der methodischen Vorgehensweise

Unsere Bewertung der Minderungszusagen basiert auf Literaturrecherche. Die Analyse beinhaltet drei Komponenten:

- Die Minderungszusagen und nationalen Klimastrategien;
- Minderungspotenziale aus öffentlich zugänglicher Literatur;

- Ergebnisse der verschiedenen Verteilungsansätze basierend auf Gerechtigkeitsprinzipien.

Zunächst sammeln wir alle bestehenden Referenzszenarien und untersuchen die Emissionsniveaus, die sich aus den Zusagen ergeben. Wenn Länder Daten zur Verfügung stellen, die Aufschluss über die absoluten Werte der Zusagen oder das Referenzszenario geben, nutzen wir diese. Wenn alternative Referenzszenarien öffentlich verfügbar sind, stellen wir diese ebenfalls dar, um den Kontext der Analyse zu vermitteln[5]. Der zweite Schritt ist, die in der Literatur dargestellten Minderungspotenziale zusammenzustellen und anhand verschiedener Kostenkategorien zu klassifizieren:

- „No-regret"-Maßnahmen: keine oder negative Kosten;
- Maßnahmen mit positiven Nebeneffekten: Maßnahmen haben gesamtwirtschaftliche Kosten die entweder sehr gering sind oder durch bedeutsame Nebeneffekte verringert werden;
- Ambitionierte Maßnahmen: Maßnahmen, die mit höheren Kosten verbunden sind und deren potenziellen Nebeneffekte diese Kosten aus einer gesamtvolkswirtschaftlichen Perspektive nicht ausgleichen.

Für jedes Land, das untersucht wird, vergleichen wir das Minderungspotenzial mit den zugesagten Emissionsminderungen. Darüber hinaus berechnen wir mit dem „Evolution of Commitments" (EVOC) Modell die nötigen Emissionsminderungen gemäß verschiedener Verteilungsansätze. Diese Ergebnisse werden wiederum mit dem Minderungspotenzial und den Zusagen verglichen.

Im zweiten Teil des Berichts wird der Einfluss der Klimaschutzmaßnahmen der Schwellenländer auf globale Emissionspfade untersucht. Hierbei variieren wir mögliche Handlungen unserer Zielländer im Rahmen verschiedener globaler Szenarien.

Mittels des Klimamodells MAGICC[6] können wir die Effekte dieser Emissionsszenarien auf die durchschnittliche globale Erderwärmung im Jahre 2100 einschätzen und die Wahrscheinlichkeit einer Überschreitung des 2°C Grenzwertes ermitteln.

Wesentliche Schlussfolgerungen

Schwellenländer haben einen entscheidenden Einfluss auf das zukünftige Emissionsniveau aufgrund ihrer derzeitigen Werte und zu erwartenden hohen Wachstumsraten. Unsere Untersuchung hat wesentliche Minderungspotenziale für diese Länder aufgezeigt. Nur mit ambitionierten Maßnahmen in allen Ländern bis 2020 können globale Emissionen kosteneffizient auf ein Niveau verringert werden, das eine Steigerung der globalen Temperatur auf maximal 2°C begrenzt.

Sofortige Maßnahmen sind erforderlich, sowohl von entwickelten Ländern als auch von den Schwellenländern. Mit jedem weiteren Jahr Verzögerung können wir weniger des

[5] Wir entwickeln keine eigenen Referenzszenarien oder bewerten politische Maßnahmen in den Ländern

[6] "Reduced complexity coupled climate/carbon-cycle model MAGICC 6"

ursprünglichen Minderungspotenzials in 2020 erreichen. Mit jeder Verzögerung sinkt die Wahrscheinlichkeit, die Zusagen auch tatsächlich erfüllen zu können. Es bedeutet auch, dass die Reduktionsmaßnahmen zu einem späteren Zeitpunkt deutlich schneller umgesetzt werden müssten und teurer werden. Um sicherzustellen, dass die Zusagen erreicht werden, müssten alle identifizierten „No-regret“ Maßnahmen in den Zielländern dieses Berichts sobald wie möglich umgesetzt werden. Die für die Erreichung der Zusagen notwendige Umsetzung aller erforderlichen Maßnahmen in den verbleibenden acht Jahren mag heute viel anspruchsvoller erscheinen als zu dem Zeitpunkt, als die Zusagen zum ersten Mal diskutiert wurden. Dies liegt daran, dass der Zeitrahmen für die technische Umsetzung nun sehr viel kürzer ist als damals.

Die Intensität der Emissionsreduktionen der internationalen Zusagen verglichen mit den Referenzszenarien ist von Land zu Land unterschiedlich. Chinas und Indiens internationale Zusagen sind dem prognostizierten Referenzniveau sehr nah. Demnach stehen die Chancen gut, dass sie diese Ziele erreichen oder sogar übertreffen. Mexiko und Südkorea hingegen haben sehr ehrgeizige Zusagen gemacht, die eine große Abweichung von den Referenzszenarien erfordern. Südafrikas Zusage von 34% unter dem Referenzwert ist eine erhebliche Minderung, jedoch hat Südafrika für das Referenzszenario sowie für die daraus resultierende Zusage eine große technische Unsicherheit angegeben und lässt somit kein endgültiges Urteil zu. Ähnliche - oder gar noch schwerwiegendere - Probleme gibt es in Brasilien, wo die Ungewissheit über die Emissionen der Landnutzung, Landnutzungsänderung und Forstwirtschaft kein Urteil darüber erlaubt, ob ein Erreichen der zugesagten Minderung eine wesentliche Verbesserung gegenüber den Referenzwerten darstellen würde.

Die Zusagen der Schwellenländer machen sehr unterschiedlich Gebrauch von deren Minderungspotenzialen. Während Südafrika und Mexiko einen großen Teil ihres Potenzials ausschöpfen müssten, müssten China und Indien dies nur zu einem sehr geringen Teil tun. Brasilien und Südkorea sind in dieser Hinsicht aufgrund der Datenunsicherheit nur schwer einzuschätzen.

Die Verteilung der globalen Emissionsminderungen basierend auf ausgewählten Gleichheitsprinzipien würde, für einige dieser Prinzipien, eine strengere Zusage seitens China und möglicherweise auch von Brasilien erfordern. Die Ergebnisse aus verschiedenen Ansätzen unterscheiden sich beachtlich, zeigen jedoch in ihrer Tendenz, dass die Zusagen von Indien, Mexiko, Südafrika und Südkorea im Rahmen der Anforderungen der Verteilungsansätze liegen, wobei hingegen Chinas Bestrebungen, Emissionen zu vermindern, einigen Verteilungsansätzen nach höher liegen sollten. Auch Brasilien sollte, den meisten Ansätzen folgend, die Ambitionen der Zusagen erhöhen. Aber auch hier lässt die hohe Ungewissheit über Emissionen aus Landnutzung, Landnutzungsänderung und Forstwirtschaft nur eine sehr vage Einschätzung zu.

Für einige Länder gibt es Verteilungsansätze, die ein niedrigeres Emissionsniveau verlangen als das, welches sich durch die Umsetzung des vollen, hier identifizierten Minderungspotenzials ergibt. Es ist jedoch wichtig klarzustellen, dass das Minderungspotenzial in dieser Studie unvollständig ist: Zum einen ist in der verwendeten Literatur auf der diese Studie basiert möglicherweise nicht das volle Potenzial dargestellt. Zum anderen haben wir nur einen Satz ausgewählter Maßnahmen pro Landuntersucht, die als die Wichtigsten identifiziert wurden.

Unterstützung der entwickelten Länder ist gefragt: Für einige Länder geht das Minderungspotenzial deutlich über die Ergebnisse verschiedener Verteilungsansätze hinaus.

Für die Länder, die in diesem Bericht untersucht wurden, trifft das vor allem für Indien, Südafrika und Mexiko zu. Außerdem müssen einige Länder - wie Südafrika - teurere Maßnahmen umsetzen, um ihre Zusagen einhalten zu können. Daraus schließen wir, dass eine Unterstützung für diese Länder durch die entwickelten Länder nötig ist, um das Minderungspotenzial komplett auszuschöpfen. Eine genauere Formulierung des Unterstützungsbedarfs seitens der Schwellenländer könnte dabei helfen, schnell Fördermittel zu generieren und Maßnahmen zeitnah umzusetzen.

Die Verfügbarkeit von Daten ist sehr gering und die Ungewissheit ist sehr hoch. Dies erschwert eine Bewertung und eine Vergleich der Länder. Zudem sind die Minderungszusagen im Allgemeinen nicht als absolute Emissionswerte in 2020 definiert, sondern relativ zu den Referenzszenarien. Diese wiederum werden häufig neu definiert oder die Abdeckung verschiedener Sektoren geändert. In einigen Fällen sind die Szenarien an das Wirtschaftswachstum gekoppelt, für welches Vorrausagen ebenfalls ungewiss sind.

Das absolute Emissionsniveau, das sich aus einer Minderungszusage ergibt, hängt von einer Vielzahl von Faktoren und Interpretationen ab und setzt einige Annahmen voraus. Die folgende Tabelle gibt einen Überblick über einige wichtige Parameter der Zusagen und zeigt grob unsere generelle Einschätzung der Zusage.

Tab. 1 Überblick über die Informationen und Bewertung der untersuchten Länder

	Brasilien	China	Indien	Mexiko	Südafrika	Südkorea
Treibhausgasin-ventar in den letzten Jahren zur Verfügung gestellt	✓	✓*	✓	✓	✓	✓
Absoluter Wert der Minderungszusage in 2020 ist klar und festgesetzt	✓					✓
Absoluter Wert der Minderungszusage in 2020 ist variabel		✓	✓	✓	✓	
Änderungen der Minderungszusage seit Dezember 2009	Weniger strenges Referenz-szenario: Emissions-werte nach oben korrigiert				Weniger präzises Referenzszenario: wurde von einem Wert zu einem Bereich geändert	Ambitionierteres Referenzszenario: Emissionswerte nach unten korrigiert
Allgemeine Einschätzung der Minderungszusage	Niveau der Ambition der Zusage unklar aufgrund der hohen Ungewissheit des Referenz-szenarios und der zu Grunde liegenden Annahmen	Zusage ist weniger ambitioniert als einige Verteilungsansätze erfordern. Wird wahrscheinlich übertroffen	Zusage ist sehr nah am Referenzszenario aber ähnlich wie Verteilungs-ansätze. Wird wahrscheinlich übertroffen	Zusage ist ambitioniert gegenüber dem Potential und den Verteilungs-ansätzen	Zusage ist ambitioniert gegenüber dem Potential und den Verteilungs-ansätzen aber der Grad der Ungewissheit schränkt die Bewertung ein	Zusage ist ambitioniert gegenüber dem Potential und den Verteilungs-ansätzen. Begrenzte Informationen zum Potential

*: China hat seine zweite Nationale Kommunikation an die UNFCCC im November 2012 eingereicht (Government of China, 2012), welche ein aktuelles Treibhausgasinventar und zum ersten Mal Szenarien für zukünftige Emissionen beinhaltet. Das Dokument wurde jedoch zu spät veröffentlicht um in diesem Bericht vollständig berücksichtigt zu werden.

1 Introduction

With the Copenhagen Accord, the international community has committed to the aim of limiting anthropogenic greenhouse gas (GHG) emissions to a level resulting in an average global temperature increase of not more than 2°C (UNFCCC 2009). To achieve this objective, global emissions need to decrease to 41 to 46 $GtCO_2e$ in 2020 in comparison to a business-as-usual (BAU) pathway of 55 to 59 $GtCO_2e$ (UNEP 2011).

According to Article 3.1 of the United Nations Framework Convention on Climate Change (UNFCCC), "parties should protect the climate system (...) on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities". This principle requires developed nations to take the lead in mitigation action. It also invites them to support less developed countries in fighting climate change and adapting to its impacts.

Developed countries bear most of the responsibility in reducing emissions. Still, preventing dangerous anthropogenic climate change is only possible if, on the one hand, developed nations reduce their emissions significantly, and on the other hand, the emission trends of developing countries are also decreased quickly and sustainably.

Since the beginning of climate negotiations in the 1990s, emerging economies have gained importance in the international arena. This is reflected in their increasing economic weight, but also in rising GHG emissions. The countries this report analyses - Brazil, China, India, Mexico, South Korea and South Africa - together emitted one-third of global GHG emissions in 2008 (EDGAR 2011).

Accordingly, emerging economies also take an increasingly active role in climate change negotiations. In the context of the Copenhagen Accord, all major emerging economies have submitted voluntary national emission reduction proposals for 2020, most of which are conditional to international support for their implementation (UNFCCC, AWG-LCA 2011).

The objective of this assessment is to evaluate the level of ambition of the emission reduction proposals by Brazil, China, India, Mexico, South Africa and South Korea.

This report focuses on two main questions:

- How ambitious are the pledges of the different emerging economies when compared to their mitigation potential?
- How do the pledges and mitigation potential of the emerging economies relate to the global emissions pathway needed to limit global temperature increase to 2°C by the year 2100?

To approach these questions, we first look at the official pledges of the target countries under the UNFCCC for the year 2020 and projected BAU emissions pathways. We collect and aggregate data on mitigation potential and costs of different technologies in those countries and compare it with the pledges. Furthermore, we compare the pledged reductions to the emission levels that countries should aim for according to different effort sharing approaches.

We then aggregate emissions of the target countries and emissions of other regions to compare the total with the pathway needed to reach the limit of 2°C temperature increase. We show in which way the pledges and mitigation potential of the six countries can contribute to limiting global emissions to this pathway.

2 Methodology

The methodology of this report is orientated towards the two main questions outlined above. The first step is to evaluate the pledges made by each of the countries against their mitigation potential and the country's "fair" contribution to mitigating climate change. We then determine the impact that the six countries' mitigation potential, if realised, would have on global emission trends.

2.1 Evaluation of pledges against the mitigation potential and effort sharing approaches

The aim of this work package is to evaluate current emission reduction pledges for 2020 against their mitigation potential.

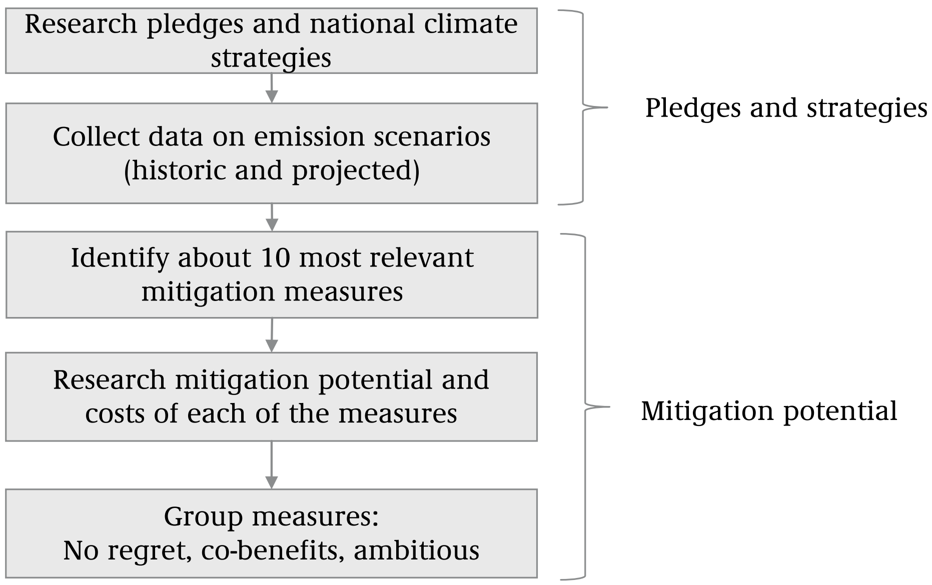


Fig. 9: Overview on methodology for evaluation of pledges and mitigation potential[7]

The evaluation is based on literature research and consists of three parts:

- The pledges and national climate strategies
- Mitigation potential
- Results of different effort sharing approaches

The detailed approach will be described in the following.

2.1.1 Pledges and national climate strategies

The analysis starts with a thorough review of literature and publicly available national and international resources related to historical and projected GHG emissions as well as information

[7] Unless otherwise specified, all figures and tables in this report are the authors' own.

on mitigation pledges under the UNFCCC. The GHG emission data form the basis for the analysis of the pledges and mitigation potential and serves as a reference for comparison.

Where available, we collect data on the sectoral level in order to evaluate the importance of different sectors in terms of GHG emissions. The table below defines the sectors, showing into which sector various gases are included in our data collection.

Tab. 3: Definition of sectors for aggregation of emission data

Sector	Emission sources included
Industry	Process emissions, direct emissions from fuel consumption, electricity related emissions, fugitive emissions from oil and gas
Buildings	Direct emissions from fuel consumption, electricity related emissions
Transport	Direct emissions from fuel consumption, electricity related emissions
Agriculture, Forestry and Other Land Use (AFOLU)	Livestock and soils; land use, land use change and forestry (LULUCF); fuel and electricity related emissions
Waste	Emissions from solid waste and wastewater

Electricity related emissions include emissions from the electricity generation sector: fugitive emissions from coal mining, electricity grid losses, and the sector's own consumption. These emissions are allocated to the demand sectors according to their shares of electricity consumption. For countries with significant emissions from the oil and gas sector (Brazil, Mexico) we attribute these emissions to the industrial sector for the demand side evaluation. For the other countries, we assume that other energy related emissions (fugitive emissions from oil and gas production) can be distributed to the sectors in the same way as electricity.

The starting year for projections (referred to as the "base year") depends on the latest year with available historical emissions data and therefore varies from country to country. For years where data is missing we inter- or extrapolated the available data sets.

We also qualitatively compare the pledges to national plans for mitigation action that have been devised by the six countries, describing the most important elements of those plans. If possible, we include a short evaluation of whether the national plans are in line with the pledge.

2.1.2 Mitigation potential in 2020

This part of the research focuses on collecting mitigation potential from a range of existing literature. Our approach reflects a wide look at the potential including the full range of information available. Alternatives such as using only one marginal abatement cost curve or creating our own mitigation potential and cost models would only reflect one view of the potential. Our own models would furthermore require significantly more resources and may produce non-transparent results.

To grant comparability between the countries and sectors and to provide a framework for transparently disclosing assumptions, we first define a list of "standard measures" covering all areas of possible mitigation opportunities. The second step consists of prioritising standard measures for each country, which we then take a closer look at. We decided to choose only a sub-set of measures for two reasons: First, the largest proportion of a country's mitigation potential is often associated with a limited number of measures. Second, this allows us to review these measures in greater depth, allowing for the comparison of various literature sources.

Selection of areas to be assessed

Definition of "standard measures"

The list of standard measures (see annex 7.1) represents the sectors analysed: industry, buildings, transport, AFOLU, waste and energy supply. Different to the list presented in Tab. 3, we look at the energy supply sector apart from end use sectors because technical measures vary much between end use and supply sectors, although emissions overlap. The standard measures are country unspecific; their relevance however differs from country to country. The standard measures were defined based on expert knowledge from the project team and insights from mitigation studies and were verified throughout the project.

It is important to note here that the measures are limited to technical measures and do not reflect policy instruments that could be used to trigger implementation. The rationale for reviewing technical measures is that mitigation is ultimately about the implementation of concrete measures that reduce emissions. The question underlying the analysis is "what can happen?" rather than "what is needed to make this happen?"

Selection of high potential measures for each country

We select about 10 standard measures for further investigation, relying on the following criteria:

- Importance of sector and relevant subsector (e.g. share of GHG emissions)
- Proven success of the measure in other countries, including an analysis of transferability from country to country. The proven success of measures in other countries is not related to the target country; this indicator is thus the same for all countries.
- Prioritisation of measure in national plans
- Availability of data

The exact number of chosen measures per country is variable to some extent. The choice covers the major share of total mitigation potential.

Analysing potential and cost

Quantification of potential and cost

For the chosen measures, we review existing estimates of cost and mitigation potential from various national and international studies.

These studies are based on different assumptions that had to be aligned. They assume different base and/or target years, thus leading to implementation periods inconsistent with this report's outlook to 2020 and the base years chosen according to the most recent available historical data point. We therefore scale the potential to a common base year for each country and to the target year 2020. The method can depend on the measure and on the country looked at.

We apply either a linear extrapolation starting at the given base year of the study or use the given value. Using the given value for 2030 as a constant also for 2020 is appropriate if the implementation of the measure relies on an already existing, widely available technology and could reasonably be implemented within the remaining time frame to 2020.

One critical issue looking at mitigation potential of different measures is the overlap between them. There is, for example, a connection between the carbon intensity of the electricity supply and measures reducing GHG caused by final electricity consumption. Where this is not considered in the study the data is extracted from, we introduce an overlap factor by which the mitigation potential is reduced based on expert judgement.

Grouping mitigation potential in cost categories

This part of the analysis aims to reflect a more "macro-economic" view of mitigation options. While most cost assessments (including cost curves) only look at direct costs and benefits for the activity, this report reflects external effects. This includes a qualitative analysis of the co-benefits of mitigation measures as well as the negative social costs related to them.

By displaying categories instead of pure cost curves, we allow for a more comprehensive assessment of the measures, including other factors than costs as a motivation to exploit the potential. We therefore make qualitative judgements about the connected external effects and their potential impact.

We group the reduction potential into three categories:

- "No-regret" measures: no or negative costs.
- Measures with co-benefits: Measures do cost something but because of significant co-benefits, these costs are evened out on a macro-economic view (see paragraph below).
- Ambitious measures: Measures do cost something and there are no relevant co-benefits to even out these costs on a macro-economic view.

One measure can occur in several categories, for example, with a low penetration as a no-regret measure and with a high penetration as a co-benefit measure.

Investments related to climate change mitigation and adaptation can also result in many broad societal and sustainable development benefits in the areas of energy (access and security), environment, health, and economic and social welfare (Bystricky et al. 2010). Co-benefits we consider in this context include:

- Energy security
- Economic diversification
- Support of development priorities
- Creation or existence of industry
- Health benefits, including improved air quality
- Contribution to gender equality

Tab. 26 in the annex shows how different co-benefits can relate to the standard measures we have identified.

2.2 Conformity with the global 2°C emissions pathway

This part of the analysis assesses, if the pledges of the countries regarded in this report are in line with the global target of limiting global average warming to 2°C. On the one hand we compare results from different effort sharing approaches with the pledged emission levels, to evaluate if countries have pledged to do their "fair share" of necessary emission reductions. On the other hand, we determine the impact of different possible emission levels of emerging countries on global emissions and the resulting temperature increase in the long term.

2.2.1 Quantification of countries' responsibilities to reduce emissions according to different effort sharing approaches

In order to determine whether the pledges of the countries analysed are in line with global mitigation efforts needed to limit climate change, we distribute global emissions in 2020 according to different effort sharing approaches and a global emission pathway likely to keep global average temperature increase to below 2°C.

The calculations rely on the Evolution of Commitments (EVOC) model. We use a global pathway leading to 44 $GtCO_2e$ in 2020 and exclude LULUCF.

The effort sharing approaches included are:

- Common but differentiated convergence (CDC)
- Contraction and Conversion (C&C)
- Responsibility Capacity Index (GDR)
- South-North (SN) Dialogue for 2100
- Triptych

Annex 7.4 contains detailed background information on each approach and a description of the EVOC model.

Some effort sharing approaches refer to BAU scenarios. In these cases, we use the baselines in the EVOC tool. These represent a wide range of possible future emissions based on the IPCC SRES scenarios (2006), but adjusted to most recent historical emissions. In most cases, these EVOC baselines are not consistent with the data collected for the analysis of the pledges and mitigation potential. Where necessary we therefore scale the results from the EVOC model to the average of the baselines used for illustrating pledge and mitigation potential.

For Brazil, we take an additional step to take into account LULUCF emissions: We assume that under any effort sharing approach, LULUCF emissions would need to decrease linearly from today's level until 2030. We add the interpolated value for 2020 to the results from the EVOC model which exclude LULUCF. For all other countries where LULUCF emissions do not represent such a big share of emissions, we assume that scaling to the baseline including LULUCF is sufficient.

2.2.2 Aggregation of country data to a global pathway

Emission pathways until 2020

Even if one assumes that the countries analysed in this report will achieve their full mitigation potential, much in terms of achieving the 2°C global goal depends on other countries' actions.

To assess what the efforts from these two country groupings would achieve, we developed a range of pathways, varying the "ambition level" of each group of countries from BAU at the low end of the scale, through current pledges, to full estimated mitigation potential or a high level of ambition. The pathway variants are each defined by the emission levels achieved in 2020 for the different country groups, summarised in Tab. 4 below.

The highest ambition scenario used in this analysis cannot be interpreted as the lowest global level achievable. We assume BAU emissions from international aviation and marine transport and no further reductions of global emissions from deforestation in addition to those implied by the reduction potential of Brazil and currently pledged by Indonesia.

BAU emissions are derived from "reference" pathways. For the countries assessed in this report these are equal to the average BAU scenario analysed in this report and for other countries we use the PRIMAP4BIS[8] pathway. The latter is derived from scenarios that assume BAU social and economic development and no mitigation efforts beyond current policy.

We use the pledge pathways for the emerging economies developed for this analysis as well as data from the Climate Action Tracker (2012), using the low ambition pledge data set.

For the most ambitious scenario we use the full mitigation potential as identified in this report for the emerging economies and derive a high ambition pathway for the other countries based on the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (AR4 Metz et al. 2007). This report included a contribution by Annex I countries as a group to the global mitigation effort for achieving the lowest climate-stabilisation category to be a reduction of emissions by 25-40% below 1990 levels by 2020. Shortly after the publication of AR4, a separate paper estimated the associated required reductions by non-Annex I countries as 15-30% below BAU levels by 2020 in aggregate(den Elzen, 2008).

Since AR4, however, energy-economic scenarios have been updated and further research has resulted in new climate-modelling exercises. The UN Environment Programme (UNEP) Bridging the Gap Report (2011) estimated that a global emissions level in 2020 of 44GtCO_2e is consistent with 1.5 and 2°C. Based on this limit on emissions in 2020, a non-Annex I emissions allowances range can be calculated as the remainder, following the deduction of the emissions from Annex I countries (25-40% below 1990 levels), from deforestation and from international transport. This results in a range of 18-26% below the baseline of emissions allowances for Non-Annex I countries in 2020, which is still consistent with the earlier estimate of 15-30% below BAU levels.

We used the average of these ranges of reduction in Annex I and Non-Annex I countries (excluding those assessed in this report) for the most ambitious case ("IPCC ambition until 2020").

It is important to note that the pathways nomenclature adopted here reflects the perspective of the countries assessed here through 2020. The next section describes the methodology used for extending these pathways through 2100.

[8] https://sites.google.com/a/primap.org/www/the-primap-model/documentation/baselines/primap4

Tab. 4: Overview of emission pathway variants characterised by 2020 emission levels.

		Countries assessed in this report[1]			
		Reference until 2100	Reference until 2020	Pledges for 2020	Full potential for 2020
Other countries	Reference until 2100	All BAU 2100			
	Reference until 2020		All BAU 2020		
	Pledges for 2020		BAU, others pledge	All pledges	Full potential, others pledge
	IPCC ambition for 2020		BAU, others IPCC ambition	Pledges, others IPCC ambition	Full potential, others IPCC ambition

[1] Except South Korea. Due to lack of data for mitigation potential it is grouped with the "other countries".

Note: The nomenclature of pathways refers to the perspective of the countries analysed in this report in 2020 (except for BAU all)

Post-2020 extension of emission pathways

All the 8 pathway variants described above were extended from 2020 until the year 2100. The key question is what the post-2020 implications of a higher/lower global 2020 emission level are, assuming strong mitigation efforts beyond 2020.

Van Vliet et al. (2012) concluded that for 2°C scenarios, very roughly speaking, starting from different levels in 2020 leads to approximately the same aggregate post-2020 cumulative mitigation costs, if emissions converge by the end of the 21st century. For higher 2020 levels this equal-cost post-2020 pathway is, however, associated with higher climate risks, i.e. a higher probability of exceeding 2°C.

Given this assessment we set the long-term level in 2100 for all our pathways equal to that of the illustrative 2°C scenario from (van Vliet et al. 2012), which achieves the global target of keeping warming to less than 2°C above pre-industrial levels in an "optimal" manner, that is, minimising overall discounted costs over the 21st century. The different emission levels in 2020 for the resulting pathways thus are associated with equal mitigation costs post-2020, but different probabilities of exceeding 2°C. This is then assessed by a climate model as explained in the next section.

As a measure of inertia in the energy-economic system, we assume that emission scenarios that show rising emissions from now until 2020 need some time until post-2020 reductions kick in. The scenarios generated by van Vliet et al. (2012) show that the higher the emissions levels in 2020, the stronger the inertia and the longer it takes before emissions start to decline. We estimated the shape and duration for the different pathways constructed here in accordance with van Vliet et al. (2012) scenarios (the methodology is further detailed in the annex).

2.2.3 Consistency with the 2°C long-term goal

Although 2020 emission levels have limited predictive skill for determining long-term warming (e.g. Meinshausen et al. 2009), mitigation efforts leading up to 2020 and beyond will to a large extent determine the feasibility of post-2020 mitigation efforts sufficient to limit warming to below 2°C. Higher 2020 emission levels, for example, will need to be followed by faster and deeper reductions after 2020, which increases costs and reduces the tolerance for a failure to for realise the currently estimated full potential of technological options worldwide. An estimate of the climate effects associated with 2020 emission levels therefore requires information on the post-2020 options that are still feasible. We apply two complementary approaches for assessing the warming implications of our pathways.

Firstly, having calculated 2020 emission levels for our pathway variants, we will compare the global levels to those assessed in the "2020 Emissions Gap" reports (UNEP 2010; UNEP 2011). These reports indicated that a gap of 6-11 $GtCO_2e$ remains between the aggregate level of emissions consistent with the current pledges of all countries on the one hand, and the 2020 global emission level of about 44 $GtCO_2e$ that is consistent with feasible energy-economic scenarios from the scientific literature that are consistent with 2°C on the other hand. We will compare our estimated 2020 emission levels with these UNEP levels to assess which pathway variants succeed in narrowing, or closing the Gap.

Secondly, as mentioned above, we extend the emission pathways to cover the full 21st century. We use these pathways as input into a reduced-complexity carbon-cycle/climate model for directly calculating warming associated with each pathway. We apply the MAGICC model in a probabilistic set-up (Meinshausen et al. 2009), providing hundreds of climate realisations (an "ensemble") for each single emission pathway, with each single realisation drawing from a range of climate-system model parameters that vary according to their uncertainty ranges. For each set of model parameters, the climate effects are validated against observed climate variables over the past century and only those sets that allow the model to reproduce the latter are used for the overall projection. The median and uncertainty ranges over the full ensemble of climate-model realisations provide a "best-guess" climate projection and climate-system uncertainty estimate for each of the emission pathways.

2.3 Illustration of result

Fig. 10 shows an illustrative example of the country results. The graphic is divided into three parts, which all refer to the axis "GHG emissions" to the left.

The left part shows emissions developments from 1990 until 2020 according to the BAU and the pledge, each in a range of scenarios found. Additionally, we mark the average of the range with a red (BAU) and a green (pledge) line.

The middle of the figure shows the possible impact of mitigation options in 2020. Filled arrows illustrate the minimum potential found in literature, empty arrows the maximum. The colours reflect the different cost categories as indicated by the text in the graph. The horizontal lines each show the remaining emissions after using the potential.

The right side of the graph illustrates results from different effort sharing approaches, again for the year 2020. The given ranges result from different underlying BAU scenarios. The blue mark represents the average of all scenarios for each approach calculated.

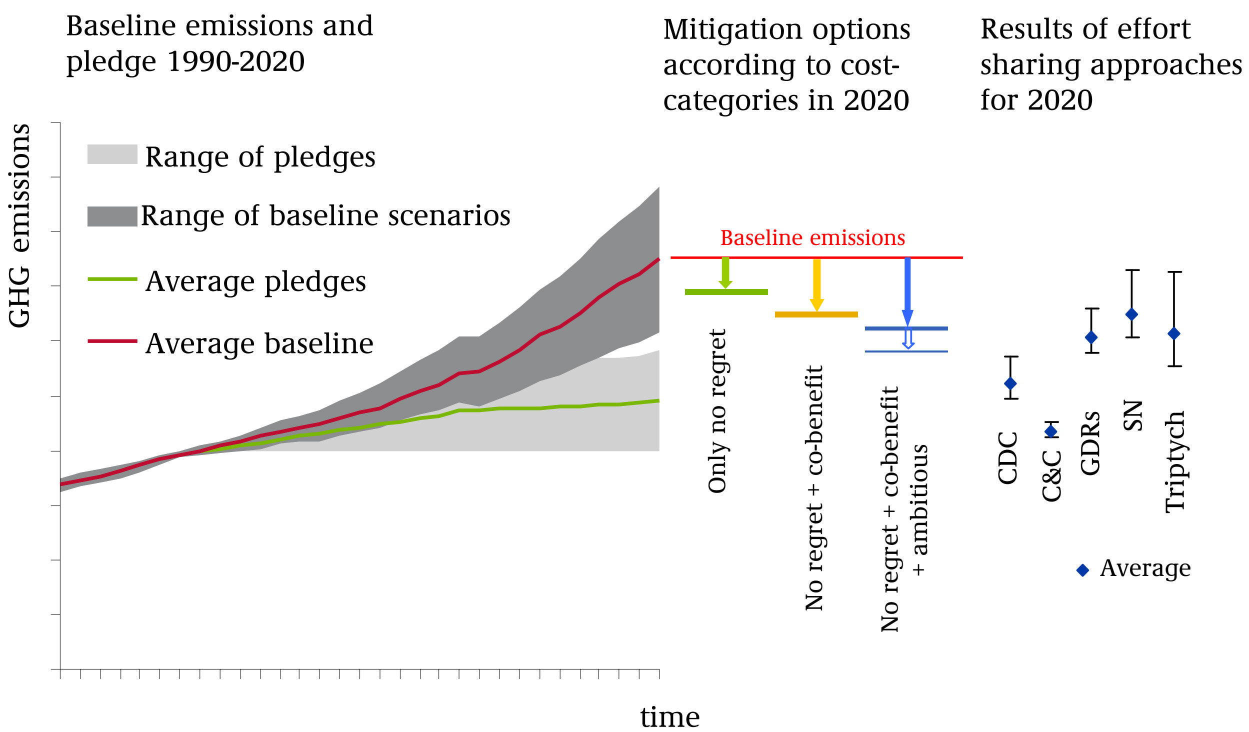


Fig. 10: Example for illustration of results per country

Additionally, we show detailed graphs which show the range of mitigation potential standard measure and costs. The illustration of the cost categories varies for the different countries because of different underlying data and approaches.

For China and India, the cost categories are displayed in a separate graph, showing the share of each cost category for each standard measure. There may be overlaps between the categories, which is why we cannot simply add up the potential. For Mexico and Brazil, we integrate the information on the cost categories and potential in one graph by showing the average cost category across the potential of one standard measure. Neither for South Africa nor South Korea we have found sufficient data to display such information.

3 Greenhouse gas mitigation proposals and potential

3.1 Brazil

Tab. 5: Key indicators – Brazil		
Population (2010)9:	195 million	Rank 6
GDP (2010)10:	1,960 billion US$ 2005 PPP	Rank 8
GDP growth (2000- 2010):	3.5%/a (41% total)	
Energy consumption (2010)11:	266 Mtoe	Rank 7
Energy consumption growth (2000 – 2010):	3.6%/a (42% total)	
GHG emissions (2008)12:	1,460 $GtCO_2e$	Rank 7

In 2008 Brazil was the sixth largest greenhouse gases emitter in the world (EDGAR 2011). With a population of approximately 195 million people in 2010 (UN 2011), Brazil has seen strong economic growth over the past 10 years, with an increase of 42% in GDP, and is expected to grow another 29% until 2017 (IMF 2012). Recent sources project that the population will increase by 14% by 2050 (UN 2011). Brazil plays an important role in reducing the greenhouse gases emissions as it is responsible for approximately 4% of global emissions today.

Brazil differs from most countries due to its unusual emissions profile. Whilst globally the main source of GHG emissions is the use of energy, the largest share of Brazilian emissions comes from the AFOLU. Even though deforestation rates have drastically decreased over the past 10 years in the country, such activities are still responsible for 70% of Brazil's current emissions. The high emissions in the AFOLU sector are partially compensated for by a rather low level of emissions from energy use: hydroelectric power is responsible for 80% of the electricity production in Brazil and ethanol has high penetration in the transport sector.

Despite these positive aspects, Brazilian emissions are today at roughly 9 tCO_2 per capita. This is however likely to change with future growth and the economy is projected to become more carbon-intensive. This proves the need for the urgent consideration of mitigation measures that would prevent the re-carbonisation of the economy and decrease total emissions in the country.

3.1.1 Historical and projected BAU development of GHG emissions in Brazil

Expected emissions until 2020

BAU scenarios for Brazil are highly uncertain, mainly due to the difficulties in estimating emissions from the AFOLU sector (see below).

As shown in Fig. 11, projections for Brazil's emissions in 2020 from different sources vary widely from 1,442 to 3,236 $MtCO_2e/a$. The share of emissions per sector is shown in Fig. 11. The AFOLU sector is responsible for 70% of Brazilian emissions, followed by the industrial sector

[9] UN 2011

[10] World Bank 2012

[11] IEA/OECD 2012

[12] EDGAR 2011

accounting for 15% (5% of which comes from oil and gas), the transport sector for 10%, waste for 3%, and the building sector for 2% of national emissions. Emissions from the AFOLU sector can be divided into emissions from agriculture and from LULUCF which account for on average 24 and 38%, respectively, of total national emissions.

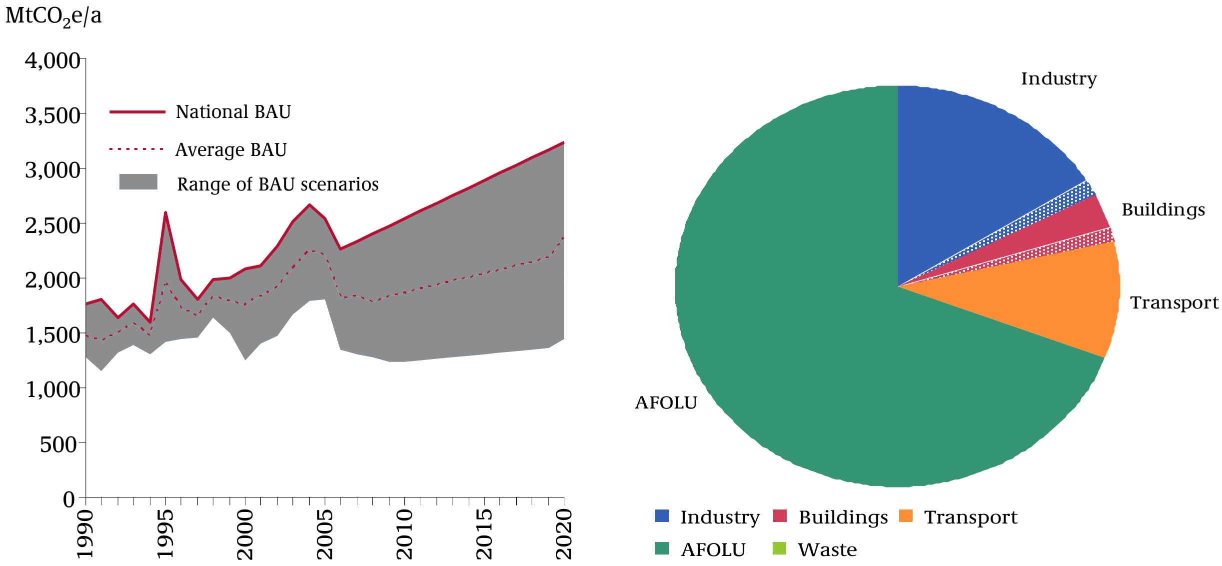


Fig. 11: Brazil: Historical GHG emissions and projections from 1990 until 2020 (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6). Pie chart on the right shows distribution of emissions to sectors as in 2020. Shaded areas are electricity related emissions

Main data sources and assumptions

Total national emissions

- National inventories (UNFCCC data): historical emissions
- National BAU (Decree n° 7390 of December 09, 2010 and Climate Action Tracker 2012): upper limit of BAU projections (3,236 $MtCO_2e/a$ in 2020)
- Brazil Low Carbon Country Case Study (Gouvello et al. 2010): lower limit of BAU projections (1,522 $MtCO_2e/a$ in 2020)
- MATCH: growth rates used to extend historical national inventories: middle range (2,097$MTCO_2e/a$ in 2020)

Emissions per sector

- All sectors: National Plan for Climate Change (NPCC, Decree n° 6263 of November 21, 2007); Climate Action Tracker (2012), Brazil Low Carbon Country Case Study (Gouvello et al. 2010), Caminhos para uma economia de baixa emissão de carbono no Brasil (Ways to a low carbon economy in Brazil - McKinsey 2009)
- Industry: Potential for reduction of CO_2 emissions and a low-carbon scenario for the Brazilian industrial sector (Henriques Jr. et al. 2010)
- AFOLU: Analysis of emissions mitigation options in the land-use, livestock and agricultural sectors (Cerri et al. 2010)

Country specific uncertainties in determining the BAU pathway

The largest source of uncertainty for BAU projections in Brazil is the AFOLU sector. Emissions in 2020 for this sector range from 887 to 2,133 $MtCO_2e/a$, depending on the source. The difference of 1 245 $MtCO_2e/a$ between the two represents around 60% of total Brazilian emissions in 2008 and is, to provide point of comparison, larger than the total emissions of Canada in that year.

The deforestation emissions projections for 2020 provided by the National Plan for Climate Change (NPCC) for the Amazon biome (roughly 70% of the deforestation emissions of the entire country) consist of the average of deforestation emissions over the period 1996-2005 (Fig. 12, grey line). Because deforestation rates have considerably decreased since 2005 (and since 2004 carbon dioxide emissions are estimated to have decreased by 57% in the Amazon region, INPE), 1996-2005 is likely not a suitable period for providing good estimations of baseline emissions in 2020. In fact, baselines projections for the AFOLU sector in 2020 from Gouvello et al. 2010 (Fig. 12, dark green dashed line), which are based on the two most recent years prior to 2010 for which data was available at that time (2006 and 2007), deliver a much lower estimate of emissions for 2020 (887 $MtCO_2e$). The analysis of national emissions (excluding LULUCF) of all studies assessed in this report reveals a much narrower range in the 2020 emissions projections (469 $MtCO_2e$) than the AFOLU sector alone. This shows that the LULUCF sector is by far the largest source of uncertainty in Brazilian BAU projections.

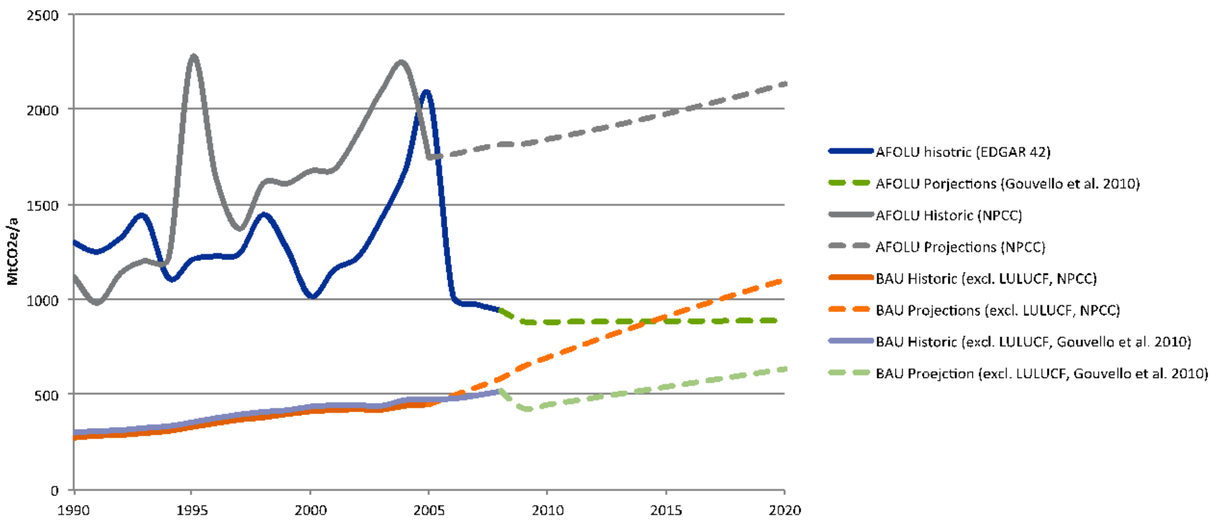


Fig. 12: AFOLU (grey, blue and dark green) and national emissions excluding LULUCF (orange, purple and light green) for Brazil from different sources.

The AFOLU sources show a difference of 1,246 $MtCO_2e/a$ in emissions in 2020 whereas national emissions excluding LULUCF differ by 469 $MtCO_2e/a$ in 2020, showing that the main source of uncertainty in national emissions is uncertainties in LULUCF projections. Historical emissions are depicted with solid and projections with dashed lines.

3.1.2 Brazil's pledge for GHG emission reductions until 2020

Brazil was one of the first large developing countries to propose an emissions target under the UNFCCC. Brazil's target is to reduce GHG emissions by 36 to 39% below BAU in 2020 and is conditional to financial support. Along with their pledge, Brazil published the reference BAU for the pledge in December 2010.

Estimated effect of Brazil's pledge on GHG emissions

Using the national BAU projections (solid red line), Brazil's target translates in absolute terms into a reduction of approximately 1,210 to 1,260 $MtCO_2e/a$ and a resulting emission level of 1997 to 2023 $MtCO_2e/a$ in 2020.

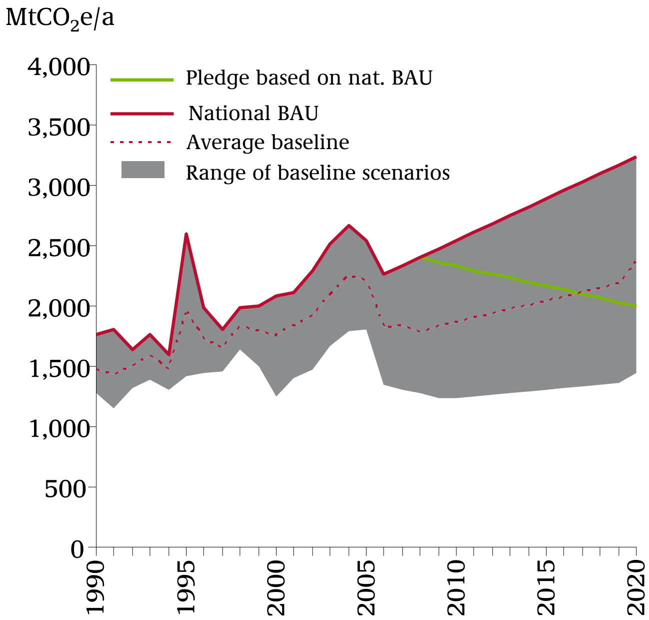


Fig. 13: Estimated emissions resulting from Brazil's pledge

Comparing the absolute pledged level with average BAU emissions in 2020, the reduction is only 342 to 387 $MtCO_2e/a$ or 14 to 16% below BAU.

Main assumptions for determination of pledge

Brazilian reduction target relies mainly on a drastic decrease in deforestation. Assuming the BAU scenario provided by the country, the pledged decrease in deforestation in the Amazon and Cerrado areas is responsible for more than half of national emission reductions in 2020. If we add the planned reductions in the agricultural sector, the AFOLU sector will be responsible for a total of 28.6 to 30.8% reduction in national emissions. Tab. 6 shows the envisaged contribution of different sectors and activities to the pledged reductions.

Tab. 6: Main mitigation actions for the different sectors in Brazil and their envisaged reduction in emissions as provided by Brazil.

Mitigation actions (NAMAs)	2020 projections	Total reduction ($MtCO_2e$)		Proportion of the total reduction	
Land-use	1084	669	669	24.7%	24.7%
Reduction of deforestation in the Amazon (80%)		564	564	20.9%	20.9%
Reduction of deforestation in the Cerrado (40%)		104	104	3.9%	3.9%
Agriculture	627	133	166	4.9%	6.1%
Pastures recuperation		83	104	3.1%	3.8%
Integrated crop-livestock		18	22	0.7%	0.8%
No-till farming		16	20	0.6%	0.7%
Biological nitrogen fixation		16	20	0.6%	0.7%
Energy	901	166	207	6.1%	7.7%
Energy efficiency		12	15	0.4%	0.6%
Increase biofuel use		48	60	1.8%	2.2%
Expansion of energy offer by hydroelectricity		79	99	2.9%	3.7%
Other renewables (PCH, bioelectricity, wind)		26	33	1.0%	1.2%
Others	92	8	10	0.3%	0.4%
Iron and steel – replacement of non-renewable charcoal		8	10	0.3%	0.4%
Total	2703	975	1052	36.1	38.9

National climate change plans relating to the pledge

Brazil has a number of relevant sectoral and regional plans to address climate change mitigation. The most important ones relate to the land use sector:

- **PPCD-Am**: The Plan for Prevention and Control of Deforestation in the Amazon was launched in 2004 and is currently under revision. The main objective is to promote the reduction of deforestation rates through a set of integrated actions, divided into three main areas: (i) territorial and tenure planning, (ii) monitoring and environmental control, and (iii) incentives to sustainable production activities. These activities will be developed in partnership with different sectors, including federal institutions, state governments, municipalities, civil society organisations and the private sector.
- **PPCerrado**: The Plan for Prevention and Control of Deforestation and Forest Fires in Cerrado aims to promote the reduction in the rate of deforestation and forest degradation, as well as the incidence of burning and forest fires in the Cerrado, through joint actions and partnerships between the federal government, states, municipalities and civil society, the business sector and academia. The plan has three main components: (i) monitoring and environmental control; (ii) protected areas and spatial planning and (iii) incentives for sustainable productive activities. Environmental education aims to cover these three areas.

Additionally there is a plan for the energy sector (Decadal plan for Energy Expansion - PDE) and to reduce emissions from iron and steel (Plan for Reducing Emissions from Iron and Steele).

3.1.3 GHG mitigation potential in Brazil in 2020

The following studies were used to determine mitigation potential and in some cases costs for this analysis:

Tab. 7: Overview of studies used for determination of GHG mitigation potential in Brazil

	Henriques Jr. et al. 2010	Gouvello et al. 2010	Cerri et al. 2010	McKinsey 2009
Short description	Potential for reduction of CO_2 emissions and a low-carbon scenario for the Brazilian industrial sector	Brazil - Low Carbon Case Study Comprehensive analysis of baseline and mitigation scenarios across all sectors by the World Bank	Analysis of emissions mitigation options in the land-use, livestock and agricultural sectors	"Caminhos para uma economia de baixa emissão de carbono no Brasil" Low carbon growth study and cost curve development for Brazil
Base year	2007 (baseline) 2010 start of measure implementation	2007 (baseline) 2010 start of measure implementation	2008 (baseline)	2005 (baseline)
Sectors covered	Industry	All	Land-use, livestock and agricultural sectors	All
Calculation method	Bottom-up	Bottom-up	Bottom-up, based on two methodologies: 1. IPCC 1996 Guidelines 2. EX-ACT	Bottom-up
Main assumptions	Based on B1 scenario from the National Energy Plan 2030 3.7% growth of economic activity and energy consumption Discount rate 8% and 15%	Discount rate 8%	Based on the National Plan on Climate Change (NPCC) with development of our own alternative baselines for different sub-sectors	
Evaluation of source	Very detailed analysis with transparent assumptions and methodology.	Comprehensive and detailed analysis with transparent assumptions.	Detailed analysis with transparent assumptions and methodology.	Detailed study, not all assumptions clearly disclosed.

Selection of measures

The specific emissions profile of Brazil is also reflected in the selected measures. Due to the low emissions from the energy and building sectors no measures for these sectors are quantified within this analysis. For the transport sector we only looked at modal shift measures, due to the already high energy efficiency of the sector. The focus of mitigation potential clearly lies with the agriculture and land use sector and in industry, where all measures were assessed. Measures to reduce emissions from waste and wastewater were analysed due to their high relative reduction potential and the large co-benefits of the measure.

Tab. 8: Standard measures assessed for Brazil

Standard measures
Industry • Energy efficiency of processes • (Includes electricity and fuel) • Alternative production routes • (E.g. increased use of recycled materials, for cement: more blended cement) • Use of sustainable biofuel • Fuel switch to other fossil fuels Waste • Reductions of emissions from waste and wastewater Transport • Modal shift • Fuel switch AFOLU • Re-/afforestation • Reduced deforestation • Reduction of non-CO_2 emissions from livestock • Reduction of non-CO_2 emissions from agricultural soils

Total potential and associated costs in Brazil

Fig. 14 illustrates the ranges of mitigation potential for 2020 from different measures found in the different studies. The text below further discusses the results for each sector and measure.

Note: Due to the large range of potential estimates for deforestation we have depicted the full range for this measure in the additional graph on the bottom of the page. Otherwise the individual potential for the other measures are difficult to identify. Be aware of the different scale of the two graphs.

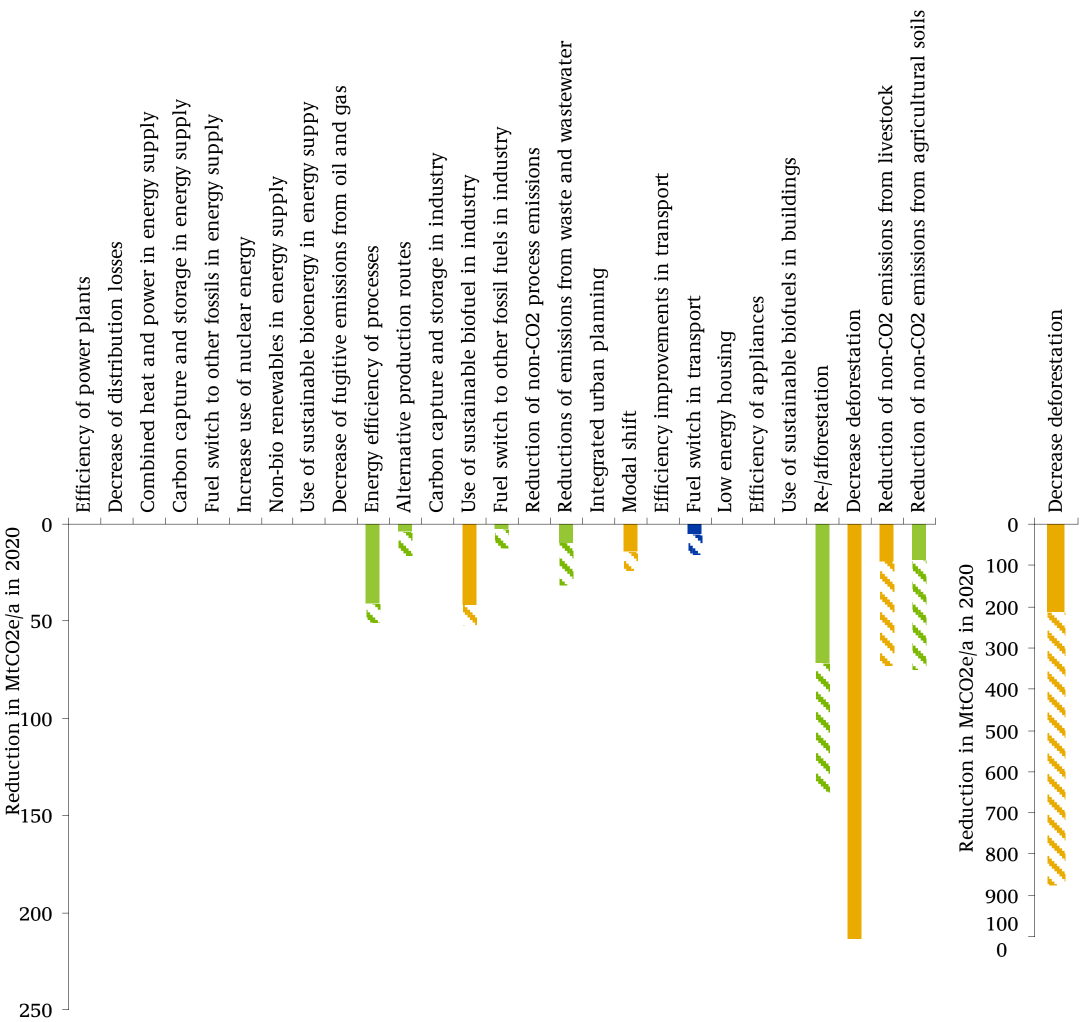


Fig. 14: **Brazil: Ranges of mitigation potential by standard measures found in different sources**

Note: green bars represent no-regret measures, orange bars co-benefit measures and blue bars ambitious measures.

The following section contains a brief introduction to each sector, accompanied by a description of the potential of the measures identified within the sector.

Industry

The industrial sector in Brazil, unlike that in many other countries, is characterised by a relatively small share of emissions from electricity consumption, even though the share of electricity in total energy use was around 20% in 2005. This is due to the low grid emissions factor for electricity. Energy use in the sector is dominated by heavy industry, with iron and steel, other metals and mining using 36% of energy consumed in the sector, followed by foods and beverages (mainly sugar and alcohol), which used almost 20% in 2005 (Henriques Jr. et al.

2010). All estimates of mitigation potential identified in this sector are taken from Henriques Jr. et al. with the exception of an estimate for recycling provided by McKinsey (2009). Gouvello et al. (2010) also provide estimates for industrial measures, but only give aggregate values for 2010 to 2030. The aggregate numbers match the aggregate values from Gouvello et al. (2010) and were used for verification only.

Energy efficiency of processes: Total estimated potential for the efficiency of industrial processes is estimated to be 40.1 MtCO_2e/a in 2020. The potential is largely driven by heat and steam recovery, but also includes combustion improvements, the switch to more efficient processes and the adoption of other energy efficiency technologies. The estimate also includes co-generation opportunities and the use of solar thermal energy in complementary processes – for low temperature applications in the food and beverage sector, for example.

The switch to more efficient processes comes at the significant cost of up to 182 US$/ton CO_2e, but all other activities come at a negative cost. Heat and steam recovery, for example, even entails savings of over 200 US$/ton CO_2e. In total the weighted average cost of the measure is clearly no-regret with substantial economic benefit.

Alternative production routes: For this measure increased recycling was evaluated with a total potential between 4.1 and 15.9 MtCO_2e/a in 2020. Henriques Jr. et al. (2010) include a detailed analysis of the use of additives in cement, of the expanded use of scrap in iron, steel and aluminium production, as well as of paper and glass recycling. The overall potential they estimate is, however, relatively low, at 4.1 MtCO_2e/a or 2% of BAU emissions.

Henriques Jr. et al. (2010) conclude that up to 7% of BAU emissions from the industrial sector could be saved through recycling at negative cost.

Use of sustainable biofuel: This measure has the largest expected potential in 2020 of 41.6 MtCO_2e/a. The largest proportion of this comes from the reduction of 'non-renewable' or non-sustainable biomass from deforestation. It includes the planting of energy forests. A small part of the potential lies in the increased use of sustainable biomass in the steel, pulp and paper industries, as well as the foods and beverages sector. It is assumed that particularly for steel production, the use of charcoal could be ramped up from 34.4% in 2007 to around 45% by 2030. Unlike the other measures in the industrial sector the use of sustainable biofuel is estimated to generate moderate positive costs and losses in the co-benefit category.

Fuel switch to other fossil fuels: The replacement of fossil fuels with a higher carbon content (e.g. oil and coal) by natural gas has a potential of 2.4 MtCO_2e/a in 2020. Although Brazil has substantial gas reserves of its own, the required pipeline infrastructure to transport the gas across the large distances in the country is seen as the main impediment to higher market penetration.

Waste

Levels of waste collection and treatment are relatively low in Brazil (McKinsey 2009). The daily per capita waste is expected to increase from 0.95 kg to more than 1.05 kg between 2010 and 2030 (Gouvello et al. 2010).

Reductions of emissions from waste and wastewater: Reduction estimates range from 9.6 to 31.3 MtCO_2e/a for 2020. Measures cover direct use of landfill gas, electricity generation from landfill gas as well as composting. The higher end of the range is determined by Gouvello et al.

(2010). They estimate that up to 80% of emissions from the sector can be mitigated by 2030 and around 50% by 2020. They identify avoiding emissions from burning CH_4 from landfill as the opportunity with the most significant potential and the lowest cost at 2.6 US$/t$CO_2$. The other activities assessed in the study have a much higher cost, overall providing a weighted average of around 25 US$.

Gouvello et al. (2010) actually estimate a total potential of 117% by 2030 for the sector, by including recycling in the calculation. According to the definition of sectors and measures used in our study, we have accounted for the significant potential they identify for this activity in the industrial sector. The remaining potential in the study delivers a 14% reduction below BAU emissions at a fully negative cost.

Transport

The transport sector in Brazil is more carbon efficient than most other countries due to the widespread use of ethanol as a fuel. The sector still represents around 50% of the total energy related emissions of the country and is expected to grow rapidly (McKinsey 2009). With 8,515 million km^2 total area it is the fifth largest country in the world (source), meaning that much travel involves long distances. Road transport is the largest source of emissions in the sector, at around 90% of the 2008 total. Urban transport, at 56% of emissions, poses the largest challenge to mitigation, as the largest growth is expected in this area (Gouvello et al. 2010).

Modal shift: The total potential assumed for this measure is 13.8 MtCO_2e/a in 2020, around 7% of expected BAU emissions for the transport sector in that year. The World Bank quantifies a wide range of activities that are all targeted to move passenger and freight transportation to lower carbon transportation modes. The largest potential is seen in the expansion of Bus Rapid Transit (BRT) systems for urban passenger transport, and in moving more freight transport to rail and waterways. Other activities with relevant potential include the very cost intensive expansion of the metro system and cost efficient traffic optimisation. On average the measures have moderate costs and large co-benefits by reducing local air pollution and time needed for travel.

Fuel switch: Replacing fossil fuels with bio-ethanol provides a potential of 5 MtCO_2e/a in 2020. Since 2003 the majority of new vehicles sold in Brazil have been equipped with flex-fuel motors that can use any mixture of gasoline and ethanol. The share of these types of vehicles is expected to grow from 29% in 2010 to 92% in 2030. The World Bank assumes that this can be achieved without further conversion of native forests. It must be noted that the study assumes that all emissions related to fossil fuels for production, fertilisers and sugar-cane burning are accounted for in the agricultural sector and emissions from ethanol for fuel use are zero.

AFOLU

The land use sector is by far the most important sector in Brazil. It constituted around 70% of total emissions in 2008. The main source of emissions within the sector is LULUCF. According to official data, LULUCF contributed 1,329 MtCO_2e/a in 2005 (Decree n° 7390), equivalent to the total emissions of Japan - the seventh largest emitter globally - in that year.

According to the USDA's Foreign Agricultural Service and Global Trade Information Services data[13], Brazil is the third largest exporter of agricultural products in the world, behind the United States and the European Union. Brazil ranks number one in world production and exports of coffee, sugar, and frozen concentrate orange juice; number two in soybeans, tobacco, beef, and poultry; and is a major producer and exporter of corn, pork, and cotton.

Re-/afforestation: We estimate that re- and afforestation measures will offer mitigation potential of between 71.6 and 137.5 $MtCO_2e/a$ for 2020. The large range in the estimates demonstrates the large uncertainty connected to the assumptions made about the availability of land for re-/afforestation and the capacity to utilise the available area of land. Estimates provide moderate positive costs and constitute large co-benefits from biodiversity and erosion management.

McKinsey (2009) provides estimates for reforestation and afforestation on grassland and cropland. Adjusted to 2020 they constitute the low end of the potential range.

Cerri et al. (2010) provide an intermediate estimate of 100 $MtCO_2e/a$ for 2020. The study also provides an alternative estimate based on a BAU scenario that includes a different estimate of newly planted area. While the scenario we used for our calculations assumes a continuation of observed increases for different types of plantation forest, the alternative scenario includes a proposition by the Brazilian Government in the BAU context to double the area of planted forest by 2020, thus offering little additional potential.

The high end of the range is given by estimates from the World Bank (Gouvello et al. 2010). The report projects a moderate carbon sink of 20 $MtCO_2e/a$ from this measure in the BAU scenario in 2030. The mitigation activities in this study focus on maximising carbon uptake associated with legal forest reserves and production forests.

Decreased deforestation: Activities to reduce deforestation offer by far the largest potential of between 213 and 874 $MtCO_2e/a$ in 2020. Forest types and level of deforestation activity vary significantly between the different areas within Brazil.

Deforestation began in Brazil as soon as the Portuguese colonized the country in 1500. The Portuguese were interested in the large profits to be gained from selling the native wood "Pau-Brasil" in Europe and explored the rainforest situated along the Atlantic coast of Brazil. This forest has since been reduced to 7% of its original cover. The Amazon has been reduced by roughly 17%, mainly due to illegal logging by international and national companies and conversion to pasture. Secondarily, the urbanisation process has also led to the loss of forest, due to, for example, the construction of roads and settlements.

Cerri et al. (2010) focus on the theoretical potential to be derived from different deforestation rates until 2020 and do not specify measures or tools which might achieve this.

The same report also calculates the potential against an alternative BAU scenario, as was done for afforestation. The "committed" mitigation scenario assumes an 80% reduction in deforestation by 2020 below the 1996-2005 average rates ("NPCC BAU"). However, the deforestation rate has dropped significantly in the 2006-2010 period. The other BAU scenario

[13] http://www.fas.usda.gov/country/Brazil/Brazil.asp

("Standby") therefore assumes an average deforestation rate of 10,000 km^2/a, roughly the average of the 2009 and 2010 rates. Depending on the BAU scenario chosen, the different mitigation scenarios deliver substantially different reductions, as illustrated in Tab. 9.

Tab. 9 Various reduction potentials from Cerri et al. (2010)

BAU scenarios / Mitigation scenarios	Average annual emissions 2010-2020 ($MtCO_2e$/a)		Average annual reductions 2010-2020 ($MtCO_2e$/a)[1]	
	NPCC[2]	Standby[3]	NPCC	Standby
	1,095	704	-	
Low	486		609	218
Committed	346		749	358
High	202		893	502

[1] Difference between BAU emissions and mitigation scenario emissions
[2] The NPCC BAU scenario corresponds to the official BAU provided by the Brazilian Government as the basis for their pledge
[3] Alternative BAU scenario using a fixed deforestation rate of 10,000 km^2/a

The different choices deliver a range of reductions between 218 and 893 $MtCO_2e$/a in 2020. This demonstrates the uncertainty connected to these reductions. The difference between the high and low ends of the estimate is 675 $MtCO_2e$/a, representing emissions equivalent to Canada's total emissions in 2009. The study provides the outer bounds of the range in potential.

Gouvello et al. (2010) estimated a potential of almost half a gigatonne. The Plan of Action for the Prevention and Control of Deforestation in the Legal Amazon (PPCD-Am) already contains a wide range of activities. The report highlights five areas of action: the expansion and consolidation of protected areas, deforestation and forest degradation monitoring, integrated project development, sustainable use of forest resources and payment for environmental services and products, and a socio-environmental register that records properties owned by people who are committed to improving the socio-environmental performance of their properties. Another important activity is the reduction of deforestation through measures to intensify livestock management to reduce the need for pastoral area.

Reduction of non-CO_2 emissions from livestock: Based on the literature we estimate the emissions reduction potential from livestock to be between 19.3 and 72.6 $MtCO_2e$/a in 2020. While this number seems small after the staggering potential from re-/afforestation and deforestation, it is still higher than the total potential identified for the waste and transport sectors together. Brazil accounts for 20% of the meat production and 23.5% of the milk production in developing countries. Enteric fermentation from grazing animals accounted for 12% of total emissions in Brazil in 2005 (Cerri et al. 2010).

Gouvello et al. (2010) analyse activities to reduce the methane production from cattle through genetic improvement, incentive programs for using genetically superior bulls in combination with improved forage and productivity gains and provide the low end of the range.

Cerri et al. (2010) distinguish between activities to reduce enteric fermentation through improved feeding practices, use of agents or dietary additives, and longer-term management changes and animal breeding and activities to improve manure management. With estimates between 36.8 and 72.6 $MtCO_2e$/a they provide for the upper end of the potential.

Reduction of non-CO_2 emissions from agricultural soils: This measure covers a wide range of activities in the different studies. Obvious targets are rice and sugarcane production as well as pasture management. The overall range of potential given across the studies is 18.4 to 74.7 $MtCO_2e/a$ in 2020.

Activities considered by Cerri et al. (2010) are no-tillage systems, water management systems in rice production and a shift to mechanical harvesting of sugarcane, maintaining crop residues in the field and thus increasing soil carbon. Gouvello et al. (2010) focus mainly on no-tillage systems, but provide a number of barriers that restrict the implementation. While the study by Cerri et al. (2010) provides the full technical potential assuming 100% of area converted to no-tillage systems by 2020, the World Bank report identifies a much smaller potential resulting from the barriers: lack of knowledge, access to technology, upfront cost of conversion, research gap and lack of infrastructure and marketing for the measure.

3.1.4 Evaluation of the pledge, mitigation potential and responsibilities of Brazil

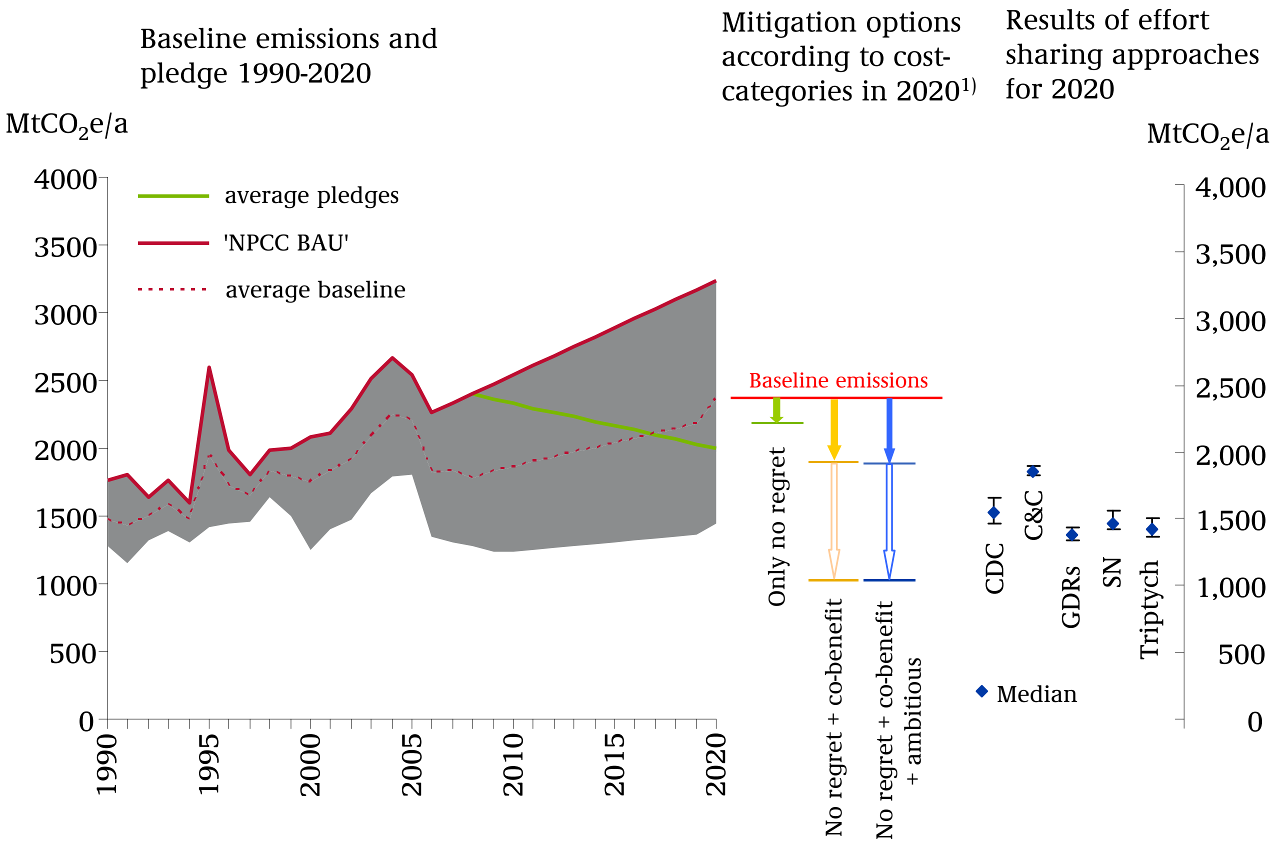
The great uncertainty around Brazil's LULUCF emissions does not allow a precise evaluation of the pledge.

Huge uncertainties associated with LULUCF lead to a mixed picture

Given the large range in BAU emissions, the evaluation of the impact of the identified mitigation potential is difficult. While the pledge to reduce emissions by 36-39% below BAU levels by 2020 seems ambitious at first sight, there are immense uncertainties connected to the data situation.

Assuming the average of the different BAU scenarios is a realistic approximation, the identified low end of the no-regret and co-benefit potentials could already overachieve the target. However, Fig. 1 illustrates the difficulty in evaluation. The pledge relates to the BAU scenario defined by the Brazilian Government, which forms the upper boundary of the range. The World Bank report (Gouvello et al. 2010) calculates a BAU emissions level that is 454 $MtCO_2e/a$ below the high end of the pledge range.

Only a small share of the identified mitigation potential comes at negative cost; this is mainly from measures in re-/afforestation, agricultural soils and energy efficiency in industry. The largest potential, from reducing deforestation, comes at moderate cost and determines the overall picture. The high ambition potential identified in a fuel switch in the transport sector will not contribute an overall significant reduction.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 15: Brazil: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches

Given the emissions profile of Brazil the most important political instrument for Brazil's mitigation trajectory is forest legislation. The Forest Law was established in 1965 to protect forest areas in Brazil. In April 2012 the Brazilian Congress passed a highly controversial amendment. Effects of this are estimated to make it harder for Brazil to meet its emissions reduction target as well as its reductions in deforestation rates (Höhne et al., 2012). The amendment was only partially approved by the President, Dilma Rousseff. At this moment it is unclear what the effects of the changes will be and how it will affect the ability of Brazil to tap the mitigation potential analysed in this study.

Separation of the pledge for LULUCF and non-LULUCF would improve transparency and increase incentives

Brazil has defined its pledge as a "range" of 36 to 39% below BAU emissions. The basis used for this reduction is at the high end of available BAU estimates and depends very much on assumptions made for the development of the LULUCF sector. Due to the high uncertainty of these assumptions we propose to differentiate the pledge to cover LULUCF and other emissions separately. This would allow for a more transparent tracking of success and provide better incentives to the non-LULUCF sectors. A revision of the LULUCF projections based on the latest findings may also be appropriate.

Pledged levels are not ambitious due to the high BAU level – effort sharing approaches ask for deeper reductions

We have used the average of several BAU emission scenarios as the best estimate for future development for all effort sharing calculations that are related to BAU emissions, i.e. all except the Contract & Convergence (C&C) approach. Under this assumption, the results show that all effort- sharing approaches require a more ambitious reduction than that pledged by Brazil. The pledge is largely in line with the C&C approach, where per capita emissions converge by 2050. The approach that would require the most stringent reduction from Brazil is the Greenhouse Development Rights (GDR) approach. This approach is a function of income, equity of distribution of income and responsibility.

LULUCF leads to large uncertainties in estimates of reduction potential

This assessment of Brazil's mitigation potential shows:

- Brazil's mitigation potential lies mainly in the land-use sector, reflecting its emissions profile. Both emission projections as well as reduction potentials in this area are characterised by a high level of uncertainty and estimates vary significantly depending on the assumptions made.
- The literature on Brazil identifies only limited potential for the energy sector. The main reduction potential outside the land-use sector is in the industrial sector and is based on improvements through increasing efficiency and on the use of sustainable biofuels, mainly replacing unsustainable biomass use.

Considering the uncertainty related to estimating emission development until 2020, Brazil's pledge seems to be not very ambitious. The emission level resulting from some of the alternative BAU projections would be higher than the official pledge levels. But even assuming that the average BAU from the different projections is a realistic estimate of real development, the pledge delivers only a 14 to 16% reduction and could be implemented at moderate costs according to all studies reviewed.

3.2 China

Tab. 10: Key indicators - China		
Population (2010)[14]:	1,340 million	Rank 1
GDP (2010)[15]:	9,950 billion US$ 2005 PPP	Rank 2
GDP growth (2000- 2010):	10.3%/a average 196% total	
Energy consumption (2010)[16]:	2,420 Mtoe	Rank 1
Energy consumption growth (2000 – 2010):	7%/a average 104% total	
GHG emissions (2008)[17]:	9.9 $GtCO_2e$	Rank 1

China is a major global economy which is experiencing significant economic growth. With a population of 1.3 billion in 2011 and a GDP of 9.94 trillion US$ (PPP constant 2005), it holds first and second place, respectively, in country rankings according to population and GDP (World Bank 2012). Its contributions to climate change have become increasingly important; both in terms of GHG emissions driving climate change and its input at international climate change negotiations.

At the international climate negotiations, China has repeatedly emphasised its development needs. Several Chinese researchers have proposed sharing future efforts for climate change mitigation using a carbon budget approach that is based on historical responsibility. Such an approach would allow equal cumulative per capita emissions from a base year in the past until a future year. China emphasises the right to develop and the need for economic growth in order to do so.

Since the opening up of the country in the 1980s, the economy has grown at very high rates. The most important sectors in terms of contribution to GDP are the industrial and service sectors. Industry accounted for a 44% share of GDP in 2011; the service sector has grown significantly over the last decades and accounted for 46% in 2011(World Bank 2012).

China is the biggest emitter of GHG, but with high levels uncertainty around the exact numbers. Total emissions have been estimated to have been 9.9 $GtCO_2e$ in 2008 (EDGAR 2011) and between 8 and 9 $GtCO_2$ e in 2010 (Guan et al. 2012) (Climate Action Tracker 2012). All issues related to climate change in China are managed under the National Development and Reform Commission, which is in charge of long-term planning, including the Five Year Plans and China's National Climate Change Programme (NDRC 2007a).

3.2.1 Historical and projected BAU development of GHG emissions in China

Expected emissions until 2020

The range of BAU scenarios points to a level of emissions between 13,300 $MtCO_2e/a$ and 13,800 $MtCO_2e/a$ in 2020. The sectoral distribution of emissions in 2020 as the average of different data sources is shown in Fig. 16. Electricity related emissions are reflected in the

[14] UN 2011

[15] World Bank 2012

[16] IEA/OECD 2012

[17] EDGAR 2011

sectors where the electricity is consumed. The sector with the highest share of emissions is the industrial sector (70%). A large share of these emissions is related to iron, steel and cement production.

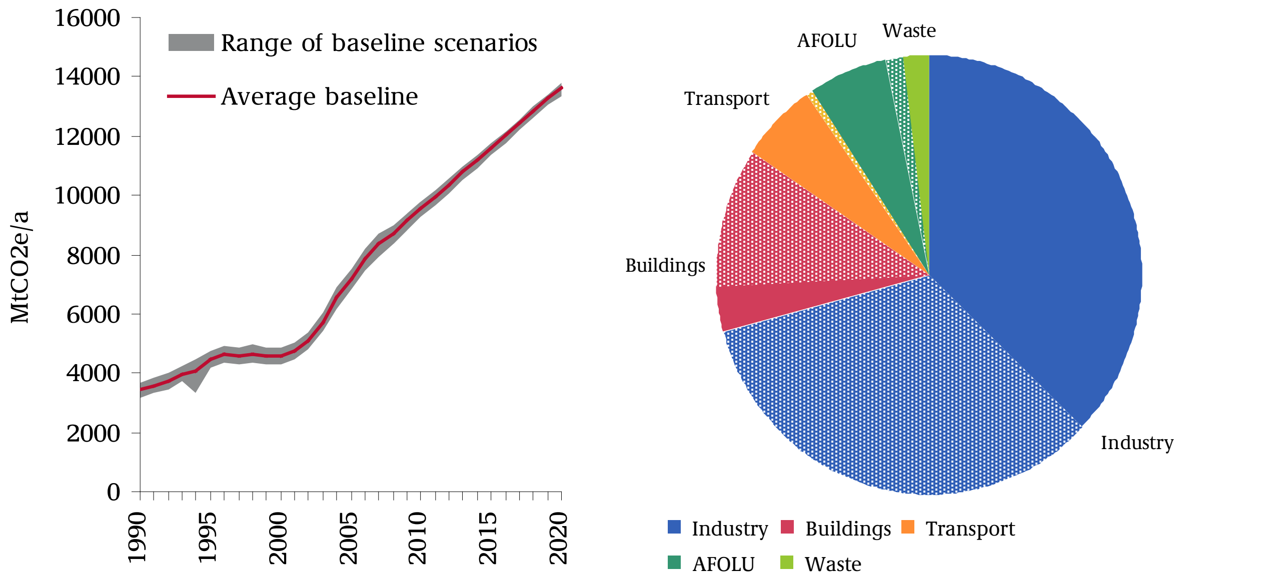


Fig. 16: China: Historical GHG emissions and projections from 1990 until 2020 (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6). Pie chart on the right shows distribution of emissions to sectors as in 2020. Shaded areas are electricity related emissions.

Main data sources and assumptions

The reports listed below served as our main data sources for Chinese emissions scenarios.

Historical data and projections:

- (IEA 2011b): The World Energy Outlook (WEO) 2011 contains all energy related CO_2 emissions. It includes historical data from 1990 to 2009 and projections until 2035 for the power supply, transport and total final consumption sectors. Economic growth is expected to be 8% on average until 2020.
- (Energy Research Institute 2009): Energy and emission scenarios developed by the Chinese Energy Research Institute (ERI). Data is available at a total national level. Economic growth around the year 2010 was assumed to be around 8% on average from 2009.
- (US EPA 2006): US Environmental Protection Agency's database includes non-CO_2 GHG emissions on the national level with historical data from 1990 to 2005 and projections until 2020 ("Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990 – 2020"). Emissions are disaggregated by source. We categorise these sources into different sectors.
- (Chen et al. 2006): The report "Greenhouse gas mitigation in China: Scenarios and opportunities through 2030" by CCAP and TERI include various sectoral emission outlooks until the year 2030. The authors look at several sectoral or subsectoral activities separately, not giving an overall emissions scenario. We use part of the data as one data source for the transport sector.

Historical data only:

- (UNFCCC 2012): Official historical data from China's GHG emissions inventory, as submitted to the UNFCCC. Only one year (1994) is available, all sectors and gases are covered and available at a disaggregated level.
- (Boden et al. 2011): CDIAC holds a database with historical CO_2 emissions from fossil fuel consumption and cement production on a national level. We use only cement production data, which is available for all years until 2008 and assign this to the industrial sector.

Except for the UNFCCC data for the year 1994, none of the sources used provide a complete data set covering all emissions and sectors. We therefore combine projections of the different sources to show the total emissions. As the only source for non-energy related CO_2 emissions is Boden 2011 with data until 2008, we apply the growth rate of the previous two years to emissions from cement production in 2008.

The data in the World Energy Outlook breaks the numbers down to power supply, transport and total final consumption. Total final consumption excluding transport makes up energy related CO_2 emissions from the industrial, buildings and AFOLU sectors. To distribute the emissions of the category in the WEO, we apply the growth rate of the total final consumption without transport to those sectors.

The upper limit of the range of resulting BAU emissions (13,800 $MtCO_2e$/a) includes IEA energy related CO_2 emissions for all demand sectors, non-CO_2 emissions from US EPA and CO_2 emissions from cement production from CDIAC. With data from ERI instead of WEO for energy related CO_2 emissions, the absolute emission level in 2020 would result in 13,700 $MtCO_2e$/a. The lower limit (13,300 $MtCO_2e$/a) consists of the same data, except for emissions from transport, which were replaced by projected emissions from Chen et al 2006.

Country specific uncertainties in determining the BAU

There are two main elements of uncertainty in determining the BAU scenario for China. The most important one is the assumption made on future GDP growth. The other - a common problem of determining a BAU pathway - is the extent to which policies are already included in the scenario. The WEO 2011 includes the 12^{th} Five Year Plan for China in its BAU scenario, while ERI does not consider it. At the same time ERI assumes lower economic growth for the years around 2010 than observed in reality, while the WEO 2011 includes the latest observations. Overall, this results in a lower emissions level for ERI than for WEO, but the difference of about 120 $MtCO_2e$/a in 2020 does not reflect the big differences in the assumptions.

In China, uncertainty around emissions data is high. Guan et al., for instance, calculate a difference of 1,400 $MtCO_2e$/a in 2010 between emissions based on national and provincial statistics (Guan et al. 2012). Additionally to the uncertainty on how to judge those emissions, it is important to remember that the size of China means that even small percentage deviations between different scenarios can lead to relatively big impacts on global emissions.

In comparison to Brazil, the LULUCF emissions are relatively small, so they lead to less uncertainty than is the case in Brazil.

3.2.2 China's pledge for GHG emission reductions in 2020

China's unconditional pledge on the international level under the UNFCCC includes three targets: Decrease of emissions intensity, increase of non-fossil primary energy and increase of forest coverage (UNFCCC, AWG-LCA 2011). This chapter describes and quantifies China's pledge.

Estimated effect of China's pledge on GHG emissions

China's three targets in detail are:

- Decrease emissions intensity of GDP by 40% to 45% by 2020 in comparison to 2005 levels. In other words, China plans to emit 40% to 45% less greenhouse gases per unit of GDP in 2020 than in 2005. The resulting absolute emission level of the pledge depends highly on future GDP growth.
- Increase the share of non-fossil fuels in primary energy consumption to 15% by 2020. This excludes the use of traditional biomass. For its statistics, China uses a primary energy factor for renewable energy which equals the average efficiency of fossil power generation. The exact value used in Chinese statistics is not publicly available. For our calculations, we assume this to be 38%.
- Increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic metres by 2020 from the 2005 levels.

According to our own calculations (see Fig. 17), China's pledge will result in total emissions between 11,200 and 13,700 $MtCO_2e/a$ in 2020. The lower value is based on emissions and primary energy consumption data from (Energy Research Institute 2009), the higher value on WEO 2011 (IEA 2011b). In comparison to the BAU scenarios, this means a reduction of 1% (based on WEO) to 18% (based on ERI) in 2020. The average baseline is in the upper range of the pledged emission level.

The large range resulting from the studies used is due mainly to their assumptions on economic growth. Giving another point for comparison, den Elzen et al. calculate that China's pledge would lead to an emission level of 4% below their BAU (13,500 $MtCO_2e/a$) and thus to 12,900 $MtCO_2e/a$ in 2020 (den Elzen et al. 2012).

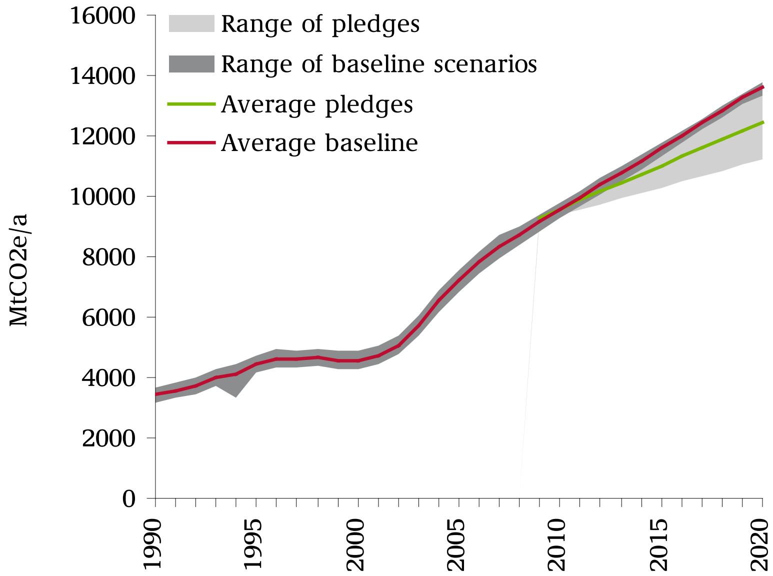


Fig. 17: Estimated emissions resulting from China's pledge

The three different targets included in the pledge are complimentary to each other: By reducing emissions in the respective sectors, the forestry target and the non-fossil energy target contribute to the overall emission intensity target. The most ambitious of the three targets will be the driving factor when looking at the absolute pledged emission level.

To quantify absolute emission levels resulting from the pledge we use the methodology and data from the Climate Action Tracker (Climate Action Tracker 2012): We first quantify the effect in terms of emission reductions and find out where overlaps exist. We assume the forestry target will have little impact on the BAU and thus not consider it further in the quantitative assessment of the pledge. We compare the emissions resulting from each single target to the BAU development. The target with the biggest emission reductions in comparison to the BAU is the target determining the absolute emission level of the pledge.

National climate change plans relating to the pledge

On the national level, China's 12th Five Year Plan provides targets and measures for the period 2011 - 2015. According to this plan, China wants to reduce the economy-wide emission intensity by 17% until 2015 in comparison to 2010, increase non-fossil energy to a share of 11.4% of primary energy until 2015 and increase forest coverage to roughly 20% of the country's area. Furthermore, China endeavours to reduce energy intensity by 16% until 2015 in comparison to 2010 (Xinhua 2011).

These short-term national targets are in line with the international pledge until 2020, if we assume that energy intensity will be decreased further beyond 2015 by 11% (until 2020).

China has also implemented a National Climate Change Strategy (NDRC 2007a), which describes major objectives and measures related to climate change mitigation and adaptation. The most important objectives included in the NDRC are:

- To control GHG emissions;
- To secure economic development;

- To conserve energy, to optimise the energy structure, and to strengthen ecological preservation and construction;
- To enhance capacities around issues related to climate change and sustainable development.

(Moltmann et al. 2011, p. 72)

3.2.3 GHG mitigation potential in China in 2020

Overview of studies used

The following studies were used to determine mitigation potential and in some cases costs for this analysis:

Tab. 11: Overview of studies used for determination of GHG emissions reduction potential for China

	(Chen et al. 2006)	(McKinsey & Company 2009a)	(ECN 2012)	(Vattenfall 2007)
Short description	Study by Tsingua University/CCAP with scenarios, mitigation options and costs for 2021	Study on China's mitigation potential including cost curves for the year 2030	MAC data collection gives an overview on different sources. The database also includes some calculations by ECN itself	"Global Mapping of Greenhouse Gas Abatement Opportunities until 2030" looks at global mitigation potential of different sectors. For the power sector, it gives a regional split of mitigation potential; among the regions is China
Base year	2005	2005/2010[18]	Various	2002
Sectors covered	Electricity supply, iron and steel industry, cement industry, paper industry and transport	Energy supply, industry, transport and buildings	Various	n.a.
Calculation method	Bottom-up	Bottom-up	Various	Top-Down
Main assumptions	Various sectoral assumptions, a GDP growth of 7.5%/a from 2000 to 2010 and 6.5%/a from 2010 to 2020. Population growth of 7.85%/a respectively 6.5%/a in those time frames. Fixed costs include: purchase, installation and maintenance, amortizing. Variable costs: energy costs based on year 2000, raw material costs in some cases	Growth rates of 9.9%/a from 2005 to 2010 and 8.2%/a for 2010 to 2020 for GDP and 0.5%/a from 2005 to 2020 for population. For mitigation technologies, global learning curves are assumed (but not disclosed for all technologies). Overlap between electricity and demand sectors considered	Various, depending on source. Not transparently disclosed in available dataset	n.a.

[18] BAU scenarios/mitigation scenarios

Evaluation of source	Very detailed study, transparent assumptions. May be outdated in some aspects	Detailed study, not all assumptions clearly disclosed.	Gives a good overview but little recent data. Most data for China is from (Chen et al. 2006).	Lack of transparency. We only use this study to compare the order of magnitude of the potential presented in other studies.

McKinsey puts electricity demand reduction before improvements in the generation, thus overlaps have already been taken into account in the report. Because Chen et al.'s study looks at each sector individually there are overlaps between electricity demand reductions and reduction of carbon intensity of electricity generation. These have been addressed in our analysis by assuming an overlap of 20% between electricity demand reduction measures and measures affecting the carbon intensity of electricity generation. This affects all measures of the energy supply sector and efficiency improvements in the building and industrial sectors.

Selection of measures assessed in detail

As described in the methodology chapter, we focus on the most important measures to determine the overall mitigation potential in 2020. The most important indicator is the share of emissions in the year 2020 of the relevant sector, which is shown in Fig. 16.

For measures affecting the electricity sector, we furthermore need to consider that these also have an impact on electricity related emissions of the demand sectors: With a decreasing carbon intensity of the energy supply sector, fewer emissions would be emitted per unit of electricity consumed. If all electricity related emissions were accounted for in the energy supply sector instead of in the demand sectors, this sector would hold a share of approximately 40%.

Resulting from these considerations, the most important sectors we want to target with our choice of measures are the energy supply and industrial sectors. We furthermore look at measures in the building and transport sectors. All "standard measures" we assessed for China are listed in Tab. 12.

The waste and AFOLU sectors are not considered further. Together, they will account for a projected 8% share in 2020 and are therefore not a priority for this assessment.

Tab. 12: Standard measures assessed for China

Standard measures
Energy Supply • Efficiency of power plants • Combined heat and power • Fuel switch to other fossils • Increase of nuclear energy • Non-bio renewables Industry • Energy efficiency of processes • (Includes electricity and fuel) • Alternative production routes • (E.g. increase use of recycled materials, for cement: more blended cement) • Use of sustainable biofuel • Fuel switch to other fossil fuels Transport • Modal shift • Efficiency improvements • Fuel switch (incl. electricity, hydrogen, natural gas and/or sustainable biofuels)

Buildings
- Low energy housing (incl. insulation of building envelope, ventilation with heat recovery, solar thermal energy and heat pumps)
- Efficiency of appliances

Total potential and associated costs in China

The overall GHG mitigation potential of China for the standard measures is found to be between 1,250 and 2,340 $MtCO_2e/a$ in 2020. Of this potential, 540 to 750 $MtCO_2e/a$ are covered by "no-regret measures", in other words by measures with negative abatement costs over the lifetime of the activity. Measures with moderate positive costs but relevant co-benefits have a reduction potential of 380 to 490 $MtCO_2e/a$ in 2020, and ambitious measures could reduce another 330 to 1,110 $MtCO_2e/a$.

Fig. 18 illustrates the range of mitigation potential of different measures for 2020 found in different studies. Fig. 19 shows the mitigation potential per measure and per cost category. The text below further discusses the results for each specific sector and measure. The annex shows further details for each standard measure assessed.

Fig. 18: China: Ranges of mitigation potential by standard measures found in different sources (measures in grey have not been assessed in detail)

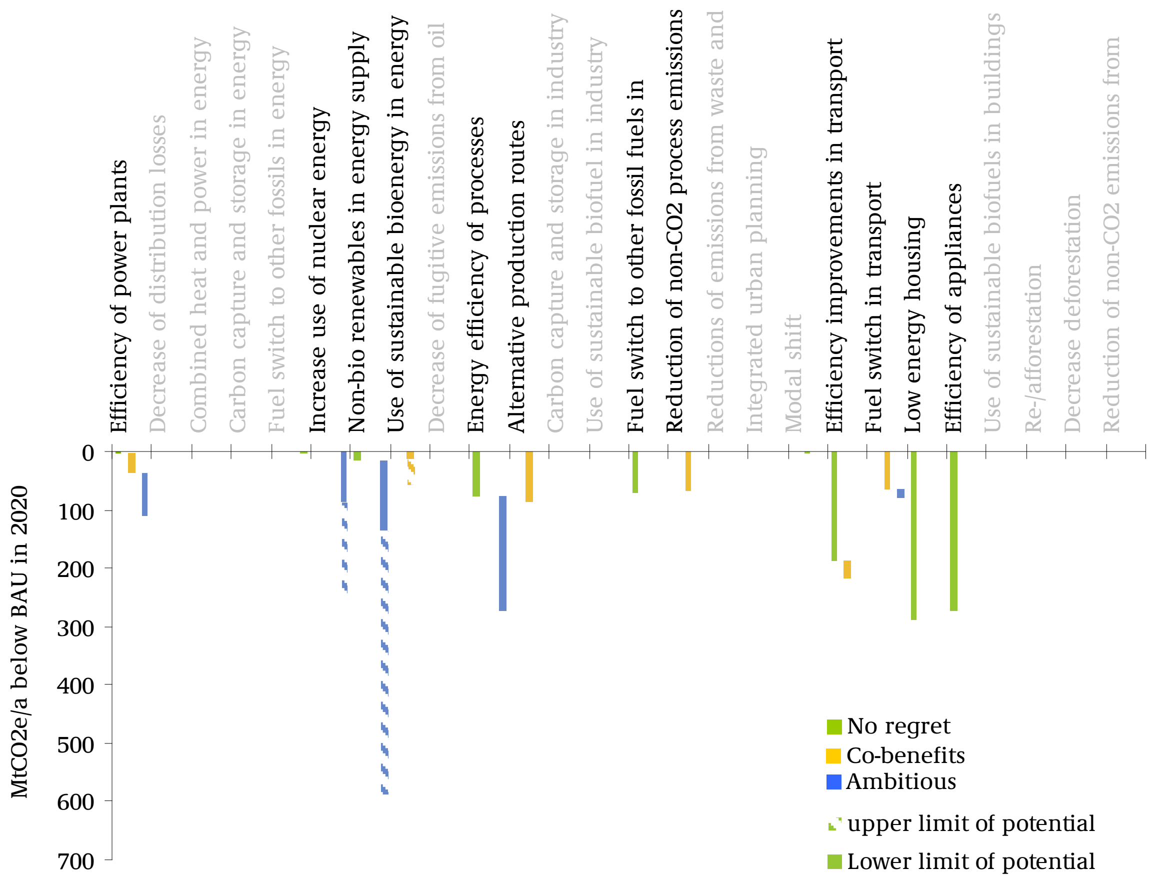


Fig. 19: **China: Mitigation potential by standard measure and cost category (measures in grey have not been assessed in detail)**

Energy Supply

The energy supply sector in China has grown substantially over the last years and is projected to keep increasing. The capacity of coal-fired power plants has increased by 300% since 2000 (IEA 2012, p. 65). Along with high economic growth, which has been accompanied by a higher level of development in China, we can expect a trend towards electrification of certain end uses for the future. In addition, specific emissions of China's power plant park are above world average today (IEA 2011a), as it relies heavily on coal-fired power plants. China relied on small, decentralized coal fired units in the past, which had a tendency to be inefficient. During the last decade, there has been a shift from smaller inefficient power plants towards large-scale projects, which are required in order to implement certain efficiency measures (Chen et al. 2006, p. 25). Under the 11th Five Year Plan, China shut down 77 GW of inefficient coal-fired power plants. In 2011, another 8 GW were closed (IEA 2012, p. 68). Along with its high share of emissions, the dynamics in the growth of the sector are set to create opportunities for cost-efficient improvements.

Given the importance of the sector, we include most defined "standard measures" in our assessment. We do not consider further reduction of distribution losses, carbon capture and storage (CCS), and reduction of fugitive emissions from oil and gas. Distribution losses and fugitive emissions both do not contribute much to GHG emissions. We do not expect CCS to be relevant in large-scale installations until 2020 because it is an immature technology.

Efficiency of power plants: The overall mitigation potential from the improved efficiency of power plants is between 47 and 111 $MtCO_2e$/a in 2020. Chen et al. include improvements using circulating fluidized bed combustion (CFBC), reconstruction of conventional thermal plants, construction of super- or ultra-supercritical plants and the option of Integrated Gasification Combined Cycle (IGCC) and Pressurized Fluidized Bed Combustion (PFBC) technology. Reconstruction of conventional plants also includes the upgrade to co-generation (Chen et al. 2006, p. 35). McKinsey looks at IGCC and CCS, the latter of which is not considered quantitatively in this report.

Of the overall mitigation potential from the improved efficiency of power plants, we classify a small share as no-regret (4 $MtCO_2e$/a reduction due to CFBC) because of negative costs according to the source. 9 to 77 $MtCO_2e$/a are in the ambitious category, with a cost range of 32 to 39 US$ and no relevant co-benefits. This potential relates to the introduction of IGCC coal power plants. Reductions of 34 $MtCO_2e$/a through reconstruction of conventional plants and super- and ultra-supercritical plants belong to the co-benefits category according to Chen et al. who cite abatement costs of 6 US$ for these technologies.

Improvements in the efficiency of coal-fired power plants can have significant co-benefits. Most important is the decrease in local air pollution. Heavy smog partly caused by the power supply sector is a major problem in vast parts of China and leads to severe health problems. Higher air quality improves health of the population, and besides increasing well-being and the standard of living, thus ultimately also has a positive impact on productivity.

Combined heat and power: No data was found for the reduction potential and costs of CHP in China. In Chen et al., it is included in the efficiency improvements of power plants. We can assume that there is a substantial potential for CHP in China, as the major conditions are given: Demand for heat (by industry and the residential sector) and relative nearness of demand and supply of heat. EPA together with the Asia Pacific Partnership on Clean Development and Climate, states that by implementing the plans as mentioned in the 2010 CHP Development Planning and 2020 Development Goal, 13 $MtCO_2e$/a could be avoided in 2020 (EPA, Asia Pacific Partnership on Clean Development and Climate 2008, p. 12).

Fuel switch to other fossil fuels: A fuel switch from coal to gas does not reveal much potential according to the studies considered. The data presented by Chen et al. points to a potential in 2020 of about 3 $MtCO_2e$/a with relative high costs of about 40 US$/$tCO_2e$, which we classify as ambitious. Other studies have not assessed the potential of a fuel switch to gas.

Increase of nuclear energy: The shift away from coal towards non-fossil energy sources is one of China's targets on the national level. Nuclear electricity generation is one option besides renewable energy and "cleaner fossil technologies", such as CCS. With 26 nuclear reactors under construction at the end of 2011 (total additional capacity of 27 GW), China is the most active country in the development of nuclear capacity (IEA 2012, p. 71).

The results from the two studies considered suggest a reduction potential in 2020 in the range of 86 to 246 $MtCO_2e$/a. McKinsey is more optimistic, showing a higher potential at smaller costs than Chen et al.

Replacing coal-fired power plants with nuclear power has co-benefits in terms of improved local air pollution. On the other hand, it implies other strongly negative environmental effects. The two major risks of nuclear energy – unsolved waste disposal and possible significant impacts of incidents – could lead to high costs for society in the long term. Large inflexible base load capacities furthermore complicate grid integration of a high share of renewables. We thus rate the potential of nuclear power as ambitious, although the two studies quantify cost in the range of 3 to 19 US$.

Non-bio renewables in electricity supply: Renewable electricity (excluding bioenergy) reveals the biggest potential of all technologies in China according to the studies surveyed. We find the potential in 2020 to be between 120 and 571 MtCO_2e/a in 2020. Chen et al., from whom the lower limit of the range is taken, name hydropower as the major opportunity in the area of renewable energy. Less relevant in their report are wind and solar thermal electricity (Chen et al. 2006, p. 41). They do not mention solar photovoltaic power. From McKinsey, we find a potential of 571 MtCO_2e/a in 2020, resulting from deployment of on- and offshore wind and solar PV (at about equal shares) and to a smaller extent from small hydropower.

Part of the potential found here is likely to already be included in the baseline shown in this report, as that contains data from the WEO 2011 including the renewable energy target from the 12th Five Year Plan.

Although the mitigation potential from renewable electricity generation is substantial, the studies used estimate cost for most of the potential to be relatively high. Over the last years, renewable energy has developed more rapidly than expected, and prices have dropped significantly. This development was not foreseen in the studies included in this report. A more optimistic view can be taken therefore in terms of expected costs. In this light, China has regularly corrected its ambition in electricity generation from renewables upwards. For example, the capacity target for 2020 for solar PV was 1.8 GW in the Medium and Long Term Development Plan for Renewable Energy in China (NDRC 2007b). In the 12th Five Year Plan, the capacity target for solar was first set at 5 GW in 2015, but later increased to 15 GW and more recently to 21 GW (Patton 2012). There are rumours that China might again double the capacity target to 40 GW (Parkinson, Sophie Vorrath 2012).

Besides co-benefits that accompany decreasing contamination from coal-fired power plants, renewable energy is also an important opportunity for the Chinese economy in terms of creating new industrial branches and diversification. The solar industry for example has grown significantly over the last years and has become a very strong competitor on the global market. In addition to direct economic gains, this leads to an increased knowledge base that in the long term can secure competitiveness.

Sustainable biofuels: Use of sustainable biofuels for electricity generation has a relatively small potential of about 13 to 54 MtCO_2e/a in 2020. The lower limit, 13 MtCO_2e/a, is from McKinsey and only includes agricultural waste as a source of energy. The upper limit is taken from (ECN 2012) with no further information on its origin.

Difficult is the definition of "sustainable" biofuels, especially considering very limited data available on the mitigation potential in this area. We assume that the potential stated in the sources used is "sustainable", which is certainly a reasonable assumption for the use of agricultural waste as evaluated by McKinsey.

Industry

The industrial sector has the highest share of GHG in China compared to other sectors. It is dominated by iron and steel and the cement industry, which are both very emission intense because of high energy consumption and process emissions. Most studies assessing mitigation potential in China focus on these activities. This is especially the case for alternative production routes, where blending of cement is the focus of most reports related to the sector's mitigation potential.

For the industrial sector, we take a closer look at opportunities related to energy efficiency, alternative production routes and fuel switch (both from one fossil to another as well as from fossil to sustainable biofuels). Just as for the energy supply sector, we do not consider CCS further. Non-CO_2 process emissions do not represent a high share of the sector, so we also do not measure reductions from these.

Energy efficiency of industrial processes: Energy efficiency in industry is one major area of improvement also acknowledged in the planning of the Chinese government (see for example Office of the State Council 2011, chapter I).

The mitigation potential found in different studies is in between 137 and 274 $MtCO_2e/a$ in 2020, of which about one third falls within the no-regret category and two-thirds in the ambitious category. No-regret measures lie especially in the area of energy management and auditing. Ambitious measures in many cases involve exchange of capital intensive equipment (for example, highly efficient cement kilns and various technologies for the iron industry.

Energy audits and modern equipment can increase (awareness of) safety on industrial plant sites and decrease health risks for employees and populations nearby.

Alternative production routes: Besides decreasing the energy intensity of a process, complete processes can also be exchanged. The mitigation potential in this area is between 17 and 86 $MtCO_2e/a$ in 2020. In this area, the studies found only include clinker substitution in cement industry. McKinsey & Company name a much higher potential (86 MtCOe2/a) than Chen et al. (17 $MtCO_2e/a$).

Reduction of non-CO_2 process emissions: Although f-gas emissions have a relatively small share of total GHG emissions (1.8% in 2010), the potential for reductions is significant, as measures are easy to implement and available at reasonable costs (compare Rhiemeier, Harnisch 2009).

According to McKinsey & Company (McKinsey & Company 2009a), the reduction potential of non-CO_2 emissions in China is at about 70 $MtCO_2e/a$ in 2020 or 40% of the f-gases in our BAU scenario (174 $MtCO_2e/a$ in 2020). This potential is to be covered at relatively low costs and improvements in this area can lead to a safer production processes. We therefore categorise it as co-benefit potential.

Fuel switch to other fossil fuels: Looking at different studies, mitigation potential derived from this measure could be found only in the cement sector, where coal is suggested to be replaced by waste products such as tires or agricultural by-products. The potential is between 20 and 70 $MtCO_2e/a$ in 2020 (according to Chen et al and McKinsey & Company).

This potential is rated as no-regret. Costs are typically negative; furthermore, co-benefits arise because of the disposal of waste. Because of the high process temperatures, a big part of harmful substances is burnt completely.

Transport

Although the transport sector is expected to account for a fairly small share of emissions in 2020, we include it in our assessment. We expect emissions from this sector to increase drastically in the future. Vehicle ownership has increased by 850% over the last decade (National Bureau of Statistics of P.R. China 2011), but per capita vehicle ownership is still far below the level of Annex I countries. This leaves much potential for vehicle ownership to rise further with a higher standard of living. Concepts for urban planning and public transport can be integrated in the development of cities and infrastructure, which is moving ahead at a fast pace in China.

In the transport sector, we include measures related to energy efficiency, modal shift and fuel switch. In some cases, a fuel switch and modal shift result from one activity, for example in the case of shifting freight transport from road to electric rail. Urban planning may be an important factor in China because of high urbanisation rates and the ongoing growth of megacities. Due to lack of data we could not assess the possibilities for this measure quantitatively.

Modal shift: This measure includes shift of freight to trains, and passenger transport to less carbon intensive modes.

Although this area of improvement can play a major role in future Chinese planning, the only data found evolves from Chen et al. and results in 5 MtCO_2e/a reduction potential in 2020. The only measure included in that report is the development of BRT. This measure has relatively low abatement costs and a number of co-benefits, such as improvements in population mobility, leading to higher productivity and less local air pollution in cities, decreasing health problems. We therefore judge this measure to be in the no-regret category.

Efficiency improvements in transport: Very high potential is expected in this area of improvement (138 to 403 MtCO_2e/a in 2020). The potential includes improvements to vehicle design as well as engines. It also covers both light vehicles and trucks. Costs are generally lower for light duty vehicles (McKinsey & Company 2009a).

Fuel switch in transport (incl. electricity, hydrogen, natural gas and/or sustainable biofuels): The total mitigation potential in this area is found to be at about 170 MtCO_2e/a in 2020, according to Chen et al. and McKinsey & Company. Chen et al. include a switch from gasoline and diesel to liquefied petroleum gas (LPG) and compressed natural gas (CNG). Their numbers lead to a mitigation potential of about 20 MtCO_2e/a in 2020 at moderate costs. McKinsey & Company looks at potential reduction of emissions through electric mobility, including plug-in hybrid and purely electric vehicles. Together, the two technologies have a potential of 150 MtCO_2e/a in 2020, 80% of which refer to plug-in hybrids.

As is the case for other measures in the transport sector, improved air quality is an important co-benefit. Furthermore, support for electric mobility could also provide opportunities to develop new high tech industries in China.

The costs of the measures are moderate to high. Purely electric vehicles have significantly higher prices than the other fuel switch options. Fuel switch to gas vehicles and plug-in hybrid are thus seen as co-benefit measures, purely electric vehicles as ambitious measures.

Buildings

The building sector, which includes the service and the residential sectors, is expected to rank third in GHG emissions in China among all sectors in 2020. As a result of increasing per capita income and technology development, households tend to utilise a greater number of electric appliances. The use of communication electronics such as computers, telephones and video cameras in particular has increased substantially. Furthermore, air conditioning has become very important, with 1.12 air conditioners per household in 2010 opposed to 0.31 in 2000 (National Bureau of Statistics of P.R. China 2011) ("Ownership of Major Durable Consumer Goods Per 100 Urban Households at Year-end"). Ongoing urbanisation is reflected in the numbers for new residential floor space in urban areas, which have increased by about 20% from 2000 to 2010 (National Bureau of Statistics of P.R. China 2011) ("Floor Space of Newly Built Residential Buildings and Housing Conditions of Urban and Rural Residents").

With a wide variety of climatic zones, buildings in China have different requirements depending on their location. In the north and towards the western parts of the country, heating is required. In the southern parts of the country, hot climates dominate and cooling is needed. With an increasing standard of living of the population, demand for these energy services grows. Furthermore, floor space per capita increases, both in rural and urban areas (National Bureau of Statistics of P.R. China 2011).

For the building sector, we focus on the measures "efficiency of electric appliances" and "low energy housing" to cover both the increased use of appliances and the development of floor space.

Low energy housing: Numbers for mitigation potential in improvements of the building envelope can be found in McKinsey & Company 2009: In 2020, about 290 $MtCO_2e/a$ could be avoided by increasing efficiency of the building envelope. Because of their high energy savings, the measures have negative costs.

Efficiency of appliances: As described above, the use of electric appliances has increased substantially during the last decade and is bound to grow further. McKinsey & Company look at improvements in lighting, electric water heating, room conditioning and other electric appliances and find a mitigation potential of about 270 $MtCO_2e/a$ in 2020.

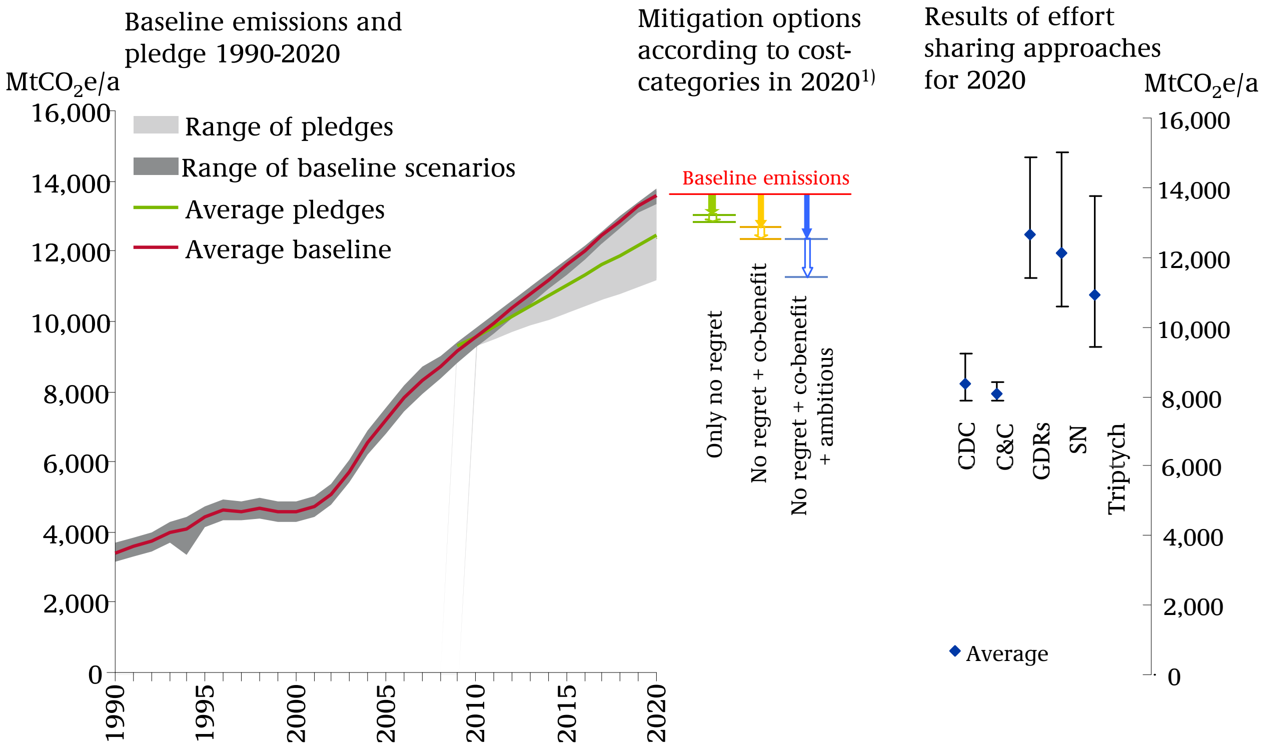
Improvements in room conditioning hold the biggest share of this potential (more than 50%) and are available at relatively low costs. Given the co-benefits of increased comfort and safety, we categorise it as a co-benefit measure. Lighting, with about 80 $MtCO_2e/a$ in 2020 has the second biggest potential, other measures another 50 $MtCO_2e/a$. Lighting and other measures have negative costs and are therefore in the no-regret category.

3.2.4 Evaluation of the pledge against the mitigation potential and results of effort sharing approaches

China's international pledge leads to improvements compared to emission trends. Mitigation potential is likely to go beyond what is pledged. Effort sharing approaches based on per capita emissions suggest a more ambitious target could be warranted. National policies may be more ambitious, but their total effect was not evaluated here.

The mitigation potential identified in this report is larger than what China pledged internationally. Effort sharing approaches based on per capita emissions would suggest a more ambitious target. Meeting the pledge, China will increase its emissions to up to 14 $GtCO_2e$. National policies may be more ambitious but their total effect was not evaluated in detail here.

China submitted its Second National Communication in November 2012 (Government of China, 2012), which for the first time includes a recent GHG emission inventory and scenarios for future emissions. The Communication was published too late to be fully considered in this report. Our preliminary analysis confirms our conclusion, China's emissions would rise to 14 $GtCO_2e$ when meetings its pledge.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with least cost options.

Fig. 20: China: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches

<u>Meeting the pledge will slightly slow down but not stop China's emissions growth</u>

Fig. 2 shows that the pledge can result in a range of emissions (from 11,200 to 13,700 $MtCO_2e/a$ in 2020), depending on different assumptions, mainly future GDP growth. The average of the pledge estimates (12,500 $MtCO_2e/a$ in 2020) is only 9% below the BAU trajectory and it is clear that making use of the mitigation potential, emission levels can be decreased further below the pledged level.

The range of pledged emissions overlaps with the range of BAU emissions. The pledge calculated based on IEA data is very close to BAU emissions based on the same information. The IEA baseline already includes some of the Chinese policies and therefore is likely to be close to the pledge. The data from the Chinese Energy Research Institutes (ERI 2009) shows a larger difference between the pledged and BAU levels.

China has put forward an emission intensity target with the rationale that international climate change mitigation commitments should not constrain economic growth and development. This view does not necessarily reflect opportunities for growth in the area of climate change mitigation ("green growth"). With its dynamic growth, China can develop this area to make use of this concept and to reduce national emissions further. China already implements many national measures that could go beyond the international pledge. As such it is likely that the pledge will be achieved or overachieved.

China's dynamic growth can also be an opportunity for mitigation actions

The main possibilities for GHG mitigation in China lie in the energy supply sector, specifically in the area of renewable energy, and in the industrial sector, specifically in the area of energy efficiency. Another important area of improvement is the building sector, which is subject to rapid changes due to increasing economic wealth.

The total potential considered here takes us below the pledged emission level calculated based on IEA data. To reach the ambitious end of the pledge range, ambitious measures will have to be taken. With all the potential assessed, only the upper range of the potential including all three cost categories goes beyond the pledged emissions.

Effort sharing approaches based on per capita emissions would suggest a more ambitious target.

The results from different effort sharing approaches vary substantially across different approaches depending also on the assumed baseline development. The different approaches find emission reductions to be necessary between 6 and 41%[19] below BAU levels in 2020, generally more stringent than the pledged level of around 8% below BAU (the average of both data sources).

The most stringent approaches for China are common but differentiated convergence (CDC) and C&C (38% and 40% below BAU), which are both based on convergence of per capita emissions. As China already has relatively high per capita emissions in comparison to other non-Annex 1 countries, these approaches lead to higher reductions that need to start immediately. Less stringent are Triptych and the South North (SN) approaches (19% and 10% below BAU). Triptych, based on converging sectoral efficiency, allows for growth in production volumes, which will be significant in China. The SN approach judges China's capacities and responsibilities to be smaller than the other three approaches by putting it into a certain stage of development. The Greenhouse Development Rights (GDR) approach is the least stringent approach (6% below BAU in 2020), because major shares of the population are still below the defined threshold of 7 500 US$ income per capita in China.

[19]The percentage indicates the mean average of the scenarios calculated with the EVOC model. The complete range is shown in Fig. 20.

3.3 India

Tab. 13: Key indicators - India		
Population (2010)[20]:	1 220 million	Rank 2
GDP (2010)[21]:	3 721 billion US$ 2005 PPP	Rank 5
GDP growth (2000- 2010):	7.5%/a (105% total)	
Energy consumption (2010)[22]:	892 Mtoe	Rank 5
Energy consumption growth (2000 – 2010):	7%/a (104% total)	
GHG emissions (2008)[23]:	2.4 $GtCO_2e$	Rank 5

After China, India is the second biggest emerging economy in terms of population. Although the population growth rate has decreased steadily since the 1980s, the rate as of 2011 was still at almost 1.5% per year today (2011). In spite of strong economic growth, India belongs to the poorest countries in the world with a low Human Development Index (HDI), a relatively low adult literacy rate and a current per capita income of 3 550 US$ PPP (GIZ 2012).

With 2 tCO_2e/capita (calculated based on (EDGAR 2011) and (2011), India's per capita emissions are very low in comparison to those of other emerging economies. Furthermore, access to electricity is limited: in 2009, 25% of the population did not have access to electricity (IEA 2012, p. 65).

In India, the Ministry for Environment and Forestry and more specifically the Climate Change Division is responsible for climate change cooperation and negotiations. In the international negotiations under the UNFCCC, India has represented the principle of equal per capita emission rights and sees the responsibility for climate change mitigation as lying with those countries which hold the greatest historical responsibility (Shukla, Dhar 2011, p. 232).

3.3.1 Historical and projected BAU development of GHG emissions in India

This section illustrates historical data and possible BAU pathways of Indian GHG emissions according to different sources.

Expected emissions until 2020

The range of BAU scenarios is calculated to be between 2,500 $MtCO_2e$/a and 4,800 $MtCO_2e$/a in 2020. The development of total emissions and the sectoral distribution of emissions in 2020 as the average of different data sources are shown in Fig. 21. Electricity related emissions are reflected in the sectors in which the electricity is consumed. The sector with the highest share of emissions is the industrial sector (44%).

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[20] UN 2011

[21] World Bank 2012

[22] IEA/OECD 2012

[23] EDGAR 2011

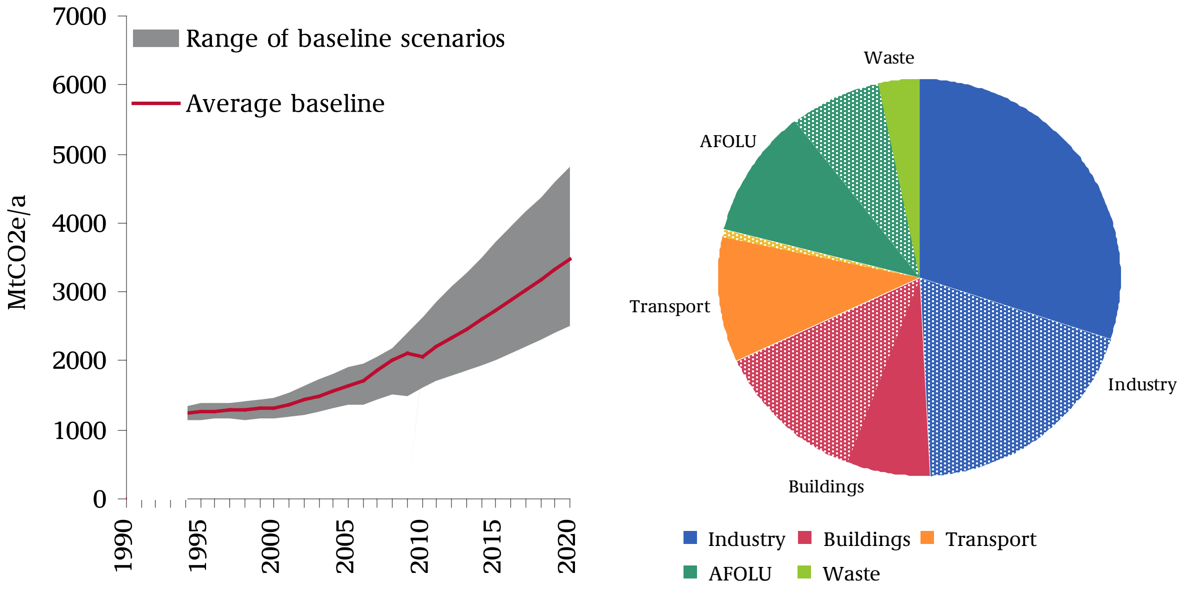


Fig. 21: India: Historical GHG emissions and projections from 1990 until 2020 (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6). Pie chart on the right shows distribution of emissions to sectors as in 2020. Shaded areas are electricity related emissions

Main data sources and assumptions

Our main data sources for India are the IEA's Energy Balances and Statistics (2012), the India's second National Communication (Government of India 2012), a study by the Climate Modelling Forum (Climate Modelling Forum 2009), which compares five emission scenarios from different sources and projections from the Planning Commission of the Government of India (Planning Commission Government of India 2011). The scenarios taken from the Climate Modelling Forum were developed before the latest global economic crisis and thus do not reflect the most recent observations available. The official data that India has submitted to the UNFCCC is for the years 1994 and 2000 and is in line with the emissions reported in the National Communication.

Unfortunately, the emission projections lack detailed data by sector. Only the WEO 2011 gives some information on the transport sector's expected development. In order to still be able to give an approximate for the distribution of emissions in the future, we assume all other sectors will grow at the growth rate of the total average emissions.

The IEA data only reflects energy related CO_2 emissions and does not include other GHG or process emissions. We therefore add process emissions from the industrial sector and agricultural emissions as reported in the National Communication to the UNFCCC which we assume will grow at the average rate of the projections from Climate Modelling Forum and LULUCF emissions from UNFCCC, which we assume will stay constant at the 2000 levels.

India's BAU emissions differ dramatically from source to source. The overall range is between 2,500 and 4,810 $MtCO_2e/a$. The lower limit of the range of resulting BAU emissions shows the sum of emissions of all sectors, according to the IEA CO_2 emissions database and our assumption that each sector's emissions will increase at the same rate as the average rate of country-wide emission scenarios. The high end of the scenario results from the high growth scenario of the Planning Commission of the Government of India (Planning Commission Government of India 2011). There are many reasons for the differences in the numbers, starting from assumptions on economic growth and population projections to methodological differences such as emission factors, base years and underlying data used.

3.3.2 India's pledge for GHG emission reductions until 2020

India has pledged to reduce emission intensity by 20 to 25% by 2020 in comparison to 2005. Emissions from the agricultural sector are excluded from the assessment of the target (UNFCCC, AWG-LCA 2011, p. 28). India does not clearly state that LULUCF emissions are considered as part of the agricultural sector, but we assume that this is the case. Thus, LULUCF emissions are not considered in the pledge. The pledge is unconditional to international support and other requirements.

Estimated effect of India's pledge on GHG emissions

Similar to the BAU emission scenario, India's pledge depends on a wide range of assumptions and thus the quantification varies according to different sources. The overall range of emissions reduction is between 3,050 and 4,350 $MtCO_2e/a$ in 2020 (den Elzen et al. 2010). Average emissions under the pledge resulting from the different sources are at about the same level as the average BAU scenario (3,490 $MtCO_2e/a$).

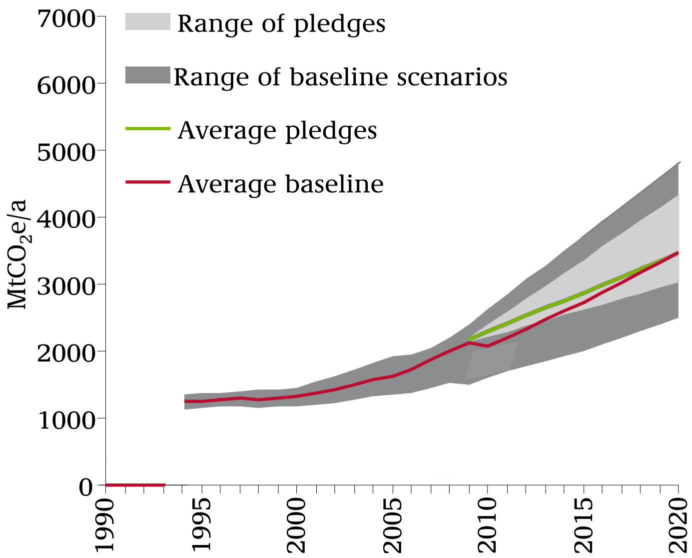


Fig. 22: Estimated emissions resulting from India's pledge

The studies included in the range given by den Elzen et al. use very different methods to assess the emission level resulting from the pledge and already vary in the assumptions on BAU developments. Most look at the 20% to 25% target, thus the differences result from differences in assumptions and methodologies (den Elzen et al. 2010, p. 57). The lower end of the range – or the most ambitious interpretation of the pledge – is given in the World Energy Outlook 2009 (IEA 2009). The least stringent interpretation, leading to the higher end of the pledge range, evolves from the scenario developed by TERI (Climate Modelling Forum 2009). In a more recent study, den Elzen et al. quantify the pledged emission level as 3,530 $MtCO_2e/a$ in 2020 (den Elzen et al. 2012, p. 34).

National climate change plans relating to the pledge

India's emission reduction target has been largely shaped by various policy measures such as the country's Five Year Plans and the National Action Plan for Climate Change (NAPCC). The NAPCC recommends mitigation actions in 8 areas in order to address climate change, including solar energy, energy efficiency, sustainable habitats, water, Himalayan ecosystem support, green India, sustainable agriculture and strategic knowledge for climate change (Government India 2008).

A Council on Climate Change was established in 2008, consisting of various ministers, the planning commission and NGOs. Within the Ministry for Environment and Forestry, the Climate Change Division is responsible for climate change cooperation and global negotiations. The Climate Change Division is also the focal point of the NAPCC and is in charge of IPCC related activities and national communications. Under the 11th Five Year Plan, networks have been established for various climate change related topics, for example. waste treatment, climate change and adaptation.

In addition to the emission levels resulting from the pledge, den Elzen et al. also show the estimated effect of the national climate change plan according to various studies. The range of remaining emissions after implementation of the plan lies below that of the pledged emission level and is between 2,500 and 3,800 $MtCO_2e$/a in 2020 (den Elzen et al. 2010, p. 56).

3.3.3 GHG mitigation potential in India in 2020

Overview on studies used

The following studies were used to determine mitigation potential and in some cases costs for this analysis:

Tab. 14: Overview of studies used for determination of GHG emissions reduction potential for India

	(TERI, CCAP 2006)	(Shukla, Dhar 2011)	(McKinsey & Company 2009b)	(Planning Commission Government of India 2011)
Short description	Study by CCAP in cooperation with TERI	Emission scenarios, of which some include measures to mitigate GHG emissions.	Study on India's mitigation potential including cost curves for the year 2030	Interim report by the expert group on low carbon strategies and inclusive growth, as basis for the 12th Five Year Plan
Base year	2005	2005	2005/2010[24]	2007
Sectors covered	Electricity supply, iron and steel industry, cement industry, paper industry and transport	Electricity supply, electric appliances, transport	Electricity supply, industry, buildings, transport, agriculture	Electricity supply, industry, transport
Calculation method	Bottom-up	Bottom-up	Bottom-up	Bottom-up
Main assumptions		GDP growth rate 2005-2030: 8.1% Population growth rate 2005-2030: 1.1% Carbon price in 2020: 4 2005US$/t$CO_2$e in base scenario	GDP growth rate 2005-2030: 7.5% Population growth rate 2005-2030: 1.2%	GDP growth rate 2007-2020: 8-9%
Evaluation of source	Very detailed study, including mitigation potential and costs for different measures for the year 2021	Peer reviewed article with detailed scenario in background. Data found for various measures only.	Detailed study, not all assumptions clearly disclosed.	Official government report

McKinsey puts electricity demand reduction before improvements in generation, thus overlaps have already been taken into account in the report. Because TERI looks at each sector individually there are overlaps between electricity demand reductions and reduction of carbon intensity of electricity generation. However, in the quantification of the total potential we have not considered this further because the only measure with data from TERI and related to electricity consumption (energy efficiency in paper industry) has a negligible potential.

Selection of measures assessed in detail

The most important indicator for the importance of measures is the share of emissions in the year 2020 of the relevant sector, which is shown in Fig. 21.

For measures affecting the electricity sector, we furthermore need to consider that these also have an impact on electricity related emissions of the demand sectors: With a decreasing carbon intensity of the energy supply sector, fewer emissions would be emitted per unit of electricity consumed. If all electricity related emissions were accounted for in the energy supply sector instead of in the demand sectors, this sector would hold a share of approximately 38-45% (depending on the source used).

[24] BAU scenarios/mitigation scenarios

Resulting from these considerations, the most important sectors we want to target with our choice of measures are the industrial sector and the energy supply sector. We furthermore look at measures in the transport and in the building sector. The waste and the AFOLU sector are not considered further because of relatively small shares of emissions and no priority in national plans. All "standard measures" we assessed for India are listed in Tab. 15.

Tab. 15: Standard measures assessed for India

Standard measures
Energy Supply • Efficiency of power plants • Fuel switch to other fossils in energy supply • Increase of nuclear energy • Non-bio renewables in energy supply Industry • Energy efficiency of processes • Alternative production routes Transport • Modal shift • Efficiency improvements • Fuel switch (incl. electricity, hydrogen, natural gas and/or sustainable biofuels) Buildings • Low energy housing (incl. insulation of building envelope, ventilation with heat recovery, solar thermal energy and heat pumps) • Efficiency of appliances

Total potential and associated costs in India

The overall GHG mitigation potential of India is found to be between 640 and 1,470 $MtCO_2e/a$ in 2020. Of this potential, 230 to 530 $MtCO_2e/a$ is provided by "no-regret measures", in other words with measures with negative abatement costs. Measures with positive costs but relevant co-benefits have a potential of 190 to 300 $MtCO_2e/a$ reduction in 2020, and ambitious measures could reduce another 220 to 650 $MtCO_2e$.

Fig. 23 illustrates the range mitigation potential of different measures for 2020 found in different studies. Fig. 24 shows the mitigation potential per measure and per cost category. The text below further discusses the results for each specific sector and measure.

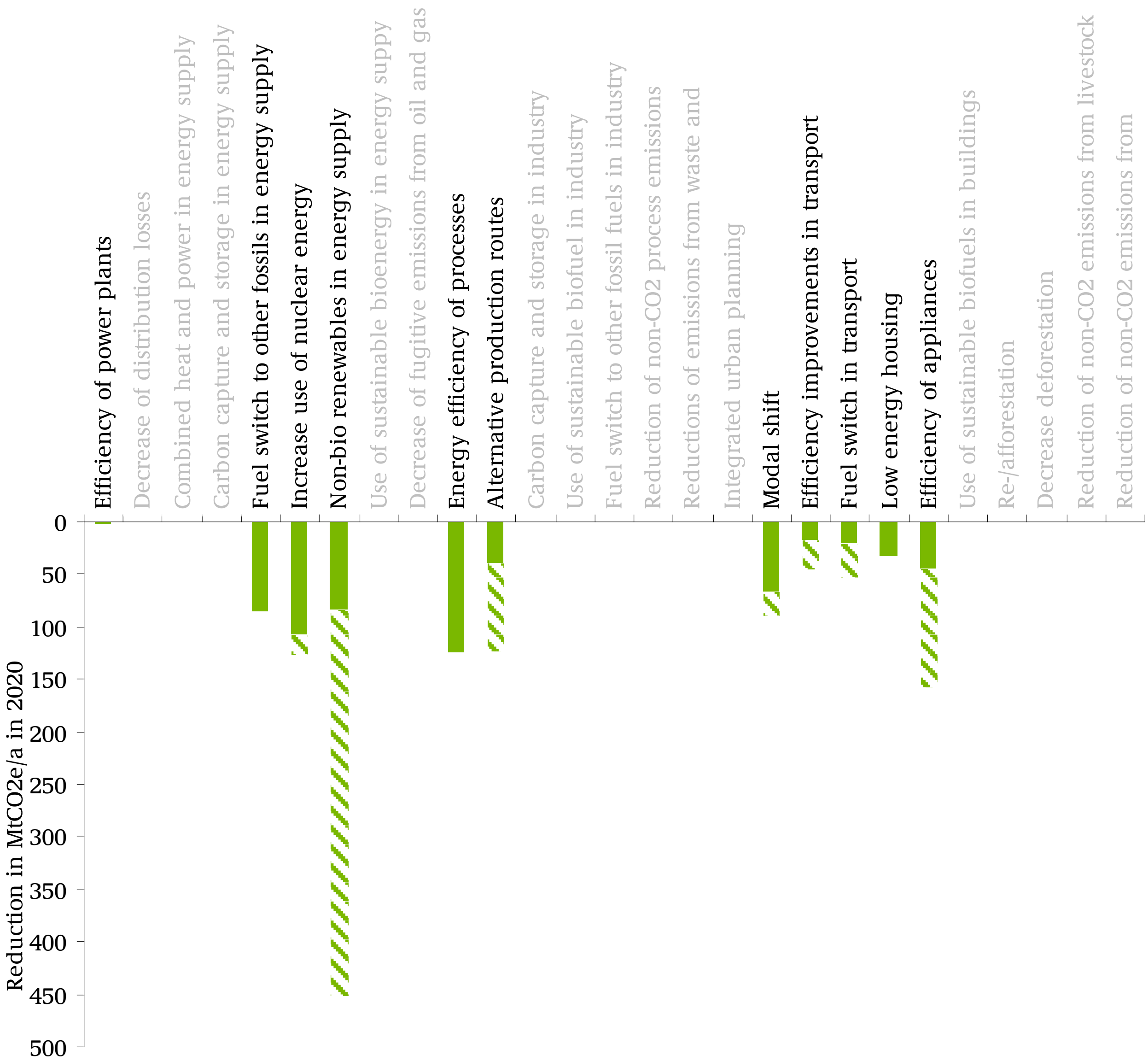


Fig. 23: India: Ranges of mitigation potential by standard measures found in different sources (measures in grey have not been assessed in detail)

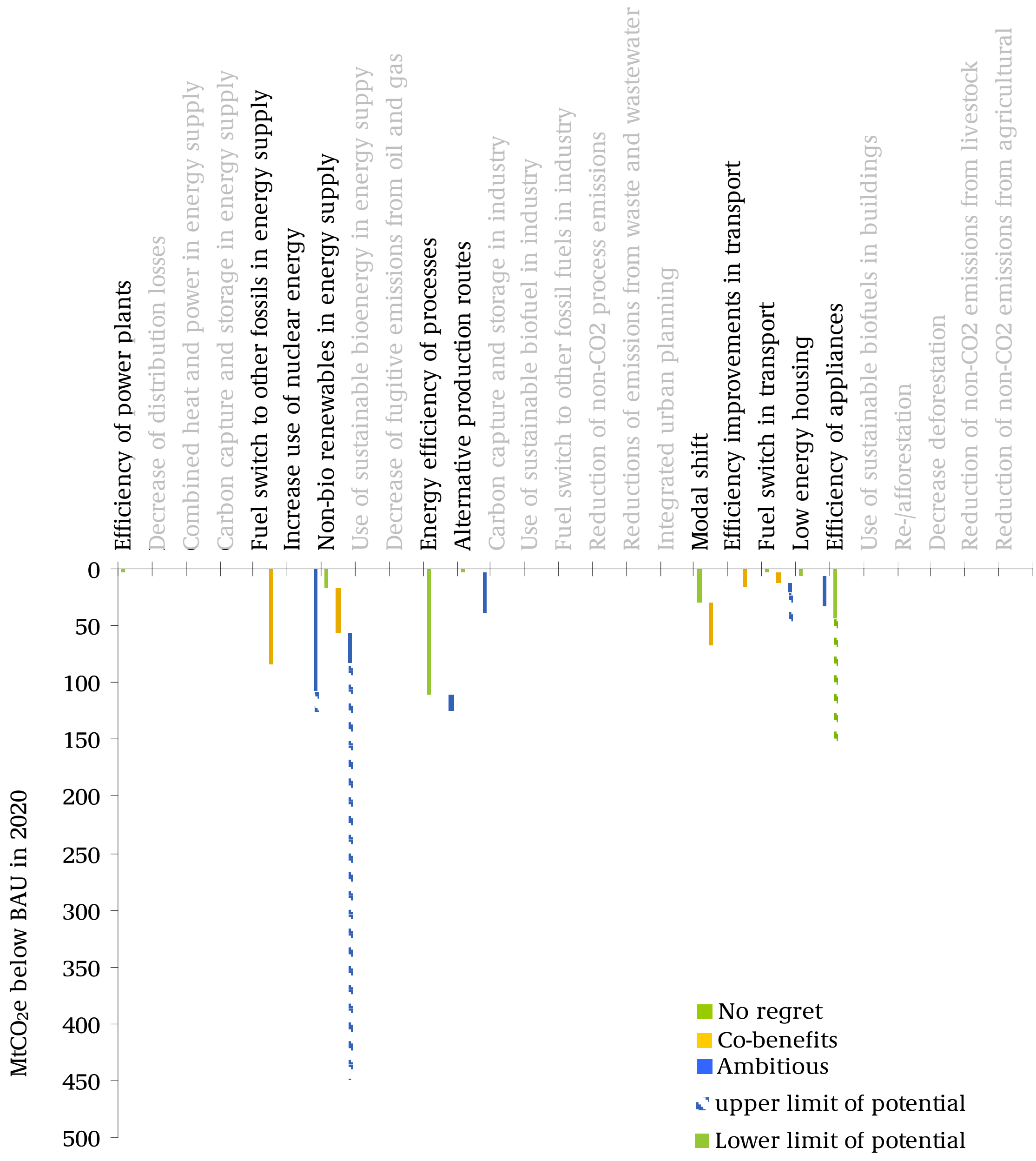


Fig. 24: India: Mitigation potential by standard measure and cost category (measures in grey have not been assessed in detail)

Energy Supply

India is rapidly scaling up its power plant capacities. Since the year 2000, coal-fired power plant capacity has increased by 50%, of which major additional capacity was constructed during the last years (IEA 2012, p. 65). There are three main factors for growing demand now and in the future:

- Rapidly increasing population
- Development leading to a higher standard of living reflected in increased ownership of electric appliances

- Plans to connect 25% of the population that currently has no access to the electricity grid (IEA 2012, p. 65)

India has significant coal reserves on its national territory and 70% of electricity generated comes from coal power plants. Another 12% come each from gas and hydropower and 3% from oil (2012).

Specific emissions of India's power plant park are almost double the world average (2012), as it relies heavily on coal-fired power plants. While the existing power plant stock consists of relatively inefficient subcritical plants, in 2011, India started to construct more efficient, supercritical plants (IEA 2012, p. 65).

We can assume that with the exchange of the existing power plants, there must be a substantial GHG mitigation potential in improving efficiency of power plants. Nevertheless, the potential identified in literature only indicates substantial reduction potential of emissions through efficiency improvements well after 2020 (TERI, CCAP 2006, p. 48).

Given the importance of the sector, we include most defined "standard measures" in our assessment. We do not consider CCS or reduction of fugitive emissions. Fugitive emissions do not contribute significantly to GHG emissions. We do not expect CCS to be relevant in large-scale installations before 2020 because it is still an immature technology.

Special attention needs to be given to distribution losses: for about 25% of the electricity generated, these are very high (2012). For the most part, these losses are not of technical nature. We do not assess the mitigation potential of this measure further, but describe it qualitatively.

Fuel switch to other fossils in energy supply: We find the total potential of shifting from coal-fired power plants to gas-generated electricity to be 85 MtCO_2e/a in 2020. The only study assessing this measure for India is (Shukla, Dhar 2011) which does not include abatement costs.

We assume the costs to be within the co-benefits category, because a shift to gas instead of coal would additionally decrease GHG release less other harmful gases into the environment, thus increasing the health of the population and lowering the environmental impact. Furthermore, a higher share of gas power plants in comparison to coal supports higher shares of renewable energy because gas plants are more flexible and can adapt to the fluctuating supply of renewable electricity.

Increase of nuclear energy: The mitigation potential of nuclear energy is around 110 and 125 MtCO_2e/a in 2020, with the lower limit resulting from (TERI, CCAP 2006) and the upper limit from (McKinsey & Company 2009b). McKinsey & Company assume an additional capacity of 30 GW until 2030, TERI/CCAP assume an absolute capacity of 21.2 GW in 2020 (TERI, CCAP 2006, p. 35). India currently has two nuclear reactors under construction (IEA 2012, p. 71).

Although nuclear energy, according to the studies looked at, can reduce emissions at relatively low costs, there are significant security risks, costs of safe waste disposal are high and India is dependent of imports of uranium because it lacks its own resources. We therefore group the potential in the ambitious category.

Non-bio renewables in energy supply: The potential of renewable electricity sources in India is very significant and at 120 to 450 MtCO_2e/a we find it to be the measure with the largest potential. The low end of the potential is derived from (TERI, CCAP 2006, p. 47) who do not include solar PV, the high end from (Shukla, Dhar 2011, nos. table 3). McKinsey & Company define a potential of 128 $MtCO_2e/a$ in 2030, resulting in 70 $MtCO_2e/a$ in 2020 with linear interpolation, but do not consider any potential from wind energy. We cannot add up the potential from both sources because it is not clear to what extent they overlap.

Similar to the issue raised in this context for China, we can be more optimistic in terms of costs for renewable energy today than was the case at the time the studies were written. Over the last years, renewable energy has developed more rapidly than expected, and prices have dropped significantly.

Industry

With 44% of total GHG emissions (incl. electricity related emissions), the industrial sector is the biggest emitter of GHG in India. The iron and steel and cement industries account for 30% of (non-electricity) fuel related and process emissions each (Planning Commission Government of India 2011, p. 18). The remaining 40% are emitted by industries of very diverse natures.

In the industrial sector, we take a closer look at opportunities related to energy efficiency, alternative production routes and use of sustainable biofuels. Just as for the energy supply sector, we do not consider CCS further. Non-CO_2 process emissions do not represent a large share of the sector, so we do not consider measures to reduce these.

Energy efficiency of industrial processes: The potential reduction of increasing energy efficiency in industrial processes is about 125 $MtCO_2e/a$ in 2020 (compare TERI, CCAP 2006 and McKinsey & Company 2009b). There is an additional potential from measures combining alternative processes and energy efficiency of up to 75 $MtCO_2e/a$ in 2020, which cannot be split to either of the measures.

The measures include efficiency in paper, steel and cement as well as more efficient pumps in various industrial branches. According to the studies used, the major part of this potential is available at negative or very low costs. Only about 15 $MtCO_2e/a$ of potential in the steel industry fall into the category “ambitious” according to data from (TERI, CCAP 2006).

The unattributed potential refers to energy efficiency and alternative processes in the cement and steel industries and falls into the “ambitious” category (TERI, CCAP 2006, Planning Commission Government of India 2011).

From the small number of measures assessed in the studies we found, we can draw the conclusion that there might be substantial potential in other subsectors that have not been covered by the studies. We can therefore assume that the potential in the area of energy efficient processes is larger than the 125 $MtCO_2e/a$ resulting from the studies.

Alternative production routes: The potential in this area is between 40 to 125 $MtCO_2e/a$ in 2020. Measures included are blended cement, steel recycling and gas-based direct reduced iron (DRI). The numbers used come from (TERI, CCAP 2006) and (McKinsey & Company 2009b).

TERI only looks at blended cement and names a potential of between 3 and 5 $MtCO_2e/a$, depending on the substance added to the regular cement. There is a significant difference in the numbers for this potential between the two studies: From McKinsey we can see a potential of almost 90 $MtCO_2e/a$ for this activity.

Both studies find costs of blending cement to be negative, so this share of the potential is within the no-regret category. The measures related to steel industry are ambitious, because they have higher costs and no significant co-benefits.

Transport

The transport sector has a share of 13% of expected emissions in 2020. In India today there are about 20 motor vehicles per 1000 inhabitants, which is one of the lowest values worldwide. (World Bank 2012). Two-wheelers are of great importance in the sector (TERI, CCAP 2006).

In the transport sector, we include measures related to energy efficiency, modal shift and fuel switch. In some cases, fuel switch and modal shift result from one activity, for example in the case of shifting freight transport from road to electric rail. Urban planning is set as one of the key elements of the national strategy. The urgent need to improve current urban structures emerges not from climate related needs but from the necessity to provide an adequate standard of living to urban population. Currently, almost 30% of India's urban population lives in slums with insufficient access to basic services (UN data 2012). The main motivation of urban planning is therefore not combating climate change but coping with high population growth and urbanisation rates. Lack of data in terms of GHG emissions does not allow us to analyse this option for mitigation potential further.

Modal shift: Measures related to shifts in transportation modes can reduce 40 to 70 MtCO_2e/a in 2020. In some areas, these measures do not only include a shift of modes, but also lead to fuel switch (e.g. shift of freight transport from road to electric rail).

Modal shift in freight transport has a potential of 15 to 30 MtCO_2e/a in 2020, changes in passenger transport can be reduced by 25 to almost 40 MtCO_2e/a, taking into account enhancing the share of public transport and additionally shifting more passenger transport to rail systems.

In terms of costs, literature takes very different positions: While McKinsey put measures related to modal shift into their most expensive and most difficult to implement category, TERI finds negative costs for these measures. Because of the strong co-benefits to the population, we rate most of the potential from McKinsey as „co-benefits".

Efficiency improvements in transport: Fuel economy in India for new vehicles today is already quite high, but opposed to the trend in most developed countries, in India cars have become less efficient over the last years. One of the reasons is the increase in sales of bigger vehicles (IEA 2012, p. 91).

The potential of efficiency improvements of vehicles is between 20 and 60 MtCO_2e/a in 2020, with the low range resulting from the Planning Commission of India (Planning Commission Government of India 2011) and the upper range from TERI (TERI, CCAP 2006). McKinsey data leads to a potential of 30 MtCO_2.

Costs of the measure are assumed to be low or negative, because fuel prices are assumed to be high enough for the investments to be recouped through fuel savings. We group the complete potential from this measure into the moderate cost category.

Fuel switch in transport (incl. electricity, hydrogen, natural gas and/or sustainable biofuels): The potential of fuel switch options in the transport sector in India is at 30 to 70 MtCO_2e/a in 2020 according to (TERI, CCAP 2006) (upper limit) and (McKinsey & Company

2009b) (lower limit). Included in this range is electric mobility, biofuels and gas-driven vehicles. The main difference from the two studies lies in the results on the potential of biofuels: While TERI conclude that 55 MtCO_2e/a could be mitigated, data from McKinsey leads to a reduction of 10 MtCO_2e/a only. The potential of electric mobility also includes electric two-wheelers, of which India holds a large share of the global market and which are bound to further increase in number (McKinsey & Company 2009b, p. 38).

According to TERI, a switch to compressed natural gas vehicles will be cost-negative in 2020. We therefore categorise this share as a no-regret measure (4 MtCO_2e/a). We assume that electric mobility is more expensive but has significant co-benefits such as avoidance of noise and local air pollution and opportunities to develop new industries in this area. Furthermore, electric two-wheelers have a lower abatement cost than electric personal cars (McKinsey & Company 2009b, p. 12). Biofuels in India have high costs according to both sources. We group them in the ambitious category.

Buildings

The building sector, which includes the service and the residential sector, ranks second in GHG emissions in India among all sectors in 2020 (including electricity related emissions). It holds about 20% of total emissions in 2020. With expected increasing development and continued population growth in the future, the sector will further increase in importance in terms of GHG emissions. Furthermore, improvements in this sector can benefit the population directly in terms of energy cost savings.

For the building sector, we focus on the measures "efficiency of electric appliances" and "low energy housing" to cover both the increased use of appliances and the development of floor space.

Low energy housing: The potential of measures to improve the building envelope can reduce India's emissions by 65 to 170 MtCO_2e/a in 2020. The higher potential results from data from the Planning Commission, the lower potential from McKinsey & Company. McKinsey sees a higher potential in buildings of the commercial sector than in residential buildings.

Abatement costs taken from McKinsey show that measures in the residential sector usually have negative costs, whereas measures in the commercial sector are more costly. We put these in the ambitious category. The Planning Commission's document does not contain cost estimates. To still include the potential, we simplify the calculation by assuming that half of their potential is available at negative costs and the other half falls into the co-benefit category.

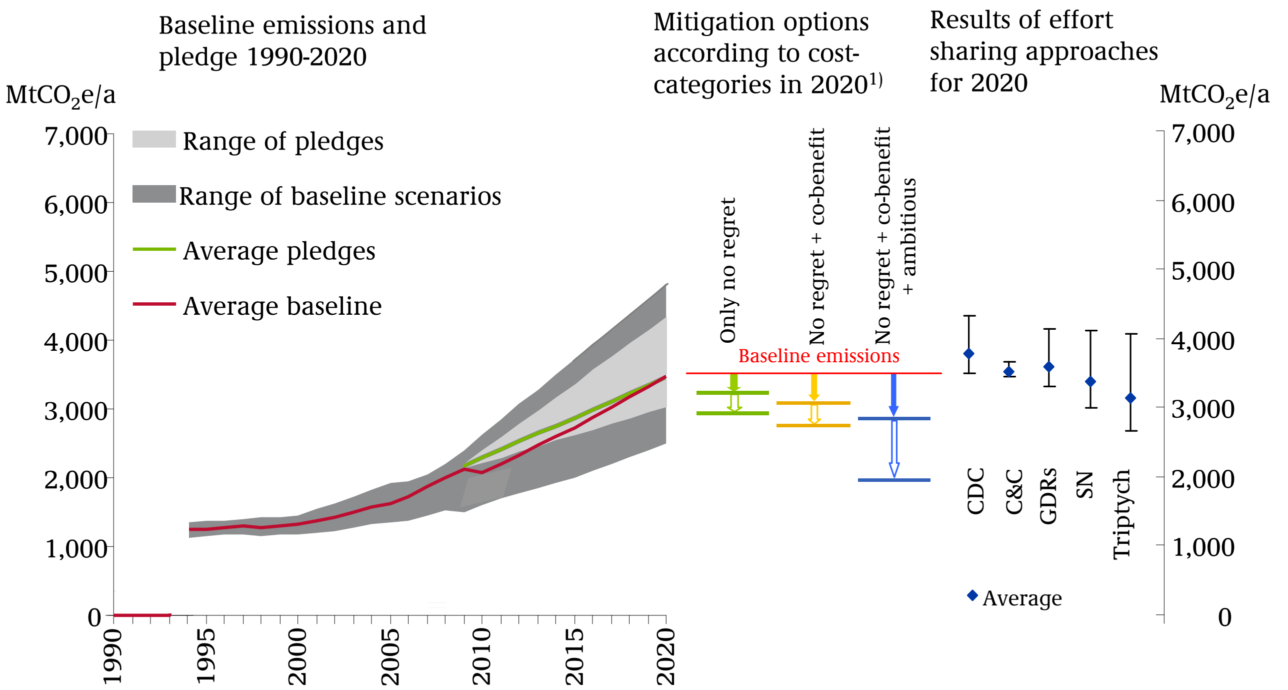
Efficiency of appliances: The mitigation potential in this area is between 90 and 155 MtCO_2e/a in 2020. The lower limit of the range comes from McKinsey & Company (McKinsey & Company 2009b), the upper limit from Shukla (Shukla, Dhar 2011).

Shukla does not further break down the potential in his report. McKinsey includes household appliances, residential and street lighting and efficient wood stoves and biogas, of which efficient appliances have the highest share (43 MtCO_2e/a). The complete potential is in the no-regret category, because the investments pay back via energy savings.

With increasing access to electricity, India's population will rely more heavily on electrical appliances. This can be seen as an opportunity to introduce efficient appliances from the beginning on before the market is flooded with inefficient equipment.

3.3.4 Evaluation of the pledge against the mitigation potential and results of effort sharing approaches

India's pledge does not exploit the full technical mitigation potential, but is in line with what some effort sharing approaches suggest. Our results thus reflect India's need for international support for additional GHG reductions.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with least cost options.

Fig. 25: India: Projected BAU and pledged emissions compared to mitigation potential and responsibilities

India's pledge does not reveal an improvement on BAU

The average of the pledges lies at about the same level as the average BAU level, meaning that no reduction below BAU can be seen. Most sources expect the pledge to be overachieved in the BAU scenario. The mitigation potential can reduce emissions further than the pledge.

Vast potential seen in the area of renewable energy

India has large mitigation potential especially in the area of renewable energy. Other important areas are efficiency and alternative processes in industry and efficiency of appliances in the building sector.

If the most optimistic numbers for mitigation potential are considered, India is able to almost halve its emissions in 2020 by implementing the identified measures. About one third of the identified potential is covered by no-regret measures. About 50% has to be exploited by the use of measures in the "ambitious" cost-category.

International support needed to make use of India’s mitigation potential

The results of the effort sharing approaches show a wide range, but many lie within the range of the pledge. At the same time, the maximum potential goes much further than the most stringent approach, taking as a reference the average BAU level for both.

The least stringent effort sharing approaches (which fall into the range of the pledged emissions) rely on convergence of per capita emissions. Because these are very low in India today, these two approaches allow a higher level of total emissions in 2020 than the others. The most stringent approach for India is Triptych, providing for global convergence of efficiencies on a sectoral level. This approach requires a major shift away from coal for all countries, which would affect India significantly.

Effort sharing approaches suggest reductions are need to, or slightly more than, the level of the pledge. Mitigation potential is available to a greater extent than that which would be required by the most stringent effort sharing approaches. This supports the need for international support for India to realise this mitigation potential.

3.4 Mexico

Tab. 16: Key indicators - Mexico

Population (2010)[25]:	113 million	Rank 11
GDP (2010)[26]:	1,411 billion US$ 2005 PPP	Rank 9
GDP growth (2000- 2010):	1.8%/a average 19% total	
Energy consumption (2010)[27]:	187 Mtoe	Rank 12
Energy consumption growth (2000 – 2010):	2.1%/a average 22% total	
GHG emissions (2008)[28]:	604 $MtCO_2e/a$	Rank 13

Mexico has been an important player in international climate policy over the last years. With 604 $MtCO_2e$ in 2008 its emissions are comparable to those of Australia and the UK and only slightly higher than South Korea, taking rank 13 globally (EDGAR 2012).

Over the last decade Mexico has seen a moderate GDP growth (source) with a slightly larger growth in energy consumption (IEA 2012), leading to increased energy intensity.

With 113 million inhabitants in 2010 it represents the 11th largest population globally. UN estimates population to grow a further 13% until 2020 (UN 2012). The country is highly urbanized, with almost 80% of the population living in cities (United Nations Department of Economic and Social Affairs (UN DESA) 2011).

Mexico is a member of the OECD and North American Free Trade Agreement (NAFTA) and is economically closely linked to the US. 80% of exports and 50% of imports cross that border (Estados Unidos Mexicanos 2009 Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a).

3.4.1 Historical and projected BAU development of GHG emissions in Mexico

Expected emissions until 2020

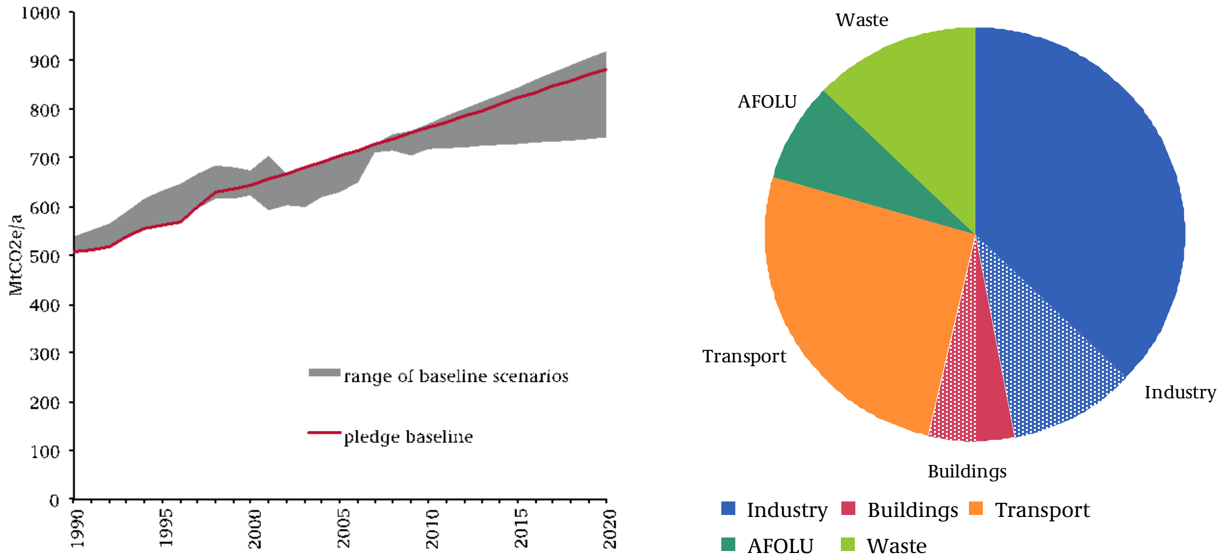
Information available for Mexico is characterized by a wide range of data both for historical emissions and for BAU projections. BAU projections for 2020 range from 741 $MtCO_2e/a$ to 920 $MtCO_2e/a$, a difference of 179 $MtCO_2e/a$ or 24% of the minimum estimate. Already historical data show a large diversity.

[25] UN 2011

[26] World Bank 2012

[27] IEA/OECD 2012

[28] EDGAR 2011



Note: In this demand side distribution to sectors emissions for the oil and gas sector are included in the industrial sector.

Fig. 26: Mexico: Historical GHG emissions and projections from 1990 until 2020 (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6). Pie chart on the right shows distribution of emissions to sectors expected in 2020. Shaded areas are electricity related emissions.

Main data sources and assumptions

Key sources for historical emissions are:

- UNFCCC data as provided by Mexico (UNFCCC 2012). Data provided to the UNFCCC exclude emissions from LULUCF up to 2002. To correct for this, emissions for LULUCF provided in the 2nd National Communication (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a) were used and extrapolated for missing years.
- The National Climate Change Plan (PECC) (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009b).
- The Climate Action Tracker (CAT 2012). The analysis is based on a number of sources including SENER energy statistics 2011, IEA energy statistics 2011, FAO data, INEGI statistics and IPCC emission factors and carbon content.

Key sources for emission scenarios (2010 – 2020) are:

- The 4th National Communication (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a)
- The Nation Climate Change Plan (PECC) (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009b).
- The Climate Action Tracker (Höhne Niklas 2012). Here we use the 'with policies' scenario as basis for the BAU projection. This scenario includes all policies in place by April 2012 and thus serves as a good estimate for expected future development in the absence of major additional new policies.

Both ends of the BAU range come from the latest National Communication (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a), representing the high and low BAU estimates. The CAT policy scenario as well as the PECC projections fall in between these extremes.

The high end BAU scenario 'PIB alto' assumes an annual GDP growth of 4.9% from 2010, while the low end scenario 'PIB bajo' assumes a 2.9% growth. Energy intensity in industry does not vary between scenarios, but industrial output is influenced by GDP. In the residential sector the level of GDP also influences energy intensity through different assumptions on the use of appliances. For the transport sector the development of energy intensity from the IEA Energy Technology Perspectives 2008 was used (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a).

Country specific uncertainties in determining the BAU

The most important source for uncertainty in determining projected emissions is the land use, land use change and forestry (LULUCF) sector. Data is still scarce for this sector and quality varies. While the share of emissions from the sector has drastically dropped in the last 20 years, the uncertainty connected to emissions from the sector - both historical data and projections - remains high.

Another factor determining the uncertainty is the expected economic development represented by GDP growth. As discussed above different assumptions on this mainly determine the upper and lower end of the range shown.

3.4.2 Mexico's pledge for GHG emission reductions until 2020

Mexico pledged to reduce GHG emissions by 30%, compared to a BAU scenario by 2020. At the UNFCCC in-session workshop in May 2012 Mexico presented the pledge and provided the baseline from the PECC with total emissions of 882 $MtCO_2e/a$ in 2020 (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2012). Around half of the reductions are expected to come from measures included in the national climate change plan PECC and another 24% from additional already identified activities. The pledge is conditional to adequate financial and technological support by developed countries.

Additional to the 2020 pledge Mexico has set a national target to reduce emissions by 50% compared to 2000 levels by 2050.

Estimated effect of Mexico's pledge on GHG emissions

The pledge directly relates to the BAU level and we calculate absolute levels from the upper and lower limits of the BAU range and from the value provided by Mexico. If the pledge was fully achieved, emissions could decrease to 518 $MtCO_2e/a$ under the lower end of BAU scenarios available, representing a slight reduction compared to average 1990 emissions. Assuming the high end of the range emissions under the pledge would be 644 $MtCO_2e/a$. The official baseline would deliver 618 $MtCO_2e/a$. Both values would represent an increase above 1990 levels but still represent a significant decrease to current emissions levels.

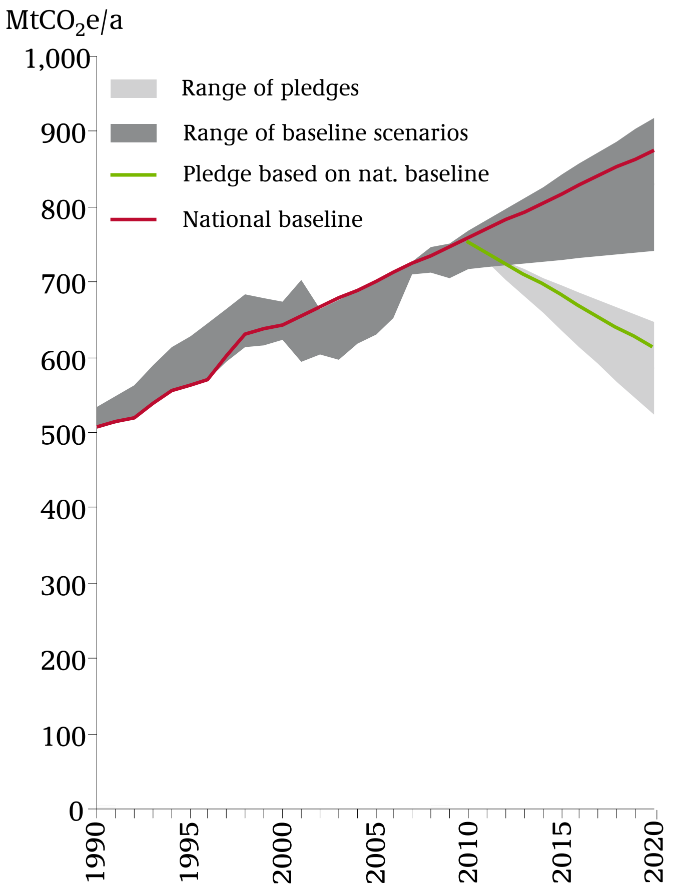


Fig. 27: Estimated emissions resulting from Mexico's pledge

National climate change plans relating to the pledge

From 2009 to 2012 the Special Climate Change Programme (Programa Especial de Cambio Climático – PECC) is the main instrument in climate change planning since 2009. It includes strategies for all sectors and specific goals and activities until the end of the legislative period. While many goals were formulated in the PECC, it lacks clear policy instruments to achieve them.

The PECC gives special attention to cleaner urban transportation, energy efficiency and renewable energy (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009b), supported by the Clean Technology Fund.

The energy savings plan (PRONASE) was developed by the National Commission for the Efficient Use of Energy (CONUEE, 2009). It targets seven priority areas: road transport, lighting, household appliances, co-generation, industrial motors, buildings and water pumpage.

In April 2012 the General Law on Climate Change (Ley General de Cambio Climático) was adopted, after earlier attempts had failed. The law consolidates the existing institutional structure and anchors a number of useful planning tools. The main points of the legislation are:

- Formulation of different targets:
    1. Reemphasis of the "Cancun pledge".
    2. Long-term emission reduction target of 50% below 2000 levels by 2050.

3. Target to provide 35% of Mexico's electricity from clean sources by 2024.

- Creation of a climate fund.
- Creation of a National Environment and Climate Change Institute (INECC).
- Establishment of an overall institutional structure responsible for planning and implementing activities.
- Requirement for mandatory emissions reporting and the creation of a public emissions registry.
- Implementation of a national strategy for climate change with a 40 year horizon and regular revisions (every 10 years the latest).

Overall the legislation does not implement direct measures. It sets targets and consolidates the efforts to provide the appropriate institutional and informational framework for future action. It also provides the framework to enable market-based mechanisms to be developed (Estados Unidos Mexicanos 2012). With the change in Government in July 2012 it has yet to be determined how fast the legislation will be implemented or if the new administration will continue the efforts at all.

3.4.3 GHG mitigation potential in Mexico in 2020

Overview of studies used

We used the following sources to determine mitigation potential and costs. All sources' research was conducted around roughly the same time and published in 2009. While there seems to be a wealth of information at first glance, most recent sources reference back to these underlying studies. The latest National Communication also uses the Johnson et al. study to provide potential for the energy sector, but also other, more sector-specific analyses. The latest IEA Energy Technology Perspectives (2012) also uses Johnson et al. and the latest electricity sector projections from SENER (2012) to derive their 2DS scenario.

Tab. 17: Overview of studies used for determination of GHG emissions reduction potential for Mexico

	McKinsey & Company 2009	Johnson et al. 2009	Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a	Quadri 2009
Short description	"Low Carbon Growth: A Potential Path for Mexico" MAC cost curve study for Mexico	"Low-Carbon Development for Mexico" Study commissioned by the World Bank	"4th National Communication to the UNFCCC" Official reporting to the UNFCCC, including the GHG inventory, projections and selected potential	"El cambio climático en México y el potencial de reducción de emisiones por sectores" Study from the Ministry of the Environment (SEMARNAT) looking at potential in all sectors
Base year	2005	2008	2002	2005
Sectors covered	All sectors	All sectors	All sectors	All sectors
Calculation method	Bottom-up	Bottom-up	Various	Various
Main assumptions	Discount rate 4% Constant 2000 US$	Discount rate 10% Constant 2005 US$	No consistent set of assumptions as different	BAU scenario is developed in two phases: 2002-2012

	McKinsey & Company 2009	Johnson et al. 2009	Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a	Quadri 2009
	Oil price US$62/ barrel in 2030 Annual GDP growth 3.5%	Fuel prices $53/ barrel in 2009 with annual increase Annual GDP growth 3.6% Annual population growth 0.6% Only interventions with a net cost below $25/t CO_2e will be deployed.	studies are used for the potential given	and 2013-2020 No changes in relative prices No new energy policies Annual population growth 1% Annual growth in electricity consumption 3%
Evaluation of source	Broad coverage but not all assumptions clearly disclosed.	Detailed study with clear, transparent assumptions. Unclear how far estimated potential for 2009 to 2012 are already captured.	Presents only some selected potential, but not a comprehensive overview. Few details given, but references to underlying studies provided.	Broad coverage but not all assumptions and calculation methods transparent.

The McKinsey study and Johnson et al. account for overlap of measures in the demand sectors resulting in reduced electricity demand and potential in the electricity sector in their calculations. The 4th National Communication does not provide a comprehensive overview, but is strongly based on the results from the Johnson et al. study for the energy sector, so we assume no overlaps.

The study by McKinsey provides 2005 as the last historical data point. Some measures in their scenario already start in 2008 ("Do it now", no-regret), but the majority of reductions start only after 2010. We have therefore not made any adjustments for late start of measures in this case.

Selection of measures

The methodology for prioritization of measures as described in the methodology section delivered a range of measures from the power, transport and waste sector. We have included some additional measures in the analysis due to a variety of reasons. The AFOLU sector is not adequately represented by the selection methodology, as the maximum reduction potential is assumed to be the expected emissions from the sector. Since the sector can, however, act as a sink and thus provide further potential, the potential derived from re-/afforestation and reduced deforestation were also analysed. Additionally the introduction of solar water heating and improved cooking stoves in the residential sector was included, as they represent simple, cost effective measures with high potential in the residential sector. In the case of improved cooking stoves this is combined with substantial co-benefits for health and time savings. In the transport sector we have included the use of biofuels also due to the high potential. All measures are summarised in Tab. 18.

Tab. 18: Standard measures assessed for Mexico

Standard measures
Based on selection methodology
Energy
• Efficiency of power plants
• Combined heat and power
• Fuel switch to other fossil fuels
• Non-bio renewables
• Use of sustainable bioenergy
• Decrease of fugitive emissions from oil and gas
Industry
• Energy efficiency of processes
Waste
• Reductions of emissions from waste and wastewater
Transport
• Modal shift
• Efficiency improvements
Additional measures selected due to other considerations
Transport
• Fuel switch (biofuels)
Buildings
• Low energy housing (solar thermal energy)
• Efficiency of appliances (improved cooking stoves)
AFOLU
• Re-/afforestation
• Decrease deforestation

Total potential and associated costs in Mexico

The overall GHG mitigation potential of Mexico is between 184 and 362 $MtCO_2e/a$ in 2020. Of this potential, 114 to 256 $MtCO_2e/a$ are covered by "no-regret measures", in other words with measures with negative abatement costs to society. Measures with positive costs but relevant co-benefits have a potential of between 69 and 106 $MtCO_2e/a$ reduction in 2020. Although some of the individual activities that were grouped under our standard measures are estimated to be more expensive, the average cost over the activities within a measure did not lead to the classification of any of the standard measures as ambitious. Where large cost differences between activities exist these are described in below under the individual measures.

Fig. 28 illustrates the range mitigation potential of different measures for 2020 found in the different studies. The text below further discusses the results for each sector and measure. The annex shows further details on each standard measure assessed.

Reduced deforestation represents the largest potential, directly followed by the deployment of non-bio renewable electricity generation technologies, efficiency in power plants, efficiency in transport and modal shift.

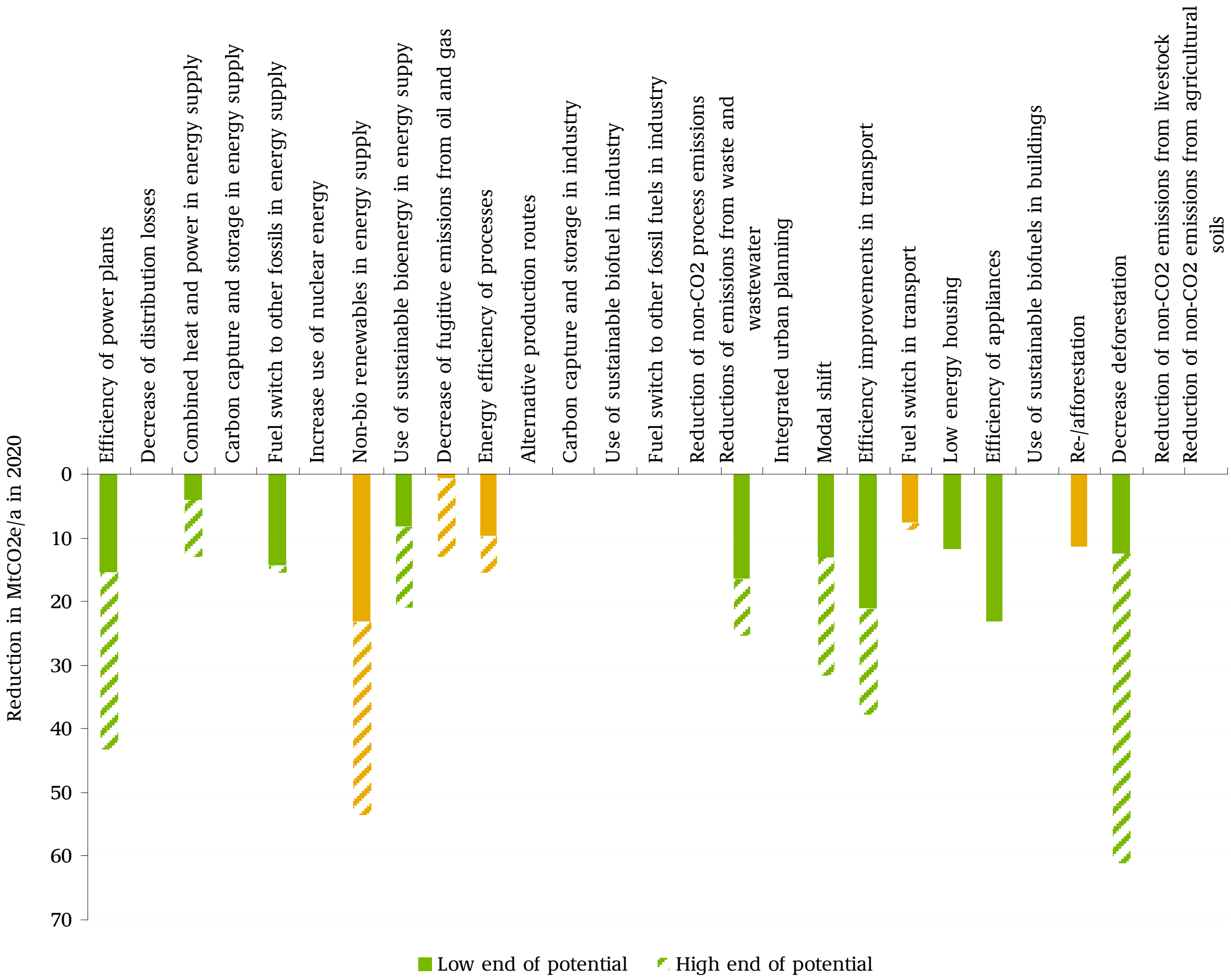


Fig. 28: Mexico: Ranges of mitigation potential by standard measures found in different sources.

Note: green bars represent no-regret measures, orange bars co-benefit measures

The following section shortly introduces each sector, followed by the description of the potential of the identified measures within the sector.

Energy Supply

The development in the electricity sector in Mexico over the last decade has been characterized by the replacement of oil by gas in electricity generation. The shares of the two fuels have been almost exactly exchanged: where oil was representing 47.6% of the generation in 1999 the share has dropped to 16.7% in 2009. The share of gas in the same time period increased from 15% to 51.8%. Coal only represented 12.4% in 2009, directly followed by hydroelectricity with 11.2%, which has decreased slightly since 1999. The two nuclear reactors in Mexico represent a constant 4.5% of production. Other renewable sources have remained insignificant over the period (Secretaría de Energía (SENER) 2012).

CCS studies have been conducted for Mexico, but so far no implementation is planned. Therefore we assume that no mitigation potential for 2020 is realistic.

While nuclear energy is still part of the planning considerations in Mexico, cheap gas prices and the Fukushima incident have so far prevented concrete activities. There is no new nuclear production capacity under construction (Secretaría de Energía (SENER) 2012), which makes it technically impossible to attribute any potential to this technology for the year 2020.

The Mexican government holds the monopoly over the energy sector. Electricity production is mainly under the state-owned electricity service provider the Federal Electricity Commission (Comisión Federal de Electricidad - CFE), the oil and gas sector under the state owned Petróleos Mexicanos (Pemex).

The oil and gas sector plays an important role in the Mexican economy. Mexico is the seventh-largest oil producer globally and derives 39% of total state revenues from the sector. This has strong implications on the structure of the energy sector in the country with oil and gas dominating the fuel mix. It also constitutes an important direct source of emissions from processing and distribution. The productivity of the country's largest oil field has been declining over the last years and so far new explorations have not been able to fully compensate this. This could provide the opportunity for a structural change in the Mexican energy system towards a low-carbon economy (International Energy Agency (IEA) 2012).

Efficiency of power plants: This measure includes a large number of individual activities and has a large potential according to some of the studies. It covers the efficiency of power plants and of processing in the oil and gas sector. We estimate this measure can reduce emissions between 7.7 and 35.5 $MtCO_2e/a$ in 2020. Cost for these measures vary between sources from negative to moderate cost and depend on the individual activities evaluated. In total the potential should be available at slightly negative cost.

Johnson et al. (2009) summarize all activities into two categories - utility efficiency and refinery efficiency - with a combined potential of 8.7 $MtCO_2e/a$ in 2030. This translates to 7.7 $MtCO_2e/a$ in 2020.

The study by McKinsey (2009) covers a far wider range of activities with a clear focus on the oil and gas sector, both upstream and downstream. Nevertheless the largest individual potential they identify is the implementation of a smart grid with 14 $MtCO_2e/a$ in 2030. All efficiency measures in the oil and gas sector add up to 13.1 $MtCO_2e/a$. Adjusting these values to 2020 we derive a total of 35.5 $MtCO_2e/a$ due to higher baseline assumptions in our scenarios than those applied in the McKinsey study.

Fuel switch to other fossil fuels: The replacement of oil with gas for electricity production has been an on-going process over the last decade and this trend is expected to continue to some extend in the BAU scenarios. It is therefore difficult to determine the additional potential that is available through speeding up this process. Only one source (McKinsey 2009) provides a quantification of this potential. They expect up to 21.8 $MtCO_2e/a$ emissions savings by 2030 at a cost of almost 12 US$/$tCO_2e$. Adjusted for BAU differences and to the year 2020 we derive a potential of 14.3 $MtCO_2e/a$.

Quadri (2009) mentions increased gas production as one of the available measures within the electricity sector but does not provide an individual estimate of the potential.

Combined heat and power: The potential for combined heat and power technologies is estimated to be moderate in 2020 with a range of 3.9 to 12.9 $MtCO_2e/a$ in 2020 at substantial negative cost. The study by McKinsey (2009) attributes only 6 $MtCO_2e/a$ of reduction potential to this measure, thus providing the lower limit of our range after baseline adjustments. The high end of the potential stems from Johnson et al (2009) and the 4th National Communication.

Non-bio renewables: Up to date only hydro plays a significant role in the Mexican energy mix with a focus on large hydro above 70MW capacity. The other sources together only represented 0.5% of total generation in 2009 with geothermal energy being the largest representative (SENER 2012). We estimate the total potential of non-bio renewable technologies to be between 23.1 and 53.5 $MtCO_2e/a$ in 2020.

The different sources all identify potential for wind, geothermal and small hydro. Estimated wind potential is relatively similar in the Johnson et al. (2009) and McKinsey (2009) studies with 23 and 28.5 $MtCO_2e/a$ in 2030. Quadri (2009) arrives at 27.4 $MtCO_2e/a$ already for 2020 and thus assumes a much faster deployment. For small hydro the estimates vary even more, between 1.4 $MtCO_2e/a$ in 2020 to between 8.8 and 15 $MtCO_2e/a$ in 2030. Estimates for mitigation potential from geothermal capacity vary even more from 5.9 $MtCO_2e/a$ in 2020 to between 10.3 and 48 $MtCO_2e/a$ in 2030.

Only McKinsey (2009) provide a quantification of potential from solar PV and solar CSP technologies. As these represent 27.9 $MtCO_2e/a$ in 2030 this explains the large range for the overall measure. Quadri (2009) and Johnson et al. (2009) exclude large-scale solar technologies due to the high cost.

Cost estimates vary strongly between the different technologies, with onshore wind and small hydro at the low end of the range with moderate cost and solar PV at higher cost. Only offshore wind and solar CSP as estimated by McKinsey (2009) would fall into the ambitious category if assessed individually.

Use of sustainable bioenergy: The total range of potential for 2020 is 8.1 to 20.7 $MtCO_2e$ at overall slightly negative cost.

The largest potential in electricity generation through biofuels was identified by Johnson et al. (2009). The largest individual potential is through direct generation from biomass, with additional smaller potential from biogas generation and biomass co-firing. In total the potential for 2030 is given at 42.9 $MtCO_2e$. In our calculations this translates to 20.7 $MtCO_2e$ for 2020. The 4th National Communication mirrors the numbers provided by Johnson et al.

The study by McKinsey gives the mitigation potential for dedicated biomass generation at zero and only 8.1 $MtCO_2e$ for co-firing in 2020.

Decrease of fugitive emissions from oil and gas: The potential emission reductions in 2020 from a range of activities to reduce fugitive emissions from oil and gas are estimated between 0.7 and 12.8 $MtCO_2e/a$ at moderate cost.

While Johnson et al. (2009) only give estimates for the reduction of leakage at negative cost, McKinsey (2009) not only determine a higher potential for leakage reduction through the replacement of seals and distribution maintenance, they also provide estimates for reduced flaring. Unlike the no-regret reduction of leakage, reduced flaring is associated with significant cost.

Industry

Mexico has a very diverse industrial structure with very large differences in technologies and efficiency. However, iron and steel production, non-metallic minerals and the chemical and petrochemical industry represent around 60% of industrial emissions. The sector does not receive subsidies for fossil fuels (apart from transport fuels) or electricity (CAT report 2012). Measures to promote emission reductions from industry have not been part of the priorities within the Mexican planning, with the exception of cogeneration (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009b) and efforts to promote GHG reporting[29].

Energy efficiency of processes: The reduction potential for the efficiency of industrial processes is estimated to be between 9.6 and 15.4 $MtCO_2e/a$ in 2020. Activities include the increased efficiency of industrial motors and cogeneration. The 4th National Communication also gives an estimate for general reduction of energy intensity in industry. Johnson et al. (2009) provide a cost range from -19.50 US$ for industrial motors to 4.90 US$ for bagasse cogeneration.

Quadri (2009) provides a top-down estimate for the overall sector, including fuel switch and non-CO_2 gases. Due to lack of underlying data for the identification of the individual measures we have accounted the full potential of 18 $MtCO_2e/a$ in 2020 in this measure discounting for the difference in base year. The study assumes costs of 40 US$/ton CO_2.

Waste

Emissions from waste have seen a rapid growth over the last decades. Emissions almost doubled between 1990 and 2000 and more than tripled between 1990 and 2010 (CAT country report 2012). We expect the sector to cover 13% of total emissions in 2020. All activities in the sector have large co-benefits in reducing health risks and increasing local air quality.

Reductions of emissions from waste and wastewater: In the surveyed studies reductions of emissions from waste and wastewater represent the measure with the highest mitigation potential. Total potential is between 16.4 and 25.3 $MtCO_2e$.

In the study from Quadri (2009) the potential for wastewater is provided with 35 $MtCO_2e$ in 2020 at almost zero cost, for the reduction of emissions from solid waste with 27.5 $MtCO_2e/a$. For the latter no cost estimate is provided. Together the study assumes a potential decrease of 36% of BAU emissions in 2020. The BAU assumed for the sector in this study is with 171 $MtCO_2e/a$ substantially higher than the BAU for the sector used in our analysis. Adjusted for this and the delay in implementation we estimate 25.3 $MtCO_2e/a$ in total reduction potential.

McKinsey provides estimates for landfill gas use and wastewater treatment[30]. Together we expect these activities to reduce emissions from the sector by 16.4 $MtCO_2e/a$ in 2030 at negative cost.

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[29] http://www.geimexico.org

[30] We do not consider waste recycling under this measure, as it mainly replaces energy use in the industrial sector and does not reduce emissions accounted in the waste sector.

The 4th National Communication provides an estimate for the reduction potential for solid waste with 18.7 $MtCO_2e$ for 2020. Since this is not covering wastewater treatment we have excluded this estimate from our calculations.

Transport

Emissions from transport show the highest growth rates of all sectors and are expected to further increase under all BAU scenarios. With growing development the number of vehicles is expected to increase both for passenger vehicles as well as freight transport (Centro de Transporte Sustenable (CTS) 2009). The car fleet is characterized by the high average age, triggered by the import of old used vehicles from the US. Gasoline and diesel prices are determined by the state that can lead to substantial subsidies in times of high world market prices for oil (Höhne 2012).

Biofuels currently play no major role in the Mexican transport sector. In 2011 only one plant produced ethanol, although mainly for beverage and pharmaceutical use. Three plants in Chiapas produced biodiesel for use of the public transport service and for research, as the production is not commercially viable at current diesel prices. A large 3rd generation biofuels plant based on algae is planned in Puerto Libertad, Sonora (USDA Foreign Agricultural Service 2011).

Modal shift: Activities to motivate a modal shift to lower carbon transport modes can in total contribute to emission reductions in the range of 13 to 31.4 $MtCO_2e/a$ in 2020 at overall negative cost.

Measures include the improvement and expansion of public transport infrastructure for passengers and freight. The McKinsey study concentrates on passenger transport with respect to motivating modal shift. Their estimate for increased and more efficient bus transport and increased public electric transport gives a potential of 23 $MtCO_2e/a$ in 2030. Both measures also have a component of increased efficiency, but for the sake of this analysis we have assumed the larger share of reductions coming from modal shift.

Johnson et al (2009) also provide potential for the shift to non-motorized transport and for road freight logistics and railway freight. Their estimate for reductions from bus system optimization alone amount to 31 $MtCO_2e/a$ and including all other activities they provide a potential of 88.8 $MtCO_2e/a$ in 2030, thus providing the upper end of the range after adjustments.

The 4th National Communication only provides estimated reductions from a number of individual projects, with a total potential of 0.7 $MtCO_2e/a$ in 2030.

Efficiency improvements in transport: Activities to improve the efficiency of vehicles could save between 21.1 and 37.5 $MtCO_2e/a$ in 2020 at overall negative cost.

All sources assume an increase in fuel economy standards. While McKinsey provides negative cost for all of their efficiency potential, Johnson et al. derive moderate to high cost, especially for border vehicle inspections to prevent inefficient vehicle imports from the US.

In July 2012 the Mexican government first published the proposed CO_2 emissions standard for passenger vehicles, which would be implemented from model year 2014. The standard is aligned with the US standards 2012-2016 although it provides some flexibility for the specific Mexican situation. Aggregate emission reductions over the period from 2013 to 2030 are estimated to be 170 $MtCO_2e$ (International Council on Clean Transportation (ICCT) July 2012).

Fuel switch: We estimate the full potential of this measure to be between 7.6 and 8.6 $MtCO_2e$ at moderate positive cost.

The Mexican Biofuels Law (Ley de Promoción y Desarrollo de los Bioenergéticos) limits the use of food grains for biofuel production and only allows the use of overproduction and residues to ensure food supply. This restricts the availability of sustainable biomass and the resulting mitigation potential which has been taken into consideration in the different studies.

Johnson et al. (2009) provide estimates for three types of biofuels: ethanol from sugarcane and sorghum and biodiesel produced from palm oil. They assume the installation of 97 plants producing ethanol from sugarcane and 19 from sorghum as well as 21 plants producing diesel from palm oil.

They attribute the resulting emission reductions to the agricultural sector based on the land use implications of the measures. Since the majority of reductions are achieved by replacing fossil fuel in the transport sector, with a small fraction replacing emissions from the electricity sector, we have included the measures into the transport sector. The overall potential identified in the study is 24.3 $MtCO_2e$ for 2030. Adjusted we assume potential reductions of 8.6 $MtCO_2e$ for 2020 at moderate positive cost

McKinsey (2009) estimates potential reductions of 13.4 $MtCO_2e/a$ in 2030 from 1st and 2nd generation biofuels. While 1st generation biofuels are expected to come at negative cost, 2nd generation fuels have a moderate positive cost.

The study by Quadri (2009) did explicitly exclude biofuels from the analysis due to the controversial environmental and social effects, like for example potential increases in food prices through enhanced agricultural production of raw materials for biofuels.

Buildings

The building sector currently represents only a small fraction of Mexico's emissions. Fuels are mainly used for cooking and hot water generation. The climate in most parts of Mexico does not require room heating. Per capita residential electricity use is still relatively low but expected to increase with rising income. Increased demand for appliances and especially air conditioning could lead to staggering growth rates in electricity consumption (Höhne 2012). A large part of rural households use open fires for cooking, leading to severe respiratory and other health problems as well as GHG emissions from CO_2 and non-CO_2 gases (Johnson et al. 2009).

Sources provide estimates for very different activities within the sector. Potential provided for the measures therefore provide the cumulative estimates across sources, which differs from other sectors, where the different sources provide the boundaries of the range.

Low energy housing: Total savings from the measure are 11.8 $MtCO_2e/a$ in 2020 at moderate cost.

The use of solar thermal water heating technologies is a highly cost efficient measure to decrease emissions from households. We estimate the potential in 2020 to be 8.6 $MtCO_2e/a$ based on Johnson et al. (2009). It provides households with long term savings on their energy bill and provides overall negative cost.

McKinsey (2009) estimates the effects of an efficiency package for new residential buildings to deliver up to 3.2 $MtCO_2e/a$ in 2020 at relatively high, but not yet ambitious cost.

Efficiency of appliances: Reduction estimates add up to 23.1 $MtCO_2e/a$ in 2020 at negative cost.

McKinsey (2009) provide a total potential for the building sector of 35 $MtCO_2e/a$ in 2030. Due to the resolution of the information provided it was not possible to identify the potential for the individual measures except the low energy housing activity described above. Individual activities regarding efficiency include lighting, electronics and appliances efficiency. Due to data availability we have attributed the remaining potential of 28.5 $MtCO_2e/a$ in 2030 to the efficiency of appliances measure.

Johnson et al. (2009) focus on the potential from efficient cooking stoves. This measure not only has a noteworthy reduction potential, but also large co-benefits for health, time used for firewood gathering and environmental protection. The potential reduction in 2030 is estimated to be 19.4 $MtCO_2e/a$ at moderate negative cost.

AFOLU

Agriculture is only contributing to emissions from the sector to a small extent in Mexico. Historically deforestation is a large source of emissions, but has decreased significantly from reported maximum levels of 157 $MtCO_2e/a$ in 2006 (2^{nd} National Communication) to 70 $MtCO_2e/a$ in 2006 (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) 2009a). This trend has continued over the last years, supported by the ProÁrbol program that was established in 2007. The program promotes forest plantations, reforestation and other forest related activities (Comisión Nacional Forestal (CONAFOR) 2010). Deforestation is driven by the conversion of forest to agricultural use, including pastures and export crops, and the development of tourist infrastructure (Comisión Nacional Forestal (CONAFOR) 2010).

Data availability and quality is low for the sector and there is a large uncertainty connected to the identified potential and the BAU scenario. For example Johnson et al. (2009) assume constant emissions from the sector at 87 $MtCO_2e/a$ from 2019, while the CAT baseline assumes a continuation of the trend leading to 15 $MtCO_2e/a$ in 2020. McKinsey provides a constant low reference case with around 23 $MtCO_2e/a$ in 2020.

Re-/afforestation: For this measure we derive a unanimous potential of 11.3 $MtCO_2e/a$ reduction by 2020. It includes afforestation measures mainly through plantation timber and reforestation and restoration activities to replace cleared native vegetation.

Decreased deforestation: Reducing deforestation represents a possibly large potential depending however largely on the estimated baseline emissions. The range of estimates varies from 19.7 to 61.1 $MtCO_2e/a$ in 2020.

Johnson et al. (2009) include a wide range of activities under their REDD category, of which we have attributed some to other measures where they replace fossil fuels in the energy production or demand sectors. Activities considered under this measure include forest management, wildlife management and payment for environmental services. McKinsey (2009) only differentiate between reduced deforestation and forest management, reducing emissions 40% below baseline.

The upper end of the range is provided by the study from Quadri (2009) that finds it feasible to reduce deforestation rates to zero by 2020, thus eliminating all emissions from the sector.

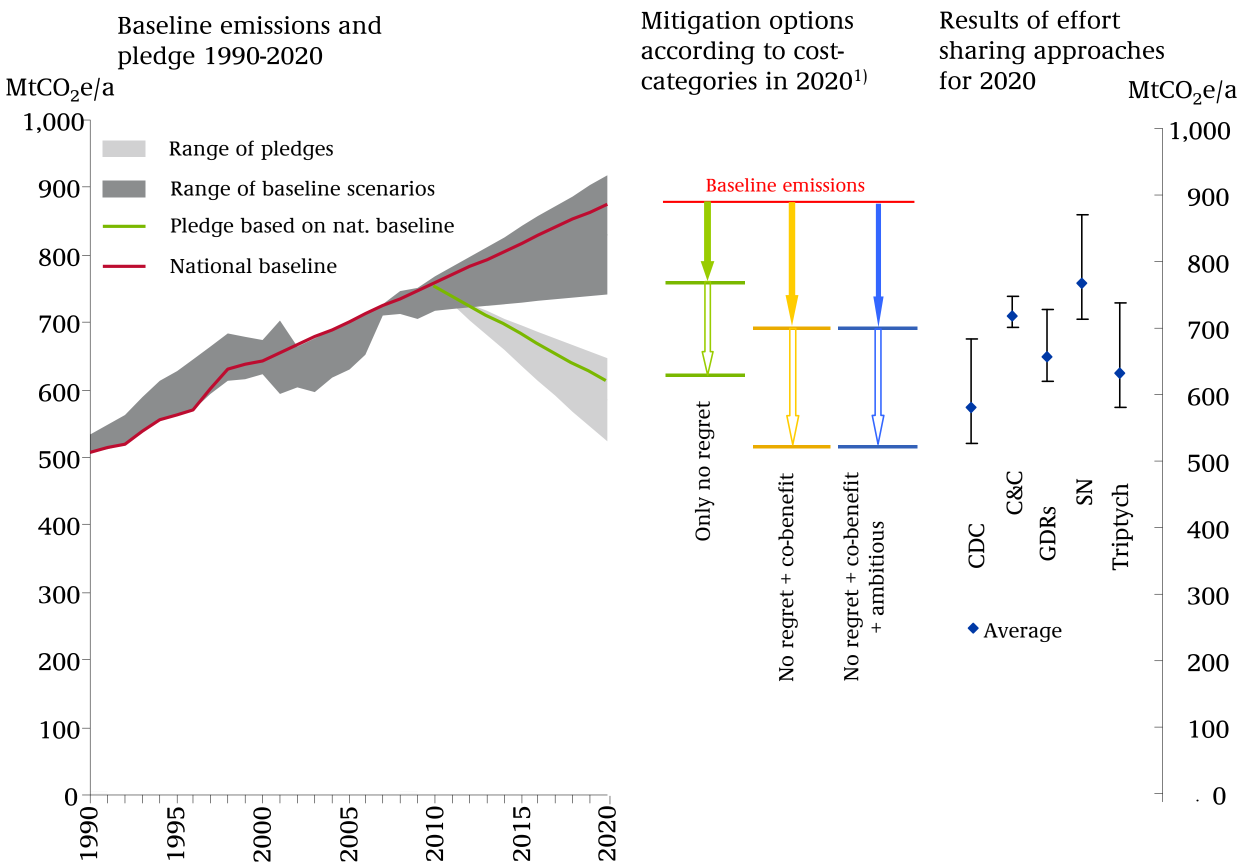
3.4.4 Evaluating pledge and mitigation potential against responsibilities

Mexico could achieve its pledge at moderate cost if it fully implemented all measures assessed in the literature. The pledge is in line or more ambitious than expectations of most effort sharing approaches. This suggests that Mexico has grounds to call for international assistance to meet the moderate costs associated with realising its pledge.

<u>Ambitious pledge based on conservative baseline could be achieved at no or moderate cost</u>

According to the potential as identified in the studies Mexico could achieve its pledge at no or moderate cost if it fully implemented all measures.

Fig. 29 shows that the baseline provided by Mexico is rather high compared to the range of projections and thus connected with a high level of uncertainty. Also the potential evaluated in the literature shows a high level of uncertainty. The total minimum potential represents the lowest common denominator between the studies and is across the categories up to 124 $MtCO_2e/a$ in 2020. The high end of the potential is given at 322 $MtCO_2e/a$. The total range is almost three times as large as the minimum potential.



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with lowest cost options.

Fig. 29: Mexico: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches

Mexico has been an active player in the international climate change arena over the last years, in the lead up to the Cancun meeting in 2010 as well as in the years since. At the national level a significant amount of legislation has paved the way for further action, including the General Law on Climate Change passed in April 2012. The institutional set-up as well as the availability of high quality national research in different sectors would allow rapid action. Since the elections in July it has not been clear how far the new government will utilise this positive starting point to implement policies and measures to tap the identified potentials.

Clarification of support requirements could speed up implementation of actions

Mexico has made the pledge conditional to international support. It has so far not specified how much funding and which types of other support would be required to achieve the pledge. As time is running out fast to implement measures that achieve substantial reductions by 2020, it would be useful to quantify the requirements for international funding.

The pledge is ambitious compared to results from effort sharing approaches

Fig. 4 shows the full ranges for the BAU scenario as well as the pledged level. The results from different effort sharing approaches are all within or above the pledge range. This means that the pledge is in line with or more ambitious than the reductions expected from the country under the different effort sharing approaches. The most ambitious effort sharing approach is the CDC, which requires a reduction to 568 $MtCO_2e/a$ in 2020 (mean), lower than the official pledged level but still within the pledge range.

The approach requiring the least ambitious reduction from Mexico is C&C. With this approach Mexico could emit 707 $MtCO_2e/a$ in 2020.

Overall it can be concluded that Mexico's pledge can be rated ambitious compared to the different effort sharing calculations. Furthermore it could likely be achieved at moderate cost to society if all measures identified in the studies are fully implemented. However, the potential as identified diminishes with each year of inaction and will make the achievement of the pledge more and more difficult and costly.

Assessment of Mexico's mitigation potential

The assessment of Mexico's mitigation potential shows:

- Mexico has a wide range of different mitigation potential in all sectors. There are some measures that draw immediate attention, like reducing deforestation and increasing renewable energy production, but no single measure has the potential to deliver the required reductions for Mexico to achieve their target.
- A wealth of information and thorough assessment from various sources exists on potential activities, technological choices and economic considerations to guide decision-making.
- Many of the potentials come at negative or very moderate cost and are connected with substantial co-benefits, for example in the transport sector, where measures could lead to improved air quality and thus reduced health problems as well as reduced time required for commuting to work, thus increasing quality of life and overall productivity.

Our analysis only covers the most important measures. The total potential is therefore underestimated. Additionally some of the studies that form the basis of this exercise did explicitly exclude high cost options, leading to a further underestimation of the real potential. This enhances the analysis that Mexico has ample potential to not only meet its pledge, but to achieve additional reductions.

3.5 South Africa

Tab. 19: Key indicators - South Africa

Population (2010)[31]:	50 million	Rank 22
GDP (2010)[32]:	475 billion US$ 2005 PPP	Rank 18
GDP growth (2000- 2010):	3.5%/a average 41% total	
Energy consumption (2010)[33]:	137 Mtoe	Rank 14
Energy consumption growth (2000 – 2010):	2.4%/a average 25% total	
GHG emissions (2008)[34]:	547 $MtCO_2e$/a	Rank 15

South Africa is the biggest economy and the biggest GHG emitter on the African continent. On a global scale South Africa ranks at number 15 in terms of GHG emissions. Beyond total emissions, it is important to note that the carbon intensity in South Africa is very high, both in terms of per capita (9.2 tCO_2e/person) (based on the data in the table) and per GDP unit (2.4 $ktCO_2e$/million 2000 US$) (World Bank 2012).

South Africa's economy relies heavily on mining and heavy industry. Energy consumption in the industrial and buildings sectors relies largely on electricity (see Fig. 30), which is produced with high carbon content by the use of domestic coal. Furthermore, a large share of industrial process emissions is due to coal use. A high share of transport fuels are domestically produced by coal to liquid processes (CTL). Overall it is estimated that 75% of South Africa's emissions are due to coal use (Marquard et al. 2011). Within a 2020 time horizon emission growth mainly stems from growth in industry and the increased electrification and electricity use of households. On a longer-term perspective, transport will also contribute significantly to emission growth (Winkler 2007a)(Marquard et al. 2011).

In 2005 South Africa initiated a process to develop its (second) National Climate Change Response Strategy, which was adopted and published in 2011 (DEA 2011b). A key knowledge base is a thorough assessment of both future emission scenarios and mitigation potential referred to as the "Long-Term Mitigation Scenarios (LTMS)", which is based on a scenario modelling exercise and stakeholder processes conducted by the Energy Research Center of the University of Cape Town.[35]

3.5.1 Historical and projected BAU development of GHG emissions in South Africa

This section illustrates historical data and possible BAU scenarios for South Africa's greenhouse gas emissions.

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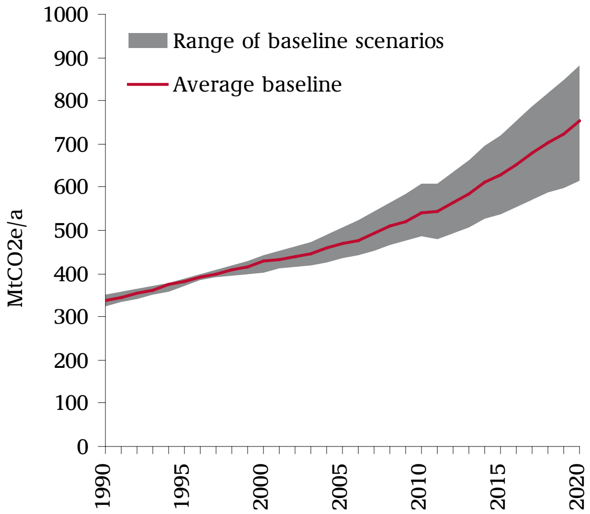
[31] UN 2011

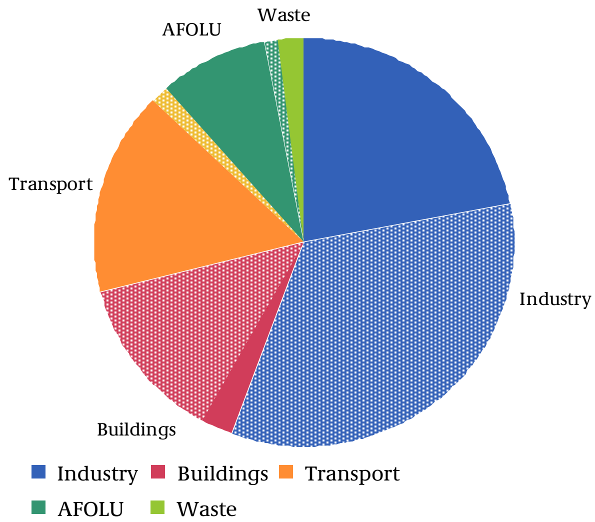
[32] World Bank 2012

[33] IEA/OECD 2012

[34] EDGAR 2011

[35] See http://www.erc.uct.ac.za/Research/LTMS/LTMS-intro.htm for both process documentation and publication of key results.





Notes: Total emissions in 2000 are 461 $MtCO_2e$. Source: Authors' own calculation based on (DEA 2011a), (IEA 2012)

Fig. 30: South Africa: Historical GHG emissions and projections from 1990 until 2020 (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6). Pie chart on the right shows distribution of emissions to sectors in 2000. Shaded areas are electricity related emissions.

Expected emissions until 2020

South Africa's GHG emissions have grown from 350 $MtCO_2e/a$ in 1990 by more than 50% to almost 550 $MtCO_2e/a$ in 2010 (DEA 2011a), (DEA 2011c). The South African government's BAU scenario estimates emissions in 2020 to range between 615 $MtCO_2e/a$ and 883 $MtCO_2e/a$. This development is based on the "Growth without Constraints" scenario of the LTMS exercise (see below), which estimates emissions in 2020 to be about 750 $MtCO_2e/a$. The South African government subsequently added a ± 0.7% p.a. error margin to allow for uncertainties in the scenario forecast.

Main data sources and assumptions

Key sources for historical emissions are:

- 1990 – 2000: South Africa's National Communication of 2010, covering 1990, 1994 and 2000 (DEA 2011a). Data gaps have been filled by linear interpolation.
- 2000 – 2010: A presentation given by South Africa's Department of Environmental Affairs in 2011 (DEA 2011c). For years for which no figures are given, estimates have been deducted from the graphs.

Key sources for emission scenarios (2010 – 2020) are:

- The LTMS, which was developed by the Energy Research Center, University of Cape Town (Winkler 2007b), (Winkler 2007c), (Winkler 2007a).
  The LTMS is the key scientific input to the national climate policy development process. The scenarios analyse possible emission trajectories up to 2050. The BAU scenario is called "Growth without Constraints" (GWC). This is contrasted by the scenario referred to as "Required by Science" (RBS), which is an ambitious mitigation scenario. Along

different bundles of mitigation measures, intermediate scenarios ("Start Now", "Use the Market", "Scale Up") and subsequent cost implications are explored. It needs to be noted that with a 2020 time horizon the differences in emissions between the various scenarios is significant: the RBS emissions level is 50% below that of GWC. However, in 2050 the difference is dramatically higher, with the GWC level 400% higher than that of RBS.

- The "Explanatory Note - Defining South Africa's Peak, Plateau and Decline Greenhouse Gas Emission Trajectory" in which the South African Government defines its BAU scenario assumptions which are the basis for its mitigation pledge (DEA 2011d).36
- Emission development scenarios have been checked for consistency with IEA data (IEA 2012). Generally, the emission projections and mitigation potential (see below) are of the same magnitude. However, as the above sources provide more detailed information, the IEA emission data has not been used for further calculations.

Data for future projections are directly taken from the lower and upper range of the BAU scenario as displayed in (DEA 2011d), which is factually based on the GWC scenario of the LTMS (see below for details on the range definition).

3.5.2 South Africa's pledge for GHG emission reductions until 2020

South Africa has made a conditional pledge to reduce its GHG emissions below the BAU emission development by approximately 34% by 2020 (and 42% by 2025). The target was proposed during the Copenhagen negations and submitted to the UNFCCC Secretariat on 29 January 2010 (DEA 2010). South Africa stresses that the extent to which these emission reductions will be achieved is conditional "on the provision of financial resources, the transfer of technology and capacity building support by developed countries" (DEA 2010). Thus, one major uncertainty regarding South Africa's emissions mitigation potential is how far the international negotiations are successful in providing support to South Africa.

The pledge refers to the BAU scenario for South Africa's emissions trajectory. However, the submission to the Copenhagen accord does not include a value for the BAU.

The Explanatory Note by the government (DEA 2011d) provides a baseline which is used on the national level for development and implementation of measures and policies. This reference baseline equals the GWC scenario in the LTMS process. Based on the argument that any forecast is characterised by uncertainty, the South African government has added a ± 0.7% p.a. error margin. Using this scenario as a basis for our analysis, the pledge consequently results in

[36] The Explanatory Note (DEA 2011d) displays data from 1990 to 2050 (historical and BAU Projection) and claims to use data on "net emissions" thus including LULUCF. However, the historical data matches the National Communication (DEA 2011a) for data "without LULUCF". Thus, for historical data we use the National Communication, assuming that a mistake was made in the Explanatory Note. The LTMS scenarios, which are quoted in the note for future projections, display net emissions, including LULUCF.

a range with upper and lower limits. The upper limit amounts to 583 $MtCO_2e/a$ in 2020 (and 614 $MtCO_2e/a$ in 2025).[37]

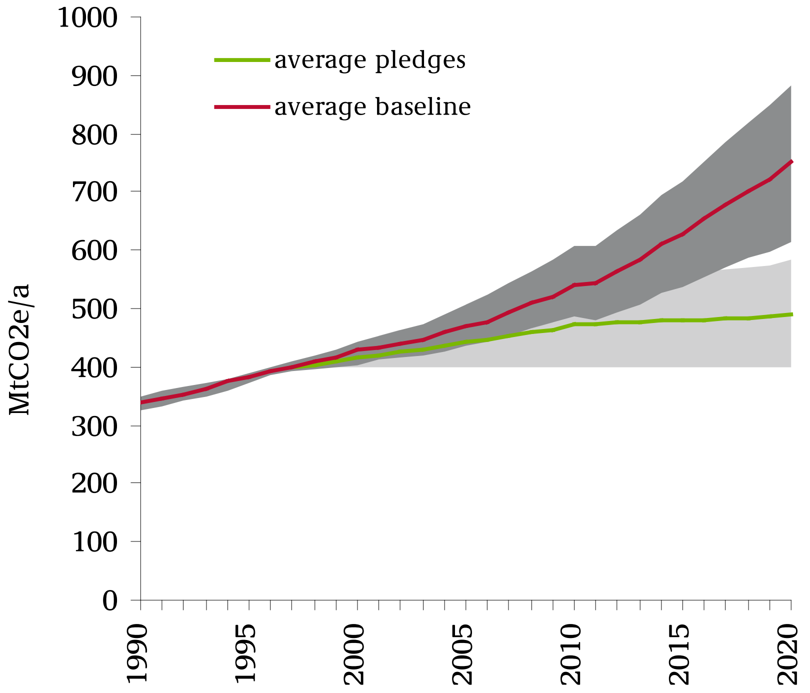


Fig. 31: Upper and lower limits of South Africa's pledge in comparison to baseline emission development

The upper limit is well above the LTMS' RBS trajectory – which has been referred to as "our aspirational goal" by the LTMS Scenario Building Team as well as in the Minister of Environment's media presentation on the July 2008 Cabinet Lekgotla climate change policy directives and initial "Presidential Copenhagen undertaking" in 2009.

[37] Values for South Africa's pledge are given from 1997 up to 2050. The values for the upper limit of the pledge are lower than the historical emissions between 2000 and 2004 as published in (DEA 2011c).

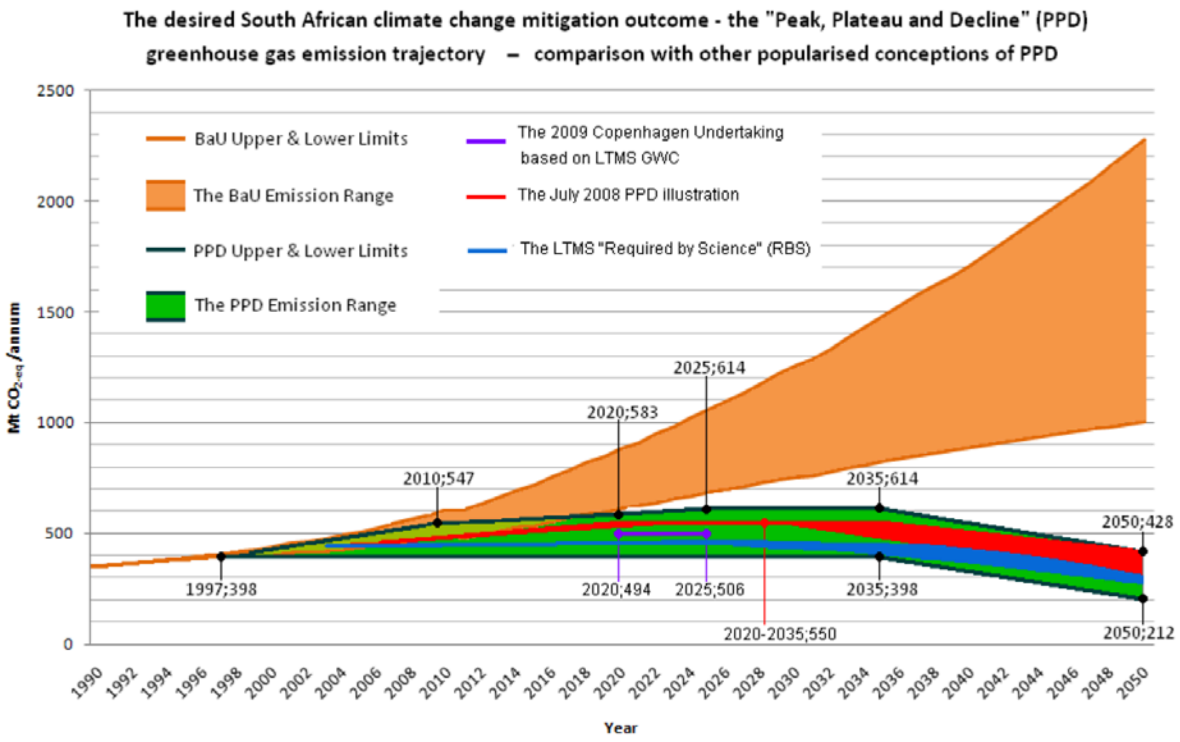


Fig. 32: South Africa's pledged emission range (green) in comparison to BAU and other, previous pledges and goals (Graph taken from (DEA 2011d)).

National climate change plans relating to the pledge

Irrespective of the conditionality of the pledge, South Africa has already established a national framework for its mitigation actions: Responsible for South Africa's climate response strategy (both mitigation and adaptation) is the Department of Environmental Affairs. It published the 'National Climate Change Response White Paper' in October 2011 (DEA 2011b). The white paper confirms South Africa's "Peak, Plateau and Decline Greenhouse Gas Emission Trajectory" which includes the country's mitigation pledges for 2020 and 2025 as well as a long-term perspective: a peak of emissions at 614 $MtCO_2e$and a decline in emissions after 2035. In the strategy a variety of mitigation actions are defined, including so-called flagship programmes as near-term priorities.

The South African Department of Energy has taken up GHG mitigation in its mission as "improving our energy mix by having 30% clean energy by 2025" (DoE 2011a). In the Integrated Resource Plan (IRP), which is the key governmental document for power generation planning in South Africa, reducing carbon emissions has been labelled a key constraint for energy planning. The IRP explicitly assesses the costs of different mitigation scenarios. In the development process of the IRP, it has been alleged that the plans for new power generation capacity will make it very difficult to meet South Africa's mitigation targets (Winkler 2010). Based on the stakeholder consultation process, the share of renewables in particular has been increased in the final draft of the IRP (DoE 2011b). However, the current plans for new coal-fired power generation in South Africa put a strong constraint on the possibility of fulfilling the country's mitigation ambition.

3.5.3 GHG mitigation potential in South Africa in 2020

Overview of key studies used

To assess the mitigation potential we mainly use the LTMS scenarios developed by the Energy Research Center, University of Cape Town (Winkler 2007a). It is a very comprehensive work, which developed both scenarios for South Africa's GHG emission trajectory and assessed bottom-up mitigation potential for all sectors. This formed the scientific basis for the formulation of the South African mitigation pledge. In addition, a recent presentation by Harald Winkler, which summarises some key mitigation potential with a 2020 and 2025 time horizon, has been used (Winkler 2010).

There are various additional sources available which give detailed information on mitigation potential in the electricity sector and explicitly in relation to renewable energy (Greenpeace / EREC 2009), (WWF 2010), (Ward 2012), (DoE 2011b), (Edkins et al. 2010). In other sectors, there is little information in addition to (Winkler 2007a)/(Winkler 2010) which is suitable for our assessments. If information is available, it is either extremely disaggregated, for example, assessments of the mitigation potential of specific projects, which can only be scaled up to the national level with an extensive analysis, or it is too aggregated, for example, the mitigation potential of full sectors, which is not consistent with our bottom-up approach. Data from the International Energy Agency has been used to validate the magnitude of mitigation potential which were identified in other sources (IEA 2012).

Tab. 20: Overview of studies used for mitigation potential in South Africa

	LTMS (Winkler 2007a)	Energy (R)evolution (Greenpeace / EREC 2009)	50% by 2030 (WWF 2010)
Short description	Holistic modelling of emissions. Assessments of mitigation potential up to 2050 – Scientific basis for national climate policy	Scenario Modelling for South Africa's Power Sector. Specific assessment of renewables potential	Scenario Modelling for South Africa's Power Sector. Specific assessment of renewables potential
Base year	2007	2008	2007
Sectors covered	all	Power Sector	Power Sector
Calculation method	Markal-TIMES scenario modelling	Scenario Modelling done by DLR	Markal-TIMES scenario modelling, done by ERC
Main assumptions	Various assumptions for different mitigation wedges, detailed cost estimates	IEA world energy outlook assumptions, higher oil prices	High renewables shares are tested against macro-economic impacts
Evaluation of source	Very comprehensive and detailed	Used to assess higher margin of renewables potential	Used to assess higher margin of renewables potential

Selection of measures

In the LTMS Scenario Analysis a detailed analysis of the mitigation potential of technologies and policy packages is given (Winkler 2007c) covering almost all of the standard mitigation measures to be analysed in this study. Consequently, it was not necessary to identify key mitigation measures according to the methodology described in chapter 2.1.2, but instead the measures analysed in the LTMS could be taken as a starting point for the assessment in this chapter. However, several measures which are estimated as having significant potential by the LTMS published in 2007 are not realistically likely to contribute before 2020 from a 2012 perspective – this is discussed in detail in the respective section (see below).

Tab. 21: List of standard measures assessed in detail for South Africa

Standard measures
Energy Supply • Carbon capture and storage • Fuel switch to other fossils • Increase use of nuclear energy • Non-bio renewables Industry • Energy efficiency of processes (Includes electricity and fuel) • Carbon Capture and Storage • Fuel switch to other fossil fuels • Reduction of non-CO_2 process emissions Waste • Reductions of emissions from waste and wastewater Transport • Modal shift • Efficiency improvements • Fuel Switch (incl. Biofuels, electrification, hydrogen, natural gas) Buildings • Low energy housing (incl. insulation of building envelope, ventilation with heat recovery, solar thermal energy and heat pumps) • Efficiency of appliances AFOLU • Re-/afforestation • Decrease deforestation

Energy Supply

South Africa's power generation relies predominantly on domestic coal and consequently is very carbon intensive. The consequence of this is even more dramatic, as electricity has a dominant role in the country: apart from transport and coal in industry it is used as *the* energy carrier for most uses in all sectors (e.g. air and water heating in formal housing is almost exclusively reliant on electricity). The importance of electricity is anticipated to increase with further economic development and electrification of the country.

Non-bio renewables in electricity supply: Key mitigation actions to reduce GHG emissions from power generation lie predominantly in the field of renewables: Various sources estimate mitigation potential for power generation from renewable sources (wind, CSP, PV) in 2020. The IEA estimates the potential to be close to 30 $MtCO_2e/a$(IEA 2012).The Energy Research Center identified a range between 32 and 38 $MtCO_2e/a$based on different scenario and technology development assumptions (Winkler 2007a), (WWF 2010). The Greenpeace Energy (R)evolutions scenario for South Africa estimates 35 $MtCO_2e/a$(Greenpeace / EREC 2009). Although growth rates for renewables have been low in past years, with the current South African Renewables Initiative (SARI) it seems feasible to implement 3600 MW of wind and solar power capacity within the next years (Ward 2012). If appropriate incentive schemes are implemented we consider it realistic that a short-term mitigation potential of 35-38 $MtCO_2e/a$in 2020 will be achieved.

Efficiency of power plants: Supercritical power plants and integrated gasification combined cycle plants have a large mitigation potential compared to the currently used coal-fired power plants. However, for all new power plants, more efficient technologies have already been included in the BAU, so that the additional potential is small (Winkler 2007a) and is not further considered in our assessment.

Increase of nuclear energy: South Africa has had a strong nuclear program in the past and has one reactor running. Thus, nuclear power could be a strong mitigation option for the country. However, nuclear power is increasingly the subject of critical debate in South Africa. The question of whether nuclear power will play in important role in SA's mitigation efforts is mainly a political one and less dependent on technical questions. The IEA assesses the mitigation potential in 2020 to be roughly 24 $MtCO_2e/a$ (IEA 2012). In contrast, the Integrated Resource Plan (IRP) for Electricity by the Department of Energy (DoE 2011b) assumes that one new reactor will be operational in 2024 at the earliest. Therefore, we consider commissioning a new reactor by 2020 (or earlier) to be highly unrealistic and assume no additional nuclear mitigation potential by 2020.

Carbon Capture and Storage in Energy Supply: Carbon Capture and Storage (CCS) would be a strong option to reduce South Africa's emissions both in the coal dominated power sector and in coal to liquid plants for transport fuel production (see also below). However, storage capacity is limited and partly a long way from emissions sources, which would increase costs due to needs for long CO_2 pipelines. The LTMS scenarios assess technical potential for carbon capture for individual plants (9 and 23 Mt / a) but express doubts about storage capacity and technical availability (Winkler 2007a). A thorough assessment of CCS potential in South Africa indicates a mitigation potential between 11 and 35 $MtCO_2e/a$ in 2030. The potential in 2020 is seen as marginal due to the later availability of the technology (Esken et al. 2012). Consequently no CCS mitigation potential up to 2020 is included in our assessment.

Industry

Energy efficiency of industrial processes: The largest short to mid-term mitigation potential in South Africa is derived from improved energy efficiency in industry, which by itself could contribute to an 8% emission reduction by 2020 (of South Africa's total emissions), or 61 $MtCO_2e/a$in 2020. Actions comprise both reductions in electricity and coal use (optimisation of boilers, steam systems, process heat, compressed air, HVAC and others) (Winkler 2007a), (Winkler 2010).

Reduction of non-CO_2 process emissions: The potential to reduce non-CO_2 process emissions comes at substantial costs for most processes (mainly methane reduction in coal mining and synfuel production). However, the potential of 5.5 $MtCO_2e/a$ can technically be achieved within a few years only and is thus an important option for decreasing emissions in the short term (Winkler 2007a), (Winkler 2010).

Waste

Reductions or emissions from waste and wastewater: Reducing emissions from waste, especially reducing landfill gas emissions (including power generation from landfill gas) has a substantial short mitigation potential, which is estimated to be 11 $MtCO_2e/a$(Winkler 2007a), (Winkler 2010).

Transport

South Africa is in a special situation: due to strategic decisions made during the Apartheid era and its large domestic coal reserves, transport fuels are to a large extent based on synfuels (coal to liquid - CTL), which is extremely carbon intensive. The BAU assumes further CTL plants will be built. A shift to transport fuels based on crude oil or natural gas holds huge mitigation potential. Additionally there is potential for biomass based transport fuels.

Fuel switch in transport (incl. electricity, hydrogen, natural gas and/or sustainable biofuels): (Winkler 2007a), (Winkler 2010) estimates a mitigation potential due to different liquid fuel supply options of 57 $MtCO_2e/a$in 2020, of which 23 $MtCO_2e/a$ would be due to reduced emissions from existing synfuels plants, 27 $MtCO_2e/a$ due to less new synfuel plants being build and 6 $MtCO_2e/a$ due to higher shares of biofuels. Given the lead times to implement these fuel switches, we estimate that between 5 and 25 $MtCO_2e/a$ emission reductions are still achievable by 2020.

With a longer time horizon, CCS for coal to liquid plants could hold a large mitigation potential for emissions in the transport sector. However, this has not been included in our analysis due a marginal contribution before 2020.

The literature points to significant long-term mitigation potential by introduction of electric or hybrid vehicles. Most of this potential is beyond 2020. Considering the current carbon intensity of South Africa's power mix, it seems difficult to achieve net emission reductions in the short term at all (own calculations based on (Doruk / Telsnik 2011)). Consequently, we do not consider the potential related to electric or hybrid vehicles.

Modal shift and efficiency improvements in transport: Huge long-term potential exists in the transport sector both with respect to improving vehicle energy efficiency and modal shift. A prerequisite for the latter often may be the introduction of integrated low-carbon urban planning approaches. To reap this potential in later years, action today is required as large infrastructure investments are made – especially in the economic hubs of the country. However, with a time horizon of 2020 urban planning approaches show very limited impact (and are not considered in the further assessment). The potential for emission reductions based on modal shift is rather small within a short-term time frame. (Winkler 2007a), (Winkler 2010) estimates this to be 3 $MtCO_2e/a$. This is due to the specific situation in South Africa: while the transport means for low-income people are already quite energy efficient (e.g. trains and minibuses), the big polluters are the growing number of private cars. However, high crime rates and urban sprawl are strong barriers to a short-term increase in public transport for the middle class. With respect to raising the energy efficiency of vehicles, international assessments show a strong short-term potential (IEA 2009). In contrast (Winkler 2007a), (Winkler 2010) estimate only 2 $MtCO_2e/a$ for more efficient vehicles. We consider this to be a rather conservative estimate, but use it for our calculations, as no other quantifiable data are available.

Buildings

Low energy housing and efficiency of appliances: A mix of technologies can support a reduction of GHG emissions from domestic sources; these include more efficient lighting and appliances, better insulated houses, solar thermal devices for water heating. According to (Winkler 2007a), (Winkler 2010) emission reductions can amount to 8 $MtCO_2e/a$in 2020. The widespread use of solar water heaters (SWH) has beneficial effects on job creation and a high impact on reducing carbon emissions as water is generally heated with electricity with its high carbon intensity (Edkins et al. 2010).

Additionally there is a significant saving potential in commercial and public buildings, which is estimated to be 5 $MtCO_2e$/ain 2020 (Winkler 2007a), (Winkler 2010).

AFOLU

Re-/afforestation: South Africa has a substantial short-term mitigation potential for reducing emission from land use estimated to be 18 $MtCO_2e$/ain 2020 (Winkler 2007a), (Winkler 2010). The key potential lies in activities targeted at “savannah thickening”, i.e. fire control and afforestation measures in savannah bush lands. The measures are cost effective, due to overall small costs per ton and have substantial co-benefits. However, it must be stressed that the given potential is the country’s maximum potential and decreases again in the long term.

Total mitigation potential and associated costs in South Africa

The assessment of the selected mitigation measures indicates a total mitigation potential of 132 to 177 $MtCO_2e$/ain 2020. A large share of this potential (66 $MtCO_2e$/a) comes as no-regret options with negative costs. Another 42 $MtCO_2e$/a can be associated with measures, which have either very low costs or strong co-benefits (especially with respect to health improvement and job generation) and are from a macro-economic perspective beneficial or neutral for South Africa. A potential of 24 to 69 $MtCO_2e$/ain 2020 comes from ambitious measures with significant costs. A large share of these measures is in the field of renewable energy power generation.

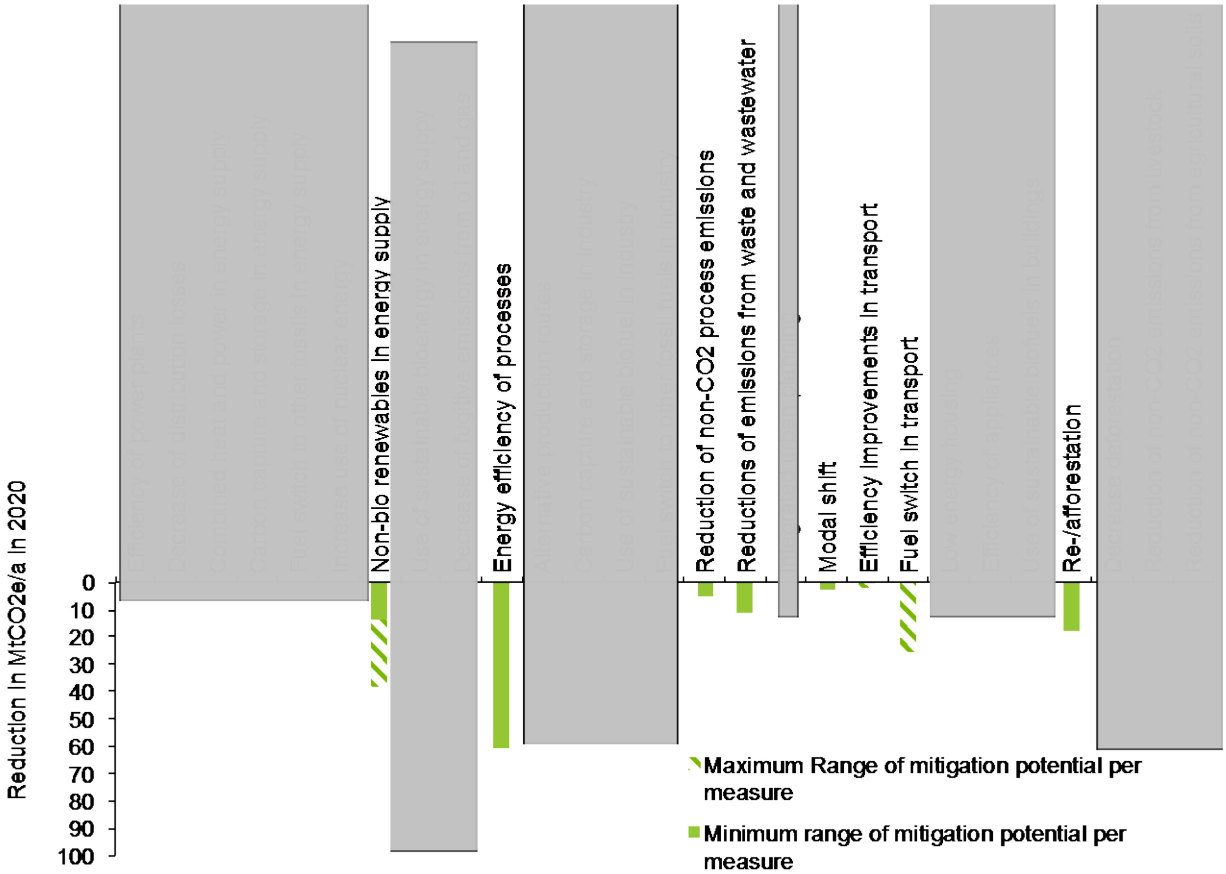


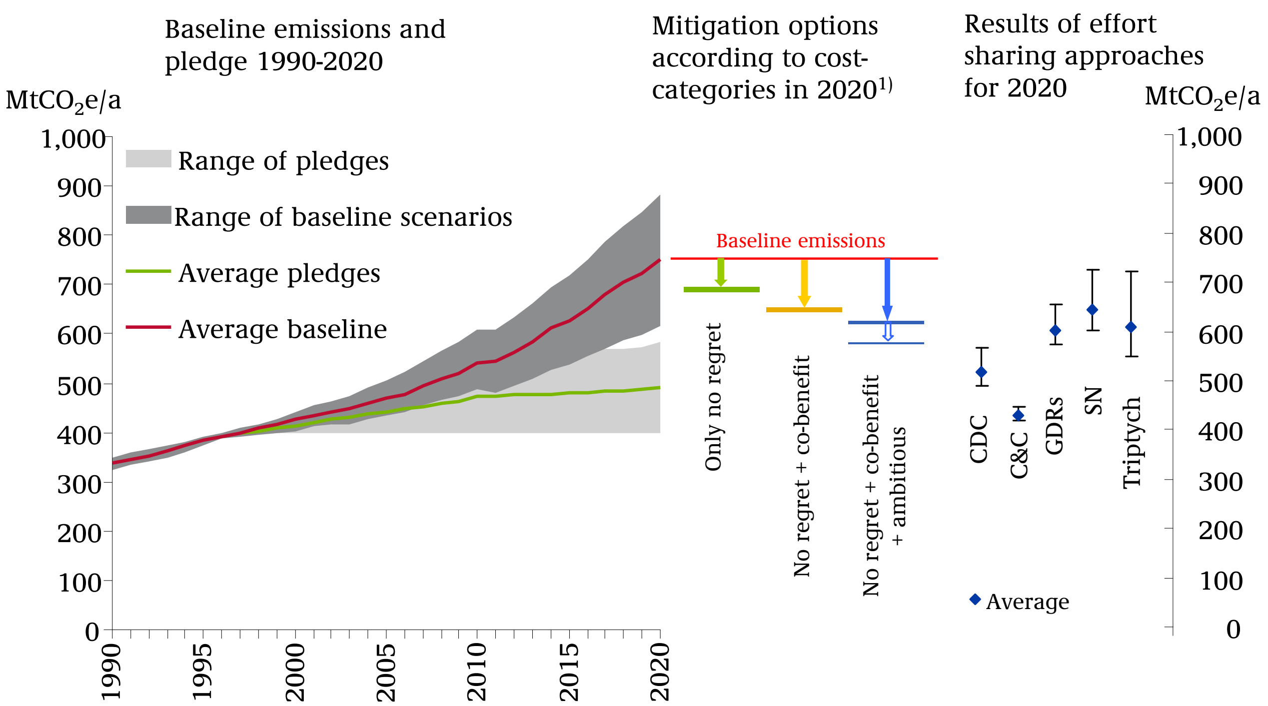
Fig. 33: South Africa: Ranges of mitigation potential by standard measures

3.5.4 Evaluation of the pledge, mitigation potential and responsibilities of South Africa

While there is substantial potential in the mid-term, meeting the 2020 pledge will require immediate and strong actions, which would need to be supported internationally.

Ambitious long-term vision for emission reductions – but not yet implemented

South Africa has developed a long-term vision for its low-carbon transformation: to peak emissions between 2025 and 2035 and decline thereafter. The National Climate Change Response (NCCR) White Paper, which was adopted in 2011, underpins the conditional pledge made by South Africa to reduce its emissions by 34% below BAU levels by 2020 (and 42% by 2025).



1) Mitigation potential includes only a subset of all potential measures. Total mitigation potential can be higher. The horizontal lines show the maximum and the minimum of remaining emissions according to different sources after step-by-step implementation of the analysed measures of different cost categories, starting with the lowest cost options.

Fig. 34: South Africa: Projected BAU and pledged emissions compared to mitigation potential and results from effort sharing approaches.

The issue of climate change has gained political momentum in the country – and not only in the run-up to the COP 17 in Durban in 2011. Very much responsible for this is the Department of Environmental Affairs, which also drafted the NCCR strategy. The whole process is well grounded in sophisticated assessments of emission scenarios and mitigation potential (mainly by the Energy Research Center, University Cape Town). In the meantime, other ministries and players have taken up the challenge of reducing GHG emissions substantially (e.g. in the 'Integrated Resource Plan' for electricity generation by the Department of Energy (DoE 2011b)).

However, the latest development of South Africa's GHG emissions indicates that no substantial deviation from the BAU trajectory has been achieved so far (DEA 2011c). South Africa's average mitigation pledge for 2020 has already been overshot (see Fig. 34). The conclusion of this is quite dramatic: due to weak implementation of mitigation actions in the past, the country will have to strive towards absolute emission reductions in the future to reduce its emissions down to the level of its average pledge.

South Africa's absolute pledged emission level unclear

South Africa has defined its pledge to be 34% below BAU. As a result, the absolute level of the pledge in 2020 is variable, depending on the actual development of GHG emissions until then. The BAU scenario used as a basis for national policy implementation is defined as a range with lower and upper limits in the White Paper. Our analysis uses this range as a basis for determining the emissions resulting from the pledge.

Looking at historic data, the range in the White Paper rather underestimates emissions in South Africa. According to the 2nd National Communication, emissions in South Africa in 2000 were 461 $MtCO_2e$ (excl. LULUCF), while the White Paper's maximum is at 437 $MtCO_2e$. The actual expected emission level in 2020 implied by the pledge is thus rather unclear.

Pledge is in line with global mitigation responsibilities

South Africa's pledge is in line with or even more ambitious than mitigation responsibilities according to the effort sharing regimes of GDR, SN and Triptych (see Fig. 34), which are based on responsibility and capability criteria. However, South Africa has relatively high emissions per capita already (>9 tCO_2e/person in 2008). Consequently the pledge is not ambitious enough to meet the criteria of per capita based equity models. The upper margin of the pledge is hardly in line with the CDC model requirements. To meet the C&C requirements, South Africa would have to fulfil the average value of its pledge range.

Assessment of South Africa's mid-term mitigation potential – stronger short-term action needed

This assessment of South Africa's mitigation potentials shows:

- Huge mitigation potential exists in South Africa at negative cost (no-regret potential) or with substantial co-benefits (e.g. reducing local emissions and subsequent health risks or supporting other development goals in South Africa). Increasing energy efficiency in industry with a no-regret potential of 61 $MtCO_2e$in 2020 is a key example.
- South Africa's mitigation pledge is based on a thorough assessment of the country's development path and its mitigation potential (Winkler 2007a). Consequently, the sum of all mitigation measures provides sufficient potential to reach the country's pledge.
- However, we estimate that neither nuclear power nor carbon capture and storage (CCS) (for both coal-fired power plants and synfuel coal to liquid plants) can make a significant contribution to South Africa's mitigation aspiration by 2020 – due to long planning horizons and uncertainties for nuclear power plants and lack of proven commercial scale technology for CCS. This assessment is irrespective of the long-term mitigation potential of these technologies in South Africa.

In conclusion, South Africa has a tremendous mid to long-term mitigation potential at moderate cost. However, meeting the country's 2020 target will require strong short-term action. South Africa will have to address all available mitigation options simultaneously, including more costly options. In this respect it needs to be noted that South Africa's pledge is conditional to international support. A large short-term mitigation potential exists specifically in the fields of energy efficiency, renewable energy, waste and land-use change. Immediate action is required to ensure its full deployment – not only to meet the countries 2020 target, but also to facilitate a cost-effective long-term mitigation pathway.

3.6 South Korea

The Democratic Republic of Korea (South Korea), OECD member since 1996, is among the fastest-growing countries in the world. Its GDP has increased by 3-5% annually in the last 20 years, making South Korea No. 13 in GDP globally in 2010 (World Bank 2012). South Korea's economy is strongly geared towards export. The country is renowned for its production of high-technology goods.

Tab. 22: Key indicators - South Korea

Population (2010)[38]:	48.2 million	Rank 24
GDP (2010)[39]:	1323 billion US$ (2005 PPP)	Rank 23
GDP growth (2000- 2010):	4.3%/a average 50% total	
Energy consumption (2010)[40]:	250 Mtoe	Rank 9
Energy consumption growth (2000 – 2010):	2,9%/a average 33% total	
GHG emissions (2008)[41]:	568 $MtCO_2e/a$ (2008)	Rank 13

South Korea's emissions have doubled from 1990 - 2008, putting it well over the OECD average increase of 27%. At the same time, the country has a high energy intensity, mainly due to its high energy consumption in the industrial sector (Randall Jones / Byungseo Yoo 2012). Korea has a high share (31%) of nuclear energy (Borowiec 2012), but has continued to establish fossil fuel based power plants. In 2009, about half of the total energy produced stemmed from coal.

In 2008, Korea's President announced 'Low Carbon, Green Growth' as South Korea's new paradigm for the coming 50 years. Following this proclamation, South Korea's legislation and institutional setup has been structured along the low-carbon and green-growth vision, and in 2009, a Five-Year Plan for Green Growth was launched. It contains a comprehensive set of projects amounting to 108.7 trillion won (96 billion US$) in total investment. In 2011, South Korea specified its announcement of reducing its emissions 30% below BAU in 2020 with sectoral targets. The government has laid out plans to research and develop 27 core green technologies, in order to become competitive with leading countries. The country plans to increase the share of public investment in basic research to 35% (Randall Jones / Byungseo Yoo 2012).

3.6.1 Historical and projected BAU development of GHG emissions in South Korea

This section illustrates historical data and a possible BAU scenario of Korean GHG emissions according to its Third National Communication to the UNFCCC from 2012 (Republic of Korea 2012), and a review of Korea's Green Growth Strategy by Jones and Yoo (R.S. Jones / B. Yoo 2011).

[38] UN 2011

[39] World Bank 2012

[40] IEA/OECD 2012

[41] EDGAR 2011

Expected emissions until 2020

Korea's National Communication of 2012 estimates total emissions of 776.1 $MtCO_2e$/a under a BAU scenario in 2020, whereas in earlier presentations of the pledge Korea presented a slightly higher estimate of 813 $MtCO_2e$/a. Jones and Yoo use the same estimates, derived of the Korean Presidential Committee from 2009. South Korea has experienced an economic downturn in 2011, which lowered the expectations for future growth. No range is given because the difference in figures is due to usage of older estimates of the same source, i.e. official estimates by the South Korean government.

According to its National Communication, the energy sector will have the single largest share of these emissions: 626.9 $MtCO_2e$/a, or 80.8% of emissions in 2020. Korea subsumes manufacturing industries and construction as well as transport under the energy sector. Thus, the number represents emissions from electricity generation as well as energy consumption, for example in cars.

Main data sources and assumptions

The main data source for Korea is its most recent National Communication (Republic of Korea 2012). It provides recent GHG inventory data until 2009, projections on expected emissions growth and South Korea's pledged reductions structured along sectors, and a comprehensive, but not quantified, set of policies and measures implemented or planned to reach these targets. Further sources include reviews of South Korea's Five Year Plan by the OECD (R.S. Jones / B. Yoo 2011; Randall Jones / Byungseo Yoo 2012), and by UNEP (UNEP 2010). However, these do not use separate calculations, but official data by the Korean government. The data used in these sources is of an earlier date, so the numbers vary slightly.

Country specific uncertainties in determining the BAU

South Korea is a fast-growing economy that relies heavily on exports. It was strongly hit by the recent global downturn. Its economy has stabilised again, but with the current uncertainty in the global economy, it is unclear if Korea's economy will continue to grow as fast as in recent years. Dents in its growth will have repercussions on its BAU scenario that are hard to predict. It is not clear how the official data used in this study reflects this uncertainty.

Also, it is not clear which measures that are already implemented by the Korean government are taken into account in the BAU scenario.

3.6.2 South Korea's pledge for GHG emission reductions until 2020

South Korea has pledged a 30% reduction from BAU in 2020. This represents the ambitious end of the 15% to 30% range that den Elzen / Höhne 2008 specified based on IPCC's recommendation for a substantial deviation below baseline by developing countries.

South Korea has broken down its pledge into detailed sectoral sub-pledges for 2020 versus their individual BAUs (Jin-Gyu Oh 2012):

- Industry 18.2%
- Power sector 26.7%
- Transport 34.3%

- Building 26.9%
- Agriculture 5.2%
- Waste 12.3%
- Public, others 25%

Estimated effect of South Korea's pledge on GHG emissions

The official BAU estimates emissions of 776.1 $MtCO_2e$ in 2020. Pledged emission reductions amount to a total of 542.1 $MtCO_2e/a$. Older sources, Korea itself has stated a slightly higher estimate of 569 $MtCO_2e/a$, as earlier BAU projections have been higher. In official Korean sources, the pledge has been adjusted according to the lower projected BAU emissions in 2020. Thus the Korea pledge does change with new BAU projections, it is not fixed to a set amount of absolute emissions at the time of the pledge. This seems to be a different interpretation compared to the other countries.

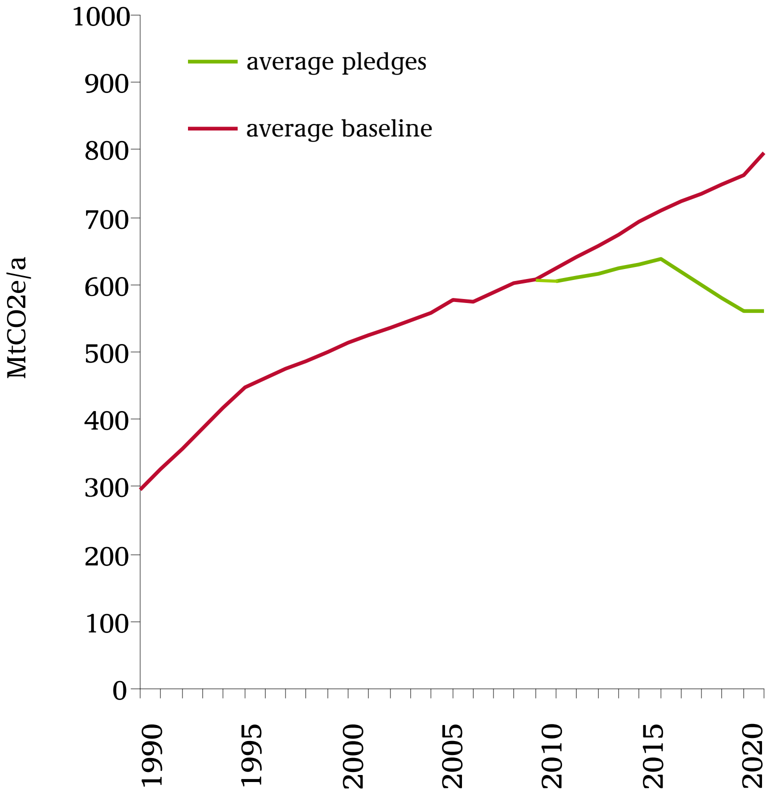


Fig. 35: Estimated emissions resulting from South Korea's pledge (Republic of Korea 2012)

Korea specifies its targets along its identified sectors:

Tab. 23: South Korea's emission reduction pledge (Republic of Korea 2012)

	2005	2015	2020	Reduction rate in 2020
Energy	469.6 (82.3%)	542.4 (85.1%)	454.9 (83.9%)	27%
Industrial processes	64.1 (11.2%)	62.5 (9.8%)	57.5 (10.6%)	51%
Agriculture	20.3 (2.9%)	19.0 (3.0%)	17.5 (3.2%)	7%
Waste	16.3 (2.9%)	13.5 (2.1%)	12.1 (2.2%)	12%
Total emissions	570.3 (100%)	637.4 (100%)	542.1 (100%)	30%

Country specific uncertainties in determining the absolute level of emissions resulting from the pledge

The value of absolute reductions changes with BAU projections. Thus, if the official BAU scenario would deviate significantly from its current value, the value for the pledge would change accordingly.

Possibly because of the economic downturn in recent years, Korea has already adapted its BAU emissions projection from 813 $MtCO_2e/a$ (R.S. Jones / B. Yoo 2011; Korean Ministry of Environment 2009) to 776.1 $MtCO_2e/a$ (Republic of Korea 2012) in 2020. Accordingly, pledged emission reductions have fallen from 569 $MtCO_2e/a$ to 542.1 $MtCO_2e/a$ in 2020.

National climate change plans relating to the pledge

A framework act on low carbon, green growth is in place since 2010. With the accompanying enforcement decree, the Five-Year Plan for Low Carbon, Green Growth was established.

South Korea has developed a comprehensive set of strategies, broken down into policies and measures, in all sectors in order to fulfil its pledge. In total the government currently lists 14 strategies to support its overarching Low Carbon, Green Growth strategy, including reduced energy demand in the industrial sector, expansion of the supply of renewable energy sources, efficiency improvements, promotion of energy-saving buildings, improvement of public transport, protection/expansion of carbon sinks in forestry, and waste reduction.

Most notably, South Korea is implementing an emissions trading system that is now expected to start operations in 2015. Due to strong opposition of Korean energy and industrial firms, the ETS was delayed by two years. In its most recent form, the effectiveness of the ETS has been reduced considerably. For the first three years, each participating facility will receive free permits up to its emission cap. From 2018, free permits will be reduced to 97%, and will drop to 90% from 2021 (Reklev 2012). In an earlier draft, legislation foresaw only 95% of free allocations from the start of the scheme (Reklev 2011).

3.6.3 GHG mitigation potential in South Korea in 2020

Finding data on mitigation potential in sectors or for different measures has proved daunting. Studies carried out by IEA (World Energy Outlook, Energy Technology Perspectives) subsume South Korea under OECD Asia Oceania, comprising Australia, Israel, Japan, Korea and New Zealand. Disaggregated data on mitigation potential is not publicly available via the OECD or IEA.

Thus, no recent data on mitigation potential could be found except for one study on potential savings in the energy sector carried out by Greenpeace and the European Renewable Energy Council (EREC) (Short / Crispin 2012). Studies carried out by the Asian Development Bank (ADB) as early as 1998 were not taken into account because of the vintage of data. The ADB is currently carrying out a project called "Economics of Climate Change and Low Carbon Growth Strategies in Northeast Asia", which includes the development of an abatement cost curve for Korea. Unfortunately, data from this project is not available yet, with the exception of a presentation held in February 2012 in Japan (Hanaoka 2012). The presentation allows discerning the potential accumulated over several sectors as identified by the authors. Also, several reports by the Korean government make reference to studies on sectoral mitigation potential carried out by Korean research institutes that formed the basis for Korea's pledge, but these are either not public, or only available in Korean. This presents a major challenge to this study and limits the assessment that can be done with respect to comparing Korea's pledge with possible mitigation potential.

The Greenpeace/EREC study sees a potential share of renewable energy sources of 10.4 - 13.8% in 2020, as opposed to 5.2% in its reference (BAU) scenario. At the same time, it assumes a decrease in the use of nuclear energy. This puts the study in contrast to South Korea's official assumptions, which foresee an increase in nuclear technologies.

Data shown in the ADB presentation graph shows mitigation potential accumulated over all sectors according to different carbon price scenarios. It shows reduction potential of 125 Mt (50 USD/tCO_2), 136 Mt (100 USD/tCO_2), and 186 Mt (200 USD/tCO_2) respectively (Hanaoka 2012). The presentation exemplifies natural gas vehicles and vehicle efficiency as no-regret measures, and biomass and wind power production as high-cost measures. Unfortunately, no exact values can be discerned from the graphs.

Overview on studies used

	(Short / Crispin 2012)	(Hanaoka 2012)	(Republic of Korea 2012)
Short description	The Advanced Energy [R]evolution—A sustainable Energy Outlook for South Korea, has been created to show the paths the country can follow can follow for a clean energy future.	Presentation held in February in Tsukuba, Japan. Part of an ongoing ADB project called "Economics of Climate Change and Low Carbon Growth Strategies in Northeast Asia"	3rd National Communication submitted to the UNFCCC in 2012. Contains most recent GHG data, projections and mitigation targets, but no data on absolute mitigation potential of the country /sectors
Base year	2011	2012	2012
Sectors covered	Energy	Whole economy (shows whole range of sectors, but values cannot be discerned from graph)	Whole economy
Main assumptions	High efficiency, gradual phase-out of nuclear, strengthening of renewables	Scenarios according to different carbon prices (50/100/200 USD/tCO_2)	Official GHG inventory and targets
Evaluation of source	Very detailed and ambitious	Preliminary data	Official data, detailed information, no sources quoted

Prioritisation of measures

The absolute potential of measures could mostly not be identified due to lack of data. Measures proposed here are not based on quantifiable reduction options; instead, promising areas for mitigation actions have been drawn from the available literature.

South Korea has a very low and partly subsidised energy price, leading to a very energy-intensive industrial structure. A reform of this would yield positive effects on energy efficiency in industry, but also in the efficiency of power plants.

Also, in particular the steel, petro-chemical and cement industries have rather low reduction targets that could be strengthened significantly through stronger efficiency targets (Randall Jones / Byungseo Yoo 2012).

South Korea's main energy source (ca. 50% of primary energy consumption) is coal. Switching to natural gas, a more efficient and less carbon intensive fossil fuel source, would save large amounts of emissions. However, high gas prices in relation to coal and high investment costs for infrastructure and plants may present a barrier to large-scale deployment (IEA 2010).

As the energy (r)evolution study by Greenpeace and EREC suggests, the share of renewables could be developed more strongly than is suggested in South Korea's pledge. Up to 21 $MtCO_2e$/a could be saved in the most ambitious Greenpeace scenario in 2020. Greenpeace's scenario suggests that this would come at significantly lower cost than the reference scenario, as there would be less cost for the installation of renewable generation capacity compared to building new nuclear power plants. The authors estimate a total investment need of 56.3 billion USD in renewables up to 2020, as opposed to 28.8 billion in the reference scenario, whereas investment in conventional fossil and nuclear power plants would diminish from 153.6 billion USD to 40.6 billion USD (Short / Crispin 2012).

South Korea has a strong commitment to nuclear energy, and has integrated a high share in its calculations for its pledge. Currently, 23 nuclear reactors are in use, with five more under construction. A further eleven are planned to be built until 2030. However, after the Fukushima disaster, a large expansion of the nuclear sector has been rendered more unlikely due to scepticism of the population (Borowiec 2012).

Other measures may be implemented in the transport sector. Korea has seen a very sharp rise in personal vehicles, and is already implementing efficiency standards for cars (UNEP 2010). Through a stronger commitment to public transport and integrated city planning, emissions could be lowered further. The sector has also been identified as having no-regret potential by the ADB (Hanaoka 2012).

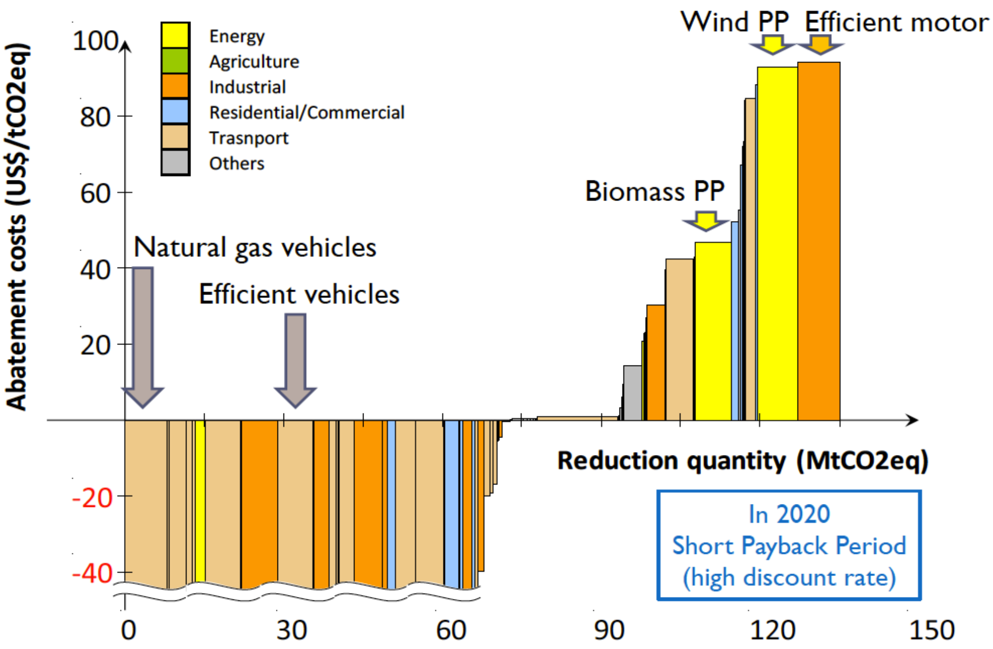


Fig. 36: GHG abatement cost curve acc. to ADB preliminary data (Hanaoka 2012)

3.6.4 Evaluation of the pledge, mitigation potential and responsibilities of South Korea

South Korea's pledge is likely to be rather ambitious, although lack of data on mitigation potential makes an assessment difficult.

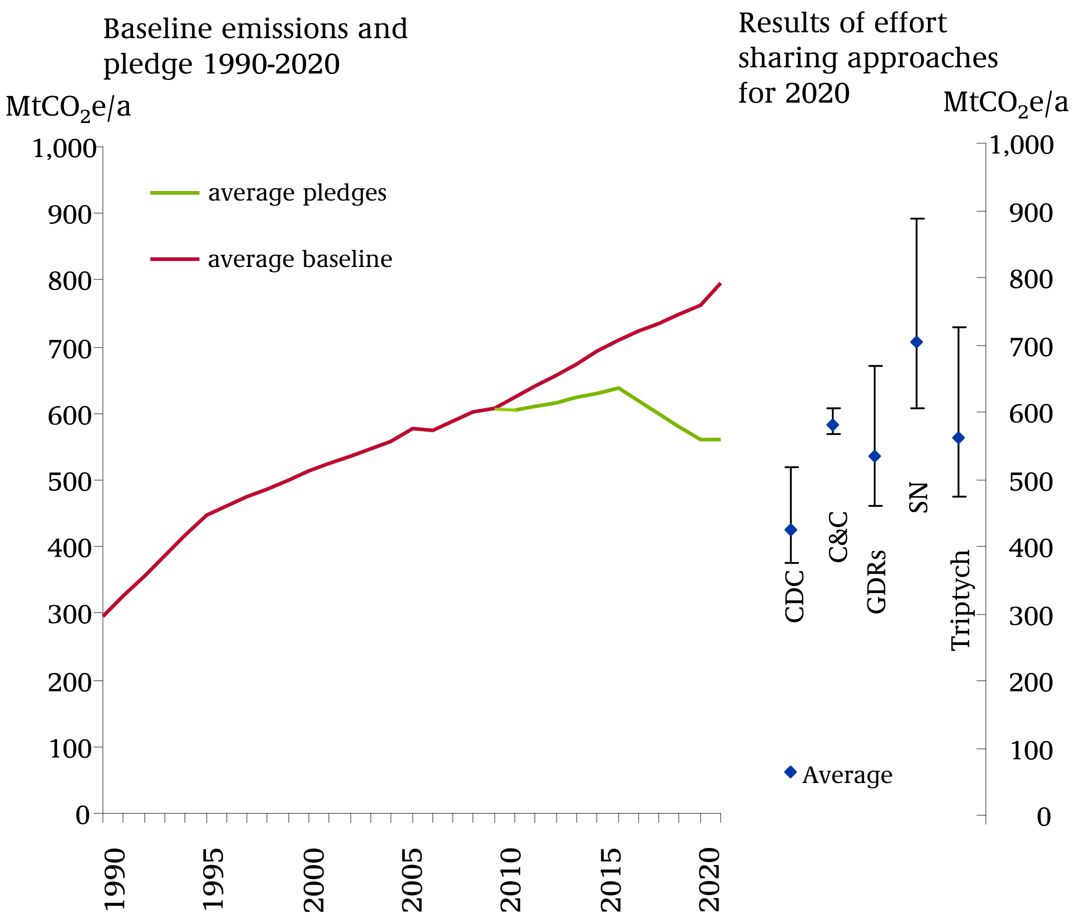


Fig. 37: South Korea: Projected BAU and pledged emissions compared to results from effort sharing approaches

Ambitious pledge - climate protection a high national priority

South Korea's pledge of 30% GHG reductions relative to BAU in 2020 is on the ambitious end of the range of effort sharing approaches we have assessed. Korea has a very fast-growing economy, and is now being classified as converging to the highest-income countries by the OECD (OECD 2012). The commitment was adopted by the Korean government in 2009 after an analysis of Korea's reduction capacity and the macroeconomic impacts of the reduction, despite the opposition of the industrial sector (R.S. Jones / B. Yoo 2011). Thus, the level of ambition South Korea is showing in its pledge seems to be fairly high. Climate protection ranks very high in the country's priorities, and is seen as an opportunity for economic expansion. The country has also adjusted its pledge accordingly as BAU projections have been lowered, making it unique amongst developing countries.

Lack of data prevents detailed analysis of full mitigation potential

An evaluation of this pledge against the country's potential is daunting as there is a distinct lack of data. If preliminary numbers of the ADB project are correct, South Korea's pledge can be interpreted as highly ambitious, as it could only be fulfilled in the highest carbon-price scenario. On the other hand, Greenpeace and EREC have identified a vast potential for renewable energy, which would even make a phase-out of Korea's nuclear energy program possible. Unfortunately, the limited availability of information makes it impossible to discern the feasibility and level of ambition of Korea's pledge. While there is a definite political commitment to green growth and climate-friendly development, the delayed implementation of South Korea's emissions trading system and its reduced ambition shows that there is still potential for more decisive action.

Wide variation in modelling of fair share

According to the CDC approach, South Korea's pledge does not fulfil its responsibility for a fair global effort sharing. On the other hand, for the SN approach even the BAU pathway falls within the range of a fair effort-sharing regime. According to the Triptych approach, South Korea's pledge correctly reflects the country's responsibility, with the median share almost exactly in line with Korea's pledge pathway in 2020.

4 Global aggregation of emissions and the 2°C pathway

Based on the evaluation of the individual emerging economies in section 3 we now analyse the impact of the mitigation potential on global emissions pathways, temperature increase and on the probability of exceeding 2°C during the 21st century.

In section 1 we describe the different pathways used. They serve to answer two sets of questions:

- Differentiated level of ambition between countries: What is the impact of the level of emissions in 2020 based on pledges and mitigation potential of the countries analysed given different levels of ambition for the rest of the world and assuming efforts after 2020 lead to an emissions level in 2100 that is in line with a 2°C pathway? How far do different emission levels in 2020 influence the effort needed and feasibility of reaching the envisaged 2100 level?
- Same level of ambition for all countries: What is the impact on emissions pathways and temperature assuming the same level of ambition for all countries and how does that compare to a world with no further action, also after 2020?

It is important to recollect here that all pathways linearly converge to a GHG emissions level in 2100 that is consistent with 2°C warming (van Vliet et al. 2012) starting from different levels in 2020. The only exception is the 'BAU all' case, which assumes all countries follow a BAU pathway until 2100. Tab. 23 illustrates how we use the scenarios identified in the methodology to answer the above research questions.

Tab. 24: Overview of emission pathway analysis scenarios

		Countries assessed in this report[1]			
		Reference until 2100	Reference until 2020	Pledges until 2020	Full potential until 2020
Other countries (incl. South Korea)	Reference until 2100	All BAU 2100			
	Reference until 2020		All BAU 2020		
	Pledges until 2020		BAU, others pledge	All pledges	Full potential, others pledge
	IPCC ambition until 2020		BAU, others IPCC ambition	Pledges, others IPCC ambition	Full potential, others IPCC ambition

1 Except South Korea. Due to lack of data on mitigation potential it is grouped within the "other countries".

To evaluate question 1 we compare the different pathways for the countries assessed in this report with a given ambition level for "other countries", i.e. we compare scenarios along the lines of the table. We do this for the “pledges” and “IPCC ambition” cases (turquoise and purple). To assess question 2 we compare the scenarios that imply the same level of ambition for all countries (blue). This analysis also includes a comparison to the “All BAU 2100” scenario.

4.1 Emission pathways

4.1.1 Effects of differentiated levels of ambition between countries

The emissions level in 2020 of the different pathways varies within the range of 44 $GtCO_2e/a$ for the ‘Full potential, others IPCC ambition’ scenario to 57 $GtCO_2e/a$ for the ‘All BAU 2020’ and ‘All BAU 2100’ scenarios, before converging to the low level of 3.72 $GtCO_2e/a$ in 2100. The UNEP Bridging the Gap Report (2011) estimated that a global emissions level in 2020 of 44 $GtCO_2e/a$ is consistent with 2 and 1.5 °C. So the most ambitious of our scenarios coincides with this level.

An emission level of 44 $GtCO_2e/a$ in 2020 is lower than estimates of current global emissions, so that emissions would need to peak well before 2020 for these values to be achieved. We have made no assumptions on the trajectory of emissions between today and 2020 and applied a linear trend.

Fig. 36 and Fig. 37 show the significant impact of the efforts of the emerging economies on 2020 global emissions level. It is important to highlight that only five of our focus countries are included here (due to lack of data, South Korea is grouped with the rest of the world).

Fig. 36 shows the effect of different levels of ambition of emerging economies if all other countries achieve their minimum pledges. It is obvious that none of the pathways stays below the 44 $GtCO_2e/a$ benchmark.

Taking into consideration the fact that higher levels of emissions in 2020 are associated with stronger levels of inertia we see that pathways with rising emissions until 2020 will continue to rise for a few years, reach a plateau before starting to decline towards 2100 emissions levels. Hence, besides differing in their emissions levels in 2020, pathways also vary in terms of the duration and thus magnitude of the overshoot post-2020.

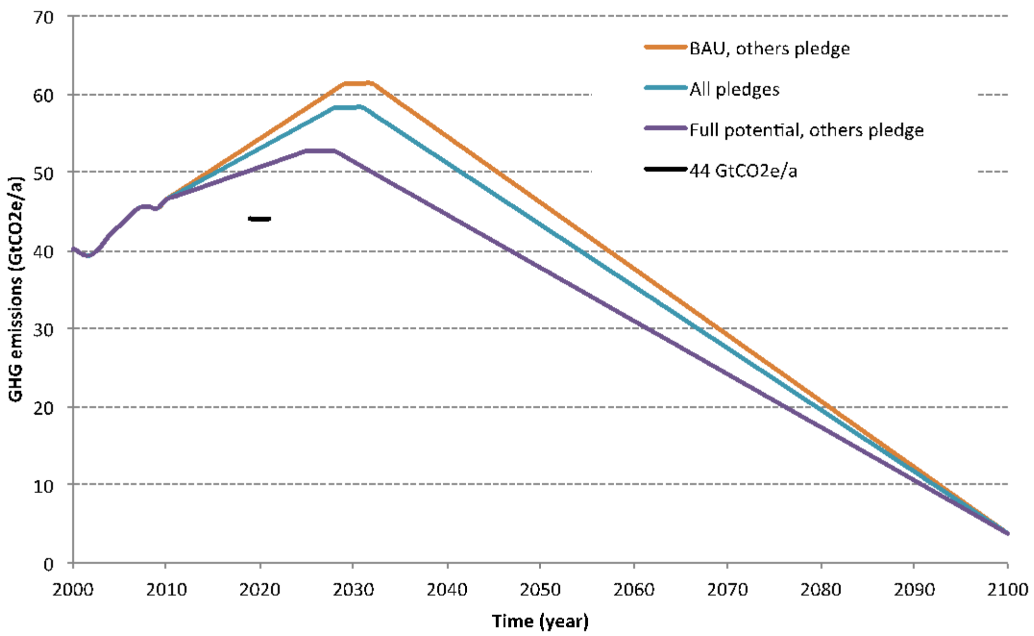


Fig. 38: Global total emissions pathways assuming all countries excluding emerging economies at minimum pledged levels

Fig. 39 shows pathways in which the rest of the world achieves in aggregate the IPCC ambition level, while the ambition level of emerging economies varies in 2020. In our analysis an emissions level of 44 $GtCO_2e/a$ is achieved when the emerging economies realise their full mitigation potential (bottom right case of Tab. 24).

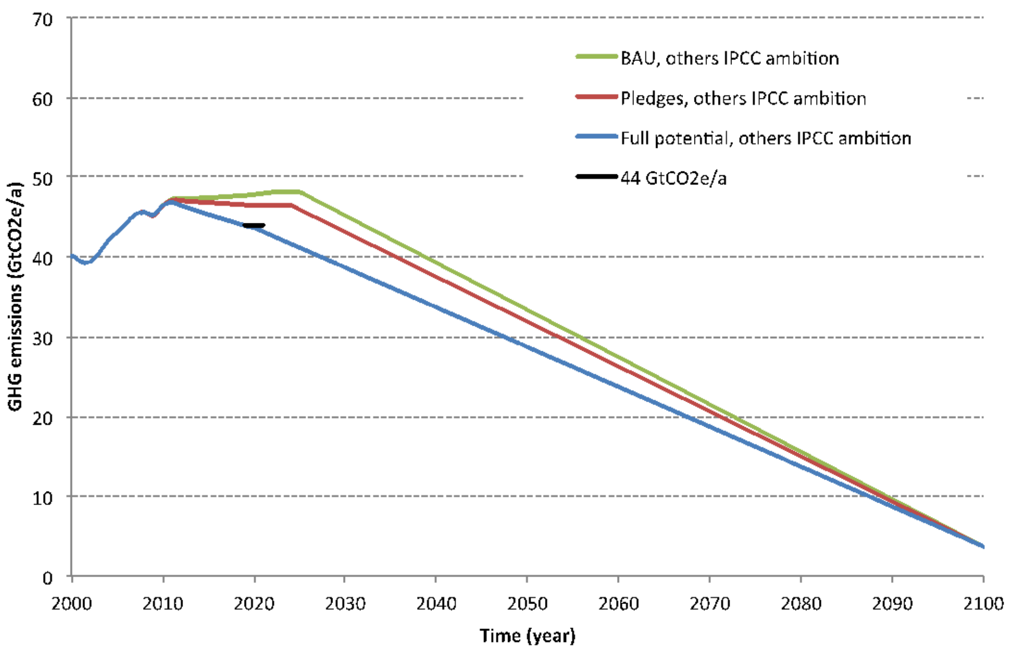


Fig. 39: Global total emissions pathways assuming all countries excluding emerging economies at full mitigation potential, assumed equal to "IPCC ambition"

The 44 $GtCO_2e/a$ emissions benchmark derived from the current literature on Integrated Assessment Modelling represents the cost-optimal level in 2020 consistent with 2 and 1.5°C.

Such levels are not necessarily equivalent to one achieved by realizing the global full mitigation potential.

4.1.2 Implications of different pathways on the feasibility of implementation

Higher emissions in 2020 will require a faster decrease thereafter. If the other countries achieve their pledges in 2020 the average annual rates of decrease in emissions globally from the moment emissions start to decrease until 2100 varies within the range of 0.7 to 0.8 $GtCO_2e/a$, or 1.7 to 2.1% of 2000 emissions levels. In the case in which the other countries achieve the IPCC ambition levels in 2020 the average rates of decrease are reduced to 0.5 to 0.6 $GtCO_2e/a$, or 1.2 to 1.5% of 2000 emissions levels.

Cost-optimal energy-economic scenarios from Integrated Assessment Models suggest a rate of 3% of 2000 emissions levels is achievable as a maximum annual decrease extending over at least one decade (den Elzen et al 2010).

Next to the fact that we derived our post-2020 reductions and 2100 levels from van Vliet et al (2012), this provides a further indication that our pathways are within the range of what is considered feasible for the economy-energy system in the scenario literature. However, it is important to bear in mind that different trajectories and assumptions on relative reductions across regions towards the low emissions levels in 2100 imply different degrees of transformation of the economy and national and global energy systems.

Very roughly speaking, van Vliet et al. 2012 showed that the cumulative costs from 2020 to 2100 associated with emission reductions are equal for emissions pathways peaking at different times (from 2017 to 2025 roughly) and levels (44 to 55 $GtCO_2e$), as long as emission levels by 2100 converge. Most scenarios we assessed are within this range. The two exceptions are the 'BAU all 2020' and 'BAU all' pathway (see below).

4.1.3 Effects using the same level of ambition across countries

Fig. 40 compares the pathways where all countries in the world are at the same ambition level. We can see that the required reduction rates between 2020 and 2100 change drastically depending on the 2020 emission levels, as well as the overshoot shape and duration. In the 'BAU all 2020' scenario, all countries follow BAU until 2020 and then decrease to low 2100 levels. This scenario peaks in 2030 at 57 $GtCO_2e/a$. In the 'BAU all' scenario, all countries follow BAU until 2100, reaching 60 $GtCO_2e/a$ in 2100 after peaking at 76 $GtCO_2e/a$ in 2050 (Fig. 40). While a continuation of BAU until 2100 is clearly outside feasible reduction scenarios, the 'BAU all 2020' scenario is also outside this range.

As mentioned above, there is no indication in the Integrated Assessment Model scenario literature investigated here that 'BAU all 2020' is a feasible pathway. In a case in which all countries meet their pledges in 2020, a steep descent would be required to achieve low levels of emissions by 2100. The reduction rates required are consistent with the literature, but imply higher costs, higher risks and reduce the opportunity for technological choices (IEA WEO 2011). The 'BAU all 2020' scenario was included only as an illustrative scenario and this pathway is shaded in all figures to indicate low confidence.

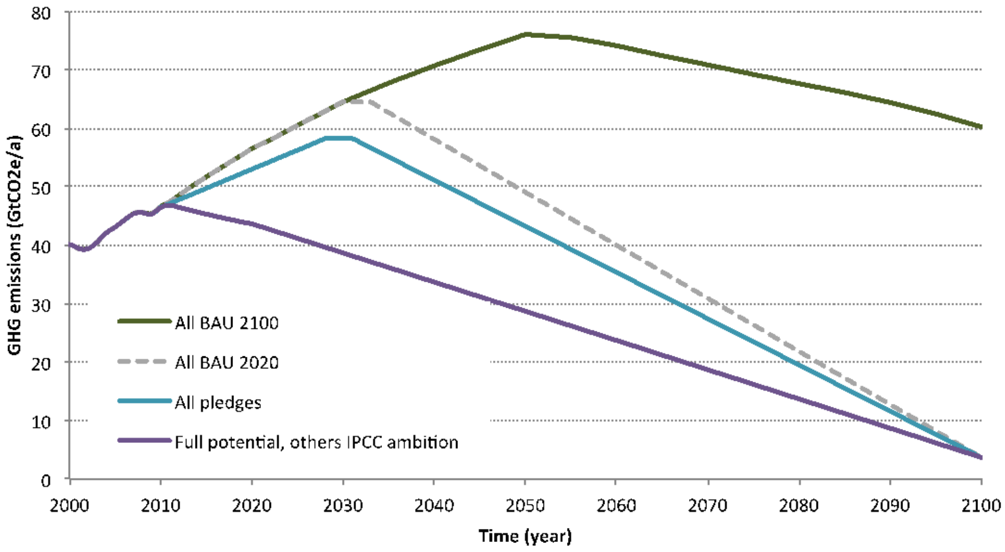


Fig. 40: Global total emissions pathways assuming the same ambition level for all countries.

4.2 Increase in temperature and probability of exceeding 2°C

4.2.1 Results for the different scenarios

We assessed the effect of the different pathways on temperature increase with climate-model calculations. Tab. 25 shows a rise in median temperature increase above pre-industrial levels with lower ambition.[42] Even more importantly, the probability of exceeding 2°C increases drastically with reduced ambition.

Tab. 25: Emissions level in 2020, median temperature increase in 2100 (and range) and probability of exceeding 2°C for the different pathways

Pathway	Emissions level in 2020 ($GtCO_2e/a$)	2020 "Emissions Gap" ($GtCO_2e/a$)	Median temperature in 2100 (16-84% range) (°C)	Probability of exceeding 2°C (%)
Full potential, others IPCC ambition	44	0	2.0 (1.6-2.5)	45%
Pledge, others IPCC ambition	46	2	2.1 (1.7-2.6)	55%
BAU, others IPCC ambition	48	4	2.1 (1.7-2.7)	60%
Full potential, others pledge	51	7	2.2 (1.8-2.8)	70%
All pledges	53	9	2.4 (1.9-3.0)	80%
BAU, others pledge	54	10	2.5 (2.0-3.1)	85%
All BAU 2020	57	13	2.6 (2.1-3.3)	90%
All BAU 2100	57	13	3.6 (3.0-4.7)	100%

[42] Results are consistent with the 15-85 % uncertainty range scenario literature (compare section 2.2.3).

If all countries except the emerging economies analysed in this study would achieve the IPCC ambition scenario in 2020, the maximum ambition level of the emerging economies leads to global 2020 emissions about 4 $GtCO_2e$/a lower than the minimum ambition level (business as usual) (Tab. 25). In the event that Brazil, China, India, Mexico and South Africa follow a BAU pathway, instead of achieving their mitigation potential, the likelihood of exceeding 2°C is one third higher than if these countries were to realise their full 2020 reduction potential. This shows that without high ambition to reduce emissions by emerging economies warming is not likely to be held below 2°C, even with high ambition in the rest of the world.

Vice versa, even if the emerging economies reach maximum ambition, the rest of the world needs to match that level of ambition and hence needs to take action well beyond what is currently pledged. This is shown by the scenario in which emerging economy countries achieve their full mitigation potential in 2020, but the rest of the world meets their current minimum pledges. This leads to a 70% probability of exceeding 2°C, compared to 45% if the rest of the world were to increase ambition to IPCC levels.

The likelihood of exceeding 2°C would at least double if all countries were to follow a BAU pathway until 2020 instead of achieving their full mitigation potential.

Note that our ‘All pledges’ scenario results in an estimated 2.4°C warming by 2100, which is much lower than the CAT projections of over 3°C (CAT 2011) for current pledges. This is a result of our assumptions that were developed to approximate equal post-2020 cost pathways compared to a cost-optimal scenario to stay below 2°C, which requires deep and ambitious post-2020 reductions even if 2020 reductions are inadequate. By contrast, the CAT projections closely track progress in international emissions not only for 2020, but for 2050 as well. There is no indication in international negotiations that the deep post-2020 reductions in our ‘All pledges’ scenario will be achieved.

The global analysis of the mitigation potential of the emerging economies assessed in this report shows how action in these six countries alone could affect global temperatures and the probability of the world exceeding 2°C.

4.2.2 Comparison of results to pathway literature

UNEP (2011) and Rogelj et al. (2011) evaluated the long-term implication of 2020 emission levels in a large library of energy-economic scenarios from the scientific literature. Most of these focus on optimal (least-cost) pathways to achieve GHG concentration stabilisation. Only recently, modelling comparison studies have started focusing on second-best scenarios . These scenarios were split into categories of long-term warming levels and for each warming level the median emissions in 2020 were extracted.

In Fig. 41below we compare these 2020 levels from the literature with those from our pathways and the temperature increase associated with these levels. Different 2020 emissions levels can still lead to the same temperature change by 2100, depending on assumptions about the development of emissions between 2020 and 2100. The comparison indicates that the pathways we created are in the range of what is feasible in the economy-energy system.

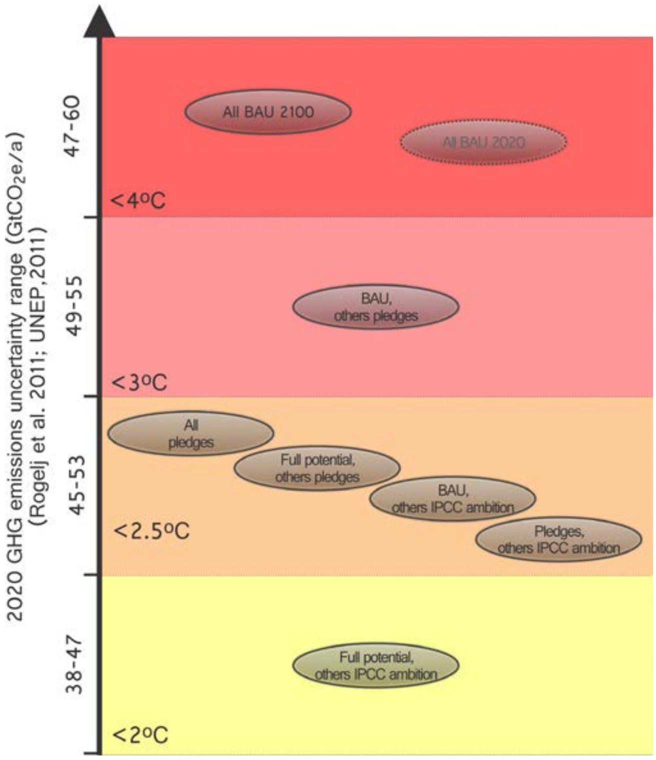


Fig. 41: 2020 global emission levels of pathways analysed in this report compared to the 2020 levels of typical scenarios from literature (15-85% uncertainty range) and associated with global average temperature change above pre-industrial levels (below 2, 2.5, 3 and 4°C).

The emissions levels in our 2020 pathways are close to the emission levels uncertainty ranges from the literature and with converging emissions in 2100 lead to comparable temperature increase during the 21st century, except for 'All BAU 2020'. Due to steep post-2020 decrease in our pathways, this pathway leads to a temperature increase of 2.6 degrees in 2020, whereas the 2020 emissions levels in this scenario would typically lead to an increase of between 3 and 4 degrees in the literature. The 'All BAU 2020' scenario serves as an illustrative pathway only, since the post-2020 reductions required to reach the low 2100 level were not shown to be feasible in the scenario literature.

The logic behind our pathways is not directly comparable to the scenarios underlying the literature, since the literature scenarios include a coherent storyline of, for example, optimal reductions through the whole century with a particular 2100 target in mind, which differs from the simple 2100 end point assumptions we made for our pathways.

Hence, comparing 2020 emissions levels from UNEP (2011) and Rogelj et al. (2011) to those obtained here provides a rough indication that most of our pathways are economically and technologically feasible; assuming the post-2020 ambition level for each pathway will be that typical of scenarios achieving comparable 2020 emission levels from the science literature.

5 Conclusions

Most important conclusions from the analysis underlying this report are:

- Pledges of emerging economies make use of the countries' potential to different degrees. While South Africa and Mexico would need to exploit a large share of their potential, India's and China's pledges are conservative as they would need to implement only a share of the potential. South Korea and Brazil are hard to evaluate in this context due to the lack or uncertainty of data.
- Emerging economies have a significant influence on future global emission levels because of their present size and high expected growth rates. But only with ambitious actions from all countries before 2020, can global emissions be reduced in line with a globally cost-efficient pathway towards 2°C.
- For some countries, the mitigation potential goes significantly beyond what the results of various effort sharing approaches imply. This calls for developed countries to take responsibility in supporting countries in exploiting their potential.
- Immediate action is necessary, also in emerging economies: With every year of delaying action, we can achieve less of the potential in 2020. This not only decreases the likelihood of reaching pledges but is also bound to make later and necessarily more rapid reductions more expensive.
- Countries considered in this report could as soon as possible implement no-regret measures, which are abundantly available and have significant co-benefits.
- Data availability is in some areas low and uncertainty is high, making it difficult to evaluate and compare countries.

Conclusions in detail

The level of ambition of the pledges compared to the BAU trajectory differs between the countries. China's and India's pledges are close to or even above BAU emissions and there is a good chance they will achieve or even over-achieve their targets. Mexico and South Korea on the other hand have rather ambitious pledges, which will require substantial deviation from BAU emissions. South Africa gives a range for both pledge and BAU and thus does not allow a precise evaluation. Similar issues arise for Brazil, where the uncertainty from LULUCF emissions is too high to allow us to determine whether reaching the pledged emission level is a significant (if any) improvement relative to BAU levels.

In comparison to the mitigation potential identified, only one country - South Africa – needs to make use of the complete potential to achieve the pledge. The implementation of measures over the remaining eight years to achieve this pledge is ambitious[43].

In comparison to results from most effort sharing approaches, the pledges of India, Mexico, South Africa and South Korea can be seen as "sufficiently ambitious", while China's pledge is

[43] Pledges may seem more ambitious today than when they were first discussed (in 2009), because as of today until 2020, there are only 8 years left and the time frame for technical implementation is much tighter.

less ambitious than what would result from most effort sharing approaches. Brazil's pledge should also be more ambitious according to most approaches.

For Mexico and especially India, the mitigation potential goes significantly further than what would be needed according to the results from various effort sharing approaches. There is scope for developed countries to support these countries in exploiting their technical potential.

For Brazil the level of ambition is difficult to assess due to the large uncertainty associated with the data. While the percentage reduction from BAU is rather ambitious, the resulting emissions level is not so clear. Official numbers place the pledged level in 2020 well above the lowest available BAU scenario, which would result in no real reduction in 2020.

For some countries, there are effort sharing approaches that result in emission levels which go beyond the mitigation potential identified in this report. This has two main reasons:

- Mitigation potential included here is incomplete. First the studies used as a basis may not have covered the complete mitigation potential and second, we analysed only a set of selected standard measures. They also sometimes rule out individual measures due to economic or political factors.
- The year 2020 is very close already, so the time frame for technical implementation is getting very tight. As a result, we see less mitigation potential for the year 2020.

To still achieve the pledged emission levels, countries should thus implement available measures now, starting with no-regret measures. Most important at this point in time is to put in place short to mid-term plans and in some cases obtain quick support from developed countries.

Overall there is a large data uncertainty both for historical data and projections. As described above for Brazil, this can lead to fundamentally different assessments, depending on data choice. The same problem arises for the evaluation of intensity targets for China and India, where assumptions on future GDP growth change the picture completely.

Globally emerging economies can contribute significantly to GHG reductions in 2020, but only with ambitious actions from all countries by 2020, can emissions be reduced in line with a globally cost-efficient pathway towards 2°C.

In the case that all countries achieve ambitious emission reductions in 2020 (based on IPCC suggestion), countries considered in this report contribute with reductions of 4GtCO_2e/a in 2020 by using their maximum mitigation potential. This would result in global GHG emissions of 44 GtCO_2e/a in 2020 in comparison to 48 GtCO_2e/a if our target countries were not to take any actions. A decrease from 2.1°C to 2.0°C global median temperature increase and from 60% to 45% probability of exceeding the 2°C limit reflects this 4 GtCO_2e reduction.

In the event that other countries achieve their pledged emission levels, the range resulting from our target countries' actions is between 51 and 54 GtCO_2e/a in 2020, with the lower limit reflecting the use of the full potential of the emerging economies and the upper limit reflecting them taking a BAU pathway until 2020. As a result, temperature would increase by 2.2°C on average globally instead of 2.5°C, and the likelihood of exceeding the 2°C limit would decrease from 85% to 70%.

The analysis of the globally aggregated pathways shows that the emerging economies can have a substantial influence on emission levels in 2020. This results from their size and increasing development, leading high emission levels, and great mitigation potential. On the other hand, we show that even if the countries covered in this report make use of their complete potential, emission reductions will not be enough to close the "emissions gap" to achieve the most cost-efficient mitigation pathway. Immediate action is needed from all sides to decrease emissions.

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7 Annex

7.1 Key Country data

7.1.1 Brazil

Emission trajectory 1990 – 2020

Historic emissions and BAU, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Upper range (NPCC BAU)	1758	2004	2537	3236
Lower range	1284	1499	1236	1442
Average	1479	1790	1866	2364

Pledged emissions

Historic emissions and pledge, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Pledge upper range (NPCC pledge)			2331	2000
Pledge lower range	No range provided			
Pledge average				

Mitigation potential by sector in 2020

All categories, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
Energy Supply	0	0	0
Industry	89	100	95
Waste	10	31	20
Transport	19	19	19
Buildings	0	0	0
AFOLU	323	1159	741
Total	440	1310	875

Mitigation potential by category in 2020

All sectors, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
No regret	147	302	225
Co-benefits	288	1002	645
Ambitious	5	5	5
Total	440	1310	875

7.1.2 China

Emission trajectory 1990 – 2020

Historic emissions and BAU, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Upper range	3680	4870	9790	13800
Lower range	3160	4280	9260	13300
Average	3420	4580	9560	13600

Pledged emissions

Historic emissions and pledge, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Pledge upper range			9780	13700
Pledge lower range			9180	11200
Pledge average			9570	12500

Mitigation potential by sector in 2020

All categories, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
Energy Supply	268	985	627
Industry	242	498	370
Transport	176	300	238
Buildings	560	560	560
AFOLU	0	0	0
Waste	0	0	0
Total	1247	2344	1795

Mitigation potential by category in 2020

All sectors, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
No regret	544	752	648
Co-benefits	376	486	431
Ambitious	327	1106	717
Total	1247	2344	1795

7.1.3 India

Emission trajectory 1990 – 2020

Historic emissions and BAU, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Upper range		1460	2630	4810
Lower range		1170	1610	2510
Average		1310	2060	3490

Pledged emissions

Historic emissions and pledge, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Pledge upper range			2520	4350
Pledge lower range			2200	3050
Pledge average			2720	3490

Mitigation potential by sector in 2020

All categories, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
Energy Supply	277	663	470
Industry	184	336	260
Transport	67	149	108
Buildings	76	324	200
AFOLU	0	0	0
Waste	0	0	0
Total	604	1,474	1,039

Mitigation potential by category in 2020

All sectors, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
No regret	229	526	377
Co-benefits	149	181	165
Ambitious	226	766	496
Total	604	1474	1039

7.1.4 Mexico

Emission trajectory 1990 – 2020

Historic emissions and BAU, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Upper range	537	623	769	920
Lower range	506	675	718	741
PECC BAU	506	644	762	882

Pledged emissions

Historic emissions and pledge, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Pledge upper range			762	644
Pledge lower range			762	518
Pledge based on PECC			762	618

Mitigation potential by sector in 2020

All categories, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
Energy Supply	57	137	97
Industry	10	15	13
Waste	16	25	21
Transport	42	78	60
Buildings	35	35	35
AFOLU	24	72	48
Total	184	362	273

Mitigation potential by category in 2020

All sectors, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
No regret	114	256	185
Co-benefits	69	106	88
Ambitious	0	0	0
Total	184	362	273

7.1.5 South Africa

Emission trajectory 1990 – 2020

Historic emissions and BAU, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Upper range			607	883
Lower range			487	615
Average	338	442	541	752

Pledged emissions

Historic emissions and pledge, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Pledge upper range		431	547	583
Pledge lower range		398	398	398
Pledge average		415	473	491

Mitigation potential by sector in 2020

All categories, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
Energy Supply	14	38	26
Industry	67	67	67
Transport	10	30	20
Buildings	13	13	13
AFOLU	18	18	18
Waste	11	11	11
Total	132	177	154

Mitigation potential by category in 2020

All sectors, [$MtCO_2e/a$]	Low end of potential in 2020	High end of potential in 2020	average
No regret	66	66	66
Co-benefits	42	42	42
Ambitious	24	69	46
Total	132	177	154

7.1.6 South Korea

Emission trajectory 1990 – 2020

Historic emissions and BAU, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Upper range				
Lower range				
Average	296	514	625	776

Pledged emissions

Historic emissions and pledge, all sectors [$MtCO_2e/a$]	1990	2000	2010	2020
Pledge upper range				
Pledge lower range				
Pledge average	296	514	604	542

Mitigation potential by sector in 2020

No comparable data available

Mitigation potential by category in 2020

No comparable data available

7.2 List of predefined standard for emission reductions

Tab. 26: Predefined technical standard measures for emission reductions

Standard measures	Typical co-benefits
Energy supply	
Efficiency of power plants	Air quality, technology transfer
Decrease of distribution losses	Access to clean energy sources
Combined heat and power	Air quality, technology transfer
Carbon capture and storage	Technology transfer
Fuel switch to other fossils	Air quality, energy security
Increase of nuclear energy	Energy security
Non-bio renewables	Technology transfer, employment,
Use of sustainable bioenergy	Income generation, rural development
Decrease of fugitive emissions from oil and gas production	
Industry	
Energy efficiency of processes (Includes electricity and fuel)	Energy security, air quality, quality of employment
Alternative production routes (E.g. increase use of recycled materials, for cement: more blended cement)	Quality of employment
Carbon Capture and Storage	Technology transfer
Use of sustainable biofuel	Income generation, rural development

Fuel switch to other fossil fuels	Energy security, air quality
Reduction of non-CO_2 process emissions	
Waste	
Reductions of emissions from waste and wastewater	Soil quality, public health, quality of employment,
Transport	
Integrated urban planning	Air quality, public health, poverty alleviation
Modal shift	Air quality, public health
Efficiency improvements	Technology transfer, energy security,
Fuel switch (incl. electricity, hydrogen, natural gas and/or sustainable biofuels)	Technology transfer, energy security,
Buildings	
Low energy housing (incl. insulation of building envelope, ventilation with heat recovery, solar thermal energy and heat pumps)	Air quality
Efficiency of appliances	
Use of sustainable biofuels	
AFOLU	
Re-/afforestation	Biodiversity
Decrease deforestation	Biodiversity
Reduction of non-CO_2 emissions from livestock	
Reduction of non-CO_2 emissions from agricultural soils	

7.3 Overshoot estimate for post-2020 emission pathway extensions

BAU emissions are derived from "reference" pathways. For countries assessed in this report these are equal to the average BAU analysed in this report and for other countries we use the PRIMAP4BIS[44] pathway. The latter is derived from scenarios that assume BAU social and economic development and no mitigation efforts beyond current policy.

For other pathways we set the long-term level in 2100 for all our non-BAU pathways equal to that of the illustrative 2°C scenario from (van Vliet et al. 2012) that achieves a global target of keeping warming below 2°C from pre-industrial levels in an "optimal" manner, minimizing overall discounted costs over the 21st century. The different emission levels in 2020 for the resulting non-BAU pathways thus are associated with equal mitigation costs post-2020, but different probabilities of exceeding 2°C.

As a measure of inertia in the energy-economic system, emission scenarios that reach higher emission levels by 2020 exhibit an overshoot: post-2020 reductions need some time to kick in. Whether that makes a significant difference for 21st century warming for the pathways in this

[44] https://sites.google.com/a/primap.org/www/the-primap-model/documentation/baselines/primap4

report was assessed using two different approaches for extending the pathways until 2020 through 2100:

- Linear interpolation linking the 2020 level to the 2100 level for each gas.
- The scenarios generated by van Vliet et al. (2012) shows an overshoot after 2020. This overshoot can be approximated by:
    1. Continuing the trend from 2015 to 2020 for another X years after 2020:
    2. X=0.5yr/$GtCO_2e$*(Emissions2020(pathways)- Emissions2020(optimal))
    3. Reaching a plateau of constant emissions for 3 years
    4. From the achieved overshot level, linear interpolation to the 2100 levels for each gas.

The second approach will provide a more plausible estimate of the consequences of delayed emission reductions by taking into account an approximation of energy-economic inertia, but is less transparent than the first approach. We expect to have to apply the second approach, but if the assessment shows that the difference between the two is insignificant the first approach will be adopted for the default results of the climate-model calculations in this report

7.4 Detailed description of effort sharing approaches and EVOC model

7.4.1 Contraction and convergence by 2050

Under Contraction and convergence (C&C) (GCI 2005; Meyer 2000), all countries participate in the regime with quantified emission targets. As a first step, all countries agree on a path of future global emissions that leads to an agreed long-term stabilisation level for greenhouse gas concentrations ('contraction'). As a second step, the targets for individual countries are set in such a way that per capita emission allowances converge from the countries' current levels to a level equal for all countries within a given period ('convergence'). The convergence level is calculated at a level that resulting global emissions follow the agreed global emission path. It might be more difficult for some countries to reduce emissions compared to others, for example, due to climatic conditions or resource availability. Therefore, emission trading could be allowed to level off differences between allowances and actual emissions. However, C&C does not explicitly provide for emission trading.

As current per-capita emissions differ greatly between countries some developing countries with very low per capita emissions, (e.g. India, Indonesia or the Philippines) could be allocated more emission allowances than necessary to cover their emissions ('hot air'). This would generate a flow of resources from developed to developing countries if these emission allowances are traded.

7.4.2 Common but differentiated convergence

Common but differentiated convergence (CDC) is an approach presented by Höhne et al. (Höhne et al. 2006). Annex I countries' per capita emission allowances converge within, for example, 40 years (2010 to 2050) to an equal level for all countries. Individual non-Annex I countries' per capita emissions also converge within the same period to the same level but convergence starts from the date, when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average. Non-Annex I countries that do not pass this percentage threshold do not have binding emission reduction requirements. Either they take part in the CDM or they voluntarily take on positively binding emission reduction targets. Under the latter, emission allowances may be sold if the target is overachieved, but no emission allowances have to be bought if the target is not reached.

The CDC approach, similarly to C&C, aims at equal per capita allowances in the long run (see Figure 8). In contrast to C&C it considers more the historical responsibility of countries. Annex I countries would have to reduce emissions similarly to C&C, but many non-Annex I countries are likely to have more time to develop until they need to reduce emissions. Non-Annex I country participation is conditional to Annex I action through the gradually declining world average threshold. No excess emission allowances ("hot air") would be granted to least developed countries.

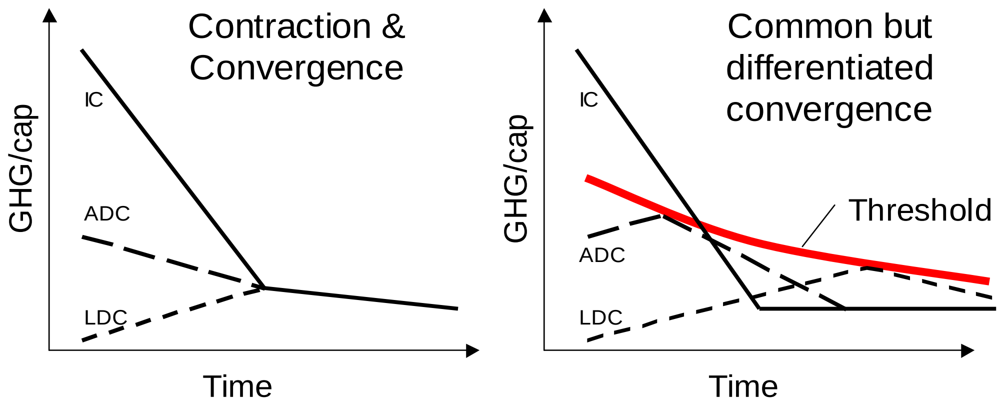

Fig. 42: Schematic representation of GHG emissions per capita for three types of countries (an industrialized country (IC), an advanced developing country (ADC) and a least developed country (LDC)) under Contraction & Convergence (left) and under Common but Differentiated Convergence (right)

7.4.3 Greenhouse Development Rights approach

The Greenhouse Development Rights (GDRs) approach to share the effort of global greenhouse gas emissions reduction was developed by Baer et al. (Baer et al. 2007, 2008; cp. also Niklas Höhne and Sara Moltmann 2008). It is based on three main pillars:

The right to develop: Baer et al. assume the right to develop as the essential part for any future global climate regime in order to be successful. Therefore a development threshold is defined. Below this level individuals must be allowed to make development their first priority and do not need to contribute to the global effort of emission reduction or adaptation to climate change impacts. Those above this threshold will have to contribute regardless their nationality. This means that individuals above this threshold will have to contribute even if they live in a country that has an average per capita income below this level. The level for this development threshold would have to be matter of international debate. However Baer et al. 2008 suggest an income-level of $7,500 per capita and year. Based on this, the effort sharing of the GDRs is based on the capacity and the responsibility of each country.

Capacity: The capacity (C) of a county is reflected by its income. The income distribution among individuals is taken into account by the gini coefficient of a country. A gini coefficient close to 1 indicates low equality while a value close to 0 indicates a high equality in income distribution. As the countries capacity is needed to define per-country emission allowances the sum of income of those individuals per country above the development threshold is summed and considered to calculate each countries capacity.

Responsibility: The responsibility (R) is based on the 'polluter pays' principle. For the GDRs according to Baer et al. it is measured as cumulative per capita CO_2 emissions from fossil fuel consumption since 1990. However, it should be distinguished between survival emissions and luxury emissions. Baer et al. assume that emissions are proportional to consumption, which again is linked to income. Emissions related to that share of income below the development threshold are equivalent to the part of national income that is not considered in calculating a country's capacity. Therefore, they shall be considered as survival emissions. Those emissions linked to income above the development threshold are luxury emissions and shall account for a country's responsibility.

Allocation of emission rights: The allocation of emission reduction obligations and resulting emission rights is based on each country's responsibility and capacity, combined in the Responsibility Capacity Index (RCI). This is defined as $RCI = R^a \cdot C^b$, where a and b are weighting factors. Baer et al. assume and equal weighting of 0.5 for *a* and 0.5 for *b*, which gives capacity and responsibility an equal weight.

Two global emissions development paths are considered. First, the BAU case and second the reduction path necessary to reach the emission level in order to stabilise global emissions (see Figure below). The difference of these two is the amount of emissions that need to be reduced globally. Each country's annual share of this reduction is determined by the relative share of its RCI compared to the sum of RCIs of all other countries.

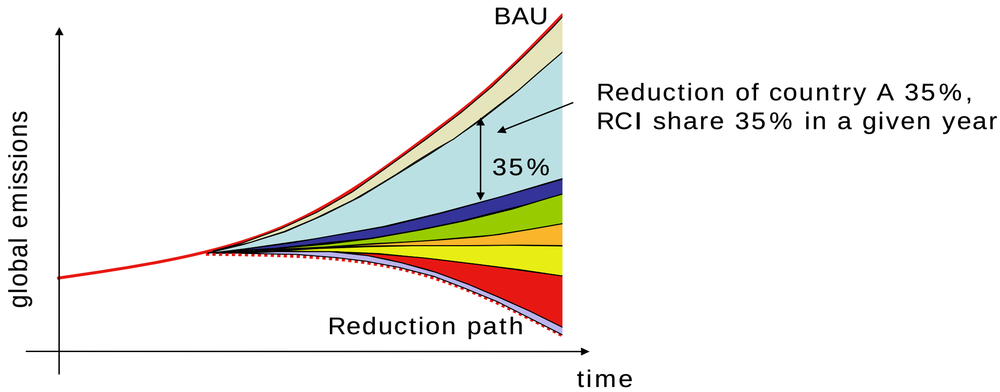

Fig. 43: Effort sharing under the Greenhouse Development Rights (GDR) approach according to the Responsibility Capacity Index (RCI)

7.4.4 Global Triptych

This approach was originally developed at the University of Utrecht (Blok et al. 1997) to share the emission allowances of the first commitment period within the European Union. It has been updated and revised subsequently (Phylipsen et al. 1998, Groenenberg 2002, den Elzen and Lucas 2003, Höhne et al. 2003, Phylipsen et al. 2004, Höhne et al. 2005, Höhne 2006).

Analogue to the first Triptych approach, the global Triptych approach is a method to allocate emission allowances among a group of countries based on several national indicators. It takes into account main differences in national circumstances between countries that are relevant to emissions and emission reduction potential. The Triptych approach as such does not define which countries should participate, but we have applied it here to all countries equally.

If the approach is applied globally, substantial reductions for the industrialised countries, especially those with carbon intensive industries (i.e. Eastern Europe and Russian Federation), are required. Substantial emission increases are allowed for most developing countries. But for lower concentration targets (e.g. 450 ppmv CO_2) these are rarely above BAU-emissions.

The Triptych methodology calculates emission allowances for the various sectors which are added to obtain a national target. Not individual sector targets but only the national targets are binding. This provides countries the flexibility to pursue any cost-effective emission reduction strategy.

The emissions of the sectors are treated differently: For 'electricity production' and 'industrial production', a growth in the physical production is assumed together with an improvement in production efficiency. This takes into account the need for economic development but constant improvement of efficiency. For the 'domestic' sectors, convergence of per capita emissions is assumed. This takes into account the converging living standard of the countries. For the remaining sectors, 'fossil fuel production', 'agriculture' and 'waste', similar reduction and convergence rules are applied.

Details on the applied methodology can be found in Phylipsen et al. 2004.

7.4.5 South North

The SN proposal (Ott et al. 2004) defines six groups of countries that should take differentiated types of commitments in a future climate regime (Figure below). Depending on the classification, the approach expects countries to achieve a certain emissions level.

	Annex II	Annex I, but not Annex II	NICs	RIDCs	Other DCs	LDCs
Potential to mitigate CO_2/GDP, 2000 GHG/capita, 2000 CO_2 emissions growth, 1991-2000	Medium Very high Narrow range	Very high High Wide range	High High Wide range	Medium Medium Wide range	Medium Low Wide range	Low Low Wide range
Responsibility to mitigate Cumulative CO_2/capita, 1990–2000	Very high	High	High	Low	Low	Very low
Capability to mitigate GDP/capita, 2000 HDI, 2000	Very high Very high	Medium High	Medium High	Medium Medium	Low Medium	Very low Low
Mitigation commitments Type of quantitative commitment	Binding (strict) absolute reduction targets, domestic reduction	Binding absolute reduction targets, domestic reduction	Absolute limitation or reduction targets, domestic mitigation*	Absolute limitation targets, if funding and technology provided from Annex I*	No targets	No targets
Qualitative action			SD-PAMs (obligatory), Sector CDM, Non-binding RE & EE targets	SD-PAMs (obligatory, co-funded), Sector CDM, Non-binding RE & EE targets	SD-PAMs (obligatory, co-funded), Sector CDM, Non-binding RE & EE targets	SD-PAMs (optional, funded), Sector CDM, Non-binding RE & EE targets
Financial transfers to support mitigation activities	High direct payments (out) to non-Annex I.	Low / no payments.	NIC co-funds mitigation, but some transfers from Annex II.	High direct payments from Annex II.	Direct payments from Annex II.	Direct payments from Annex II.

* *Targets only could become binding if all major Annex I countries have binding quantified emission reduction obligations.*

(Source: Ott et al. 2004)

Fig. 44: Regions and their responsibility according to the proposal 'South- North Dialogue – Equity in the Greenhouse'

7.4.6 The Evolutions of Commitment (EVOC) model

This section describes the Evolution of Commitments tool (EVOC) version 8, developed by Ecofys, which we use to quantify emission allowances under the various approaches in this report. It includes emissions of CO_2, CH_4, N_2O, hydroflourocarbons (HFCs), perflourocarbons (PFCs) and sulphur hexafluoride (SF_6) for 192 individual countries. Historical emissions are based on national emission inventories submitted to the UNFCCC and, where not available, other sources such as the International Energy Agency. Future emissions are based on the IPCC Special Report on Emissions Scenarios (Nakicenovic et al. 2000). The greenhouse gas emission data for 1990 to 2006 is derived by an algorithm that combines emission estimates from various sources.

We first collected historical emission estimates by country, by gas and by sector from the following sources and ordered them in the following hierarchy:

- National submissions to the UNFCCC as collected by the UNFCCC secretariat and published in the GHG emission database available at their web site. For Annex I countries, the latest available year is usually 2007. (UNFCCC 2009).
- CO_2 emissions from fuel combustion as published by the International Energy Agency. The latest available year is 2006 (IEA 2008a).
- Emissions from land-use change as published by Houghton in the WRI climate indicator analysis tool (Houghton 2003).
- Emissions from CH_4 and N_2O as estimated by the US Environmental Protection Agency. Latest available year is 2005 (USEPA 2006)
- CO_2, CH_4, N_2O, HFC, PFC and SF_6 emissions from the EDGAR database version 3.2 available for 1990 and 1995 (Olivier and Berdowski 2001).

Future emissions are derived from the MNP/RIVM IMAGE implementation of the SRES scenarios (IMAGE team 2001).

The datasets vary in their completeness and sectoral split. We first defined which of the sectors provided in the datasets correspond to seven sectors. This definition is provided in the Table below. Note that CO_2 emissions from the IEA do not include process emissions from cement production. Hence, if IEA data is chosen, process emissions from cement production are not included.

For each country, gas and sector, the algorithm completes the following steps:

- For all data sets, missing years in-between available years within a data set are linearly interpolated and the growth rate is calculated for each year step.
- The data source is selected, which is highest in hierarchy and for which emission data are available. All available data points are chosen as the basis for absolute emissions.
- Still missing years are filled by applying the growth rates from the highest data set in the hierarchy for which a growth rate is available.

As future emissions are only available on a regional basis and not country-by-country, the resulting set of emissions is then extended into the future by applying the growth rates of the respective sectors and gas of the region to which the country belongs. (See Table for detailed information on data sources and definition of sectors.)

For population, GDP in purchase power parities and electricity demand, the country base year data was taken from the United Nations (UN 2008), World Bank 2008 and IEA 2008a, respectively. These data are extended into the future by applying the growth rates from the IMAGE model for the region to which the country belongs.

Emissions until 2010 are estimated as follows: It is assumed that Annex I countries implement their Kyoto targets by 2010. Further, it is assumed that the reductions necessary to meet the Kyoto target are achieved equally in all sectors. In 2010, the level of the domestic sector is taken from the relevant reference scenario. The level of the other sectors are taken from the reference scenario and reduced, so that the Kyoto target is met. The years from the last available year to 2010 are linearly interpolated. All Non-Annex I countries follow their reference scenario until 2010.

As a default setting, all Annex I countries are assumed to reach the lower of their Kyoto target and their reference scenarios in 2010. Only the USA is assumed to follow its BAU emissions until 2010. All Non-Annex I countries also follow their reference scenario until 2010. After 2010, the emission allowances per country are calculated according to the effort sharing approaches.

A limitation of the tool is the unknown future development of emissions of individual countries. Here, we have used the standard set of future emissions scenarios, the IPCC SRES scenarios, as a basis. They provide a broad range of storylines and therefore a wide range of possible future emissions. We cover this full range of possible future emissions, economic and population development in a consistent manner. But the SRES scenarios are only available at the level of up to 17 regions (as in the IMAGE implementation) and scaling them down to individual countries introduces an additional element of uncertainty. We applied the growth rates provided for 17 world regions to the latest available data points of the individual countries within the respective regions. So, on the level of regions, we cover the full-range uncertainty about future emissions. When again aggregating the regions, the effect of downscaling cancels out. But the full level of uncertainty is not covered on the national level as substantial differences may exist for expected growth for countries within one of the 17 regions.

The future reference development of emissions, economic and population is affected by the starting values (which is data available from the countries or other international sources and which can be substantially different for countries in one region) and the assumed growth rates (which are derived from the 17 regions).

The assumed growth rates may affect the results of countries to a different extent. Some countries are less affected as they dominate their regional group, such as Brazil, Mexico, Egypt, South Africa, Nigeria, Saudi Arabia, China and India. It is for second or third largest countries in a region or for members of an inhomogeneous group, for which this method may lead to an over or underestimation of the future development.

The second or third largest countries in a region include, for instance, Argentina, Venezuela, United Arab Emirates and South Korea. Under the C&C approach, the error would be small as countries follow their reference scenario only until 2010 and converge afterwards. For CDC, Multistage and the GDR approach, the downscaling method may influence the time of participation. But the countries listed above would all participate at the earliest possible moment, based on their already today high per capita emissions. In the Triptych approach, growth in industrial and electricity production and a reduction below reference for agriculture is used, which may be affected by the downscaling method.

Members of an inhomogeneous group would be those of South East Asia, which includes Indonesia and the Philippines as lower-income countries and Malaysia, Singapore and Thailand as higher-income countries. Here the growth is averaged over the region, probably underestimated for Indonesia and the Philippines and overestimated for Singapore. The dominant element here is the starting point. The low per-capita emissions of the Philippines and Indonesia lead to their late participation, while the high per-capita emissions in Malaysia, Singapore and Thailand lead to their immediate participation. In the Triptych approach, growth in industrial and electricity production and a reduction below reference for agriculture is used, which may be affected by the downscaling method.

For Annex I countries, the future reference development is not as relevant since they always participate in the regime on the highest stage and have to reduce emissions independent of the reference development. Future values are only relevant for intensity targets (GDP) or for the Triptych approach (industrial and electricity production and agriculture).

A different uncertainty is introduced since our future emissions are static, meaning that emissions in non-participating developing countries do not change as a result of ambitious or relaxed emission reductions in developed countries. Stringent reductions could affect emissions of non-participating countries in two ways. There could be increased emissions through migration of energy-intensive industries or decreased emissions due to technology spill-over. Overall, we assume that this effect is small and not significantly influencing the results of this analysis.