CLIMATE ACTION TRACKER

How climate change mitigation makes economic sense

Assessing the cost-effective role of reducing air pollution in strengthening climate policies

Ryan Alexander, Louise Jeffery, Johannes Gütschow, Claire Fyson Potsdam Institute for Climate Impact Research

> Pieter van Breevoort, Karlien Wouters, Yvonne Deng Ecofys

Michiel Schaeffer, Bill Hare, Fabio Sferra, Florent Baarsch, Marcia Rocha Climate Analytics

Niklas Höhne, Markus Hagemann, Takeshi Kuramochi, Sebastian Sterl NewClimate Institute

December 2015

Summary

• There are strong immediate and domestic incentives to undertake greater mitigation efforts to limit global warming to 2°C, or to 1.5°C as many governments are calling for.

• Existing mitigation targets can be met and, in most cases, can be strengthened in a more cost-effective manner by properly accounting for the value of other economic and societal priorities that come from cutting emissions, such as public health and energy security.

• This report will focus on a single example of such "co-benefits" - reduced mortality risk from lower levels of harmful air pollution, which causes respiratory illnesses, cardiopulmonary disease and lung cancer.

• Within this limited scope, we present three methods for assessing the cost-effectiveness of six major emitters' Intended Nationally Determined Contributions (INDCs).

• Our result show that the emissions gap in 2030 between governments' INDCs and the 2°C temperature goal, currently around 17 $GtCO_2e$,¹ could be closed **by 4.6 – 7.8 GtCO_2e or 27-46%**, without imposing additional economic burdens on those undertaking the additional effort.

• For the 1.5°C temperature goal, the larger emissions gap in 2030 of around 23 GtCO₂e could be closed by **20-34%**.

The results of each method of the three methods we apply are shown below:

	Measure-by- measure	Marginal abatement cost curve	Macro-economic modelling
Additional cost-effective mitigation potential	4.6 GtCO₂e	6.1 GtCO ₂ e	7.8 GtCO₂e
Proportion of 2030 emissions gap to reach 2°C goal	27%	36%	46%
Proportion of 2030 emissions gap to reach 1.5°C goal	20%	27%	34%

¹ Climate Action Tracker, INDCs lower projected warming to 2.7°C: significant progress but still above 2oC, <u>http://climateactiontracker.org/assets/publications/</u>

CAT_global_temperature_update_October_2015.pdf, October 2015, accessed 22/11/15.

- Governments can offset the cost of stronger climate policies by taking into account the savings associated with reduced mortality from harmful anthropological air pollutants such as particulate matter and ozone.
- Reduced air pollution lowers the risk of mortality from air pollution-related illnesses, such as respiratory and cardiovascular diseases, that would otherwise impose significant economic impacts on national health care systems and economies.
- To monetise the reduced mortality risk, we use a globally uniform conservative value of \$2.8 million for the Value of Statistical Life the Value of Statistical Life is equal in every country we assess² which includes an upwards adjustment of 56% in all countries to correct for developed country regions' greater willingness to pay for reductions in mortality risk. We only consider the costs associated with mortality, not those associated with air pollution-related disease or disability.
- Without incurring a net economic burden, most major emitters could strengthen their INDC targets:

Country	Additional cost- effective mitigation	Proportion of emissions gap in 2030		Current INDC target	INDC target including cost-effective
	potential ³	2°C	1.5°C		mitigation potential
			8 - 28%	20% non-fossil share	40 – 65% non-fossil share
China ⁴ 1.8 – 6.5 GtCO ₂ e	38%	60 – 65% below 2005 emissions intensity		65 – 85% below 2005 emissions intensity	
EU	up to 0.3 GtCO ₂ e	up to 2%	up to 1%	40% below 1990 emissions	Up to 45% below 1990 emissions
India	up to 1.2 GtCO ₂ e	up to 7%	up to 5%	33 – 35% below 2005 emissions intensity	Up to 47 – 49% below 2005 emissions intensity
Japan	0.1 – 0.4 GtCO ₂ e	1 – 2%	up to 2%	26% below 2013 emissions	30 – 55% below 2013 emissions
Russia	0.8 – 1.2 GtCO ₂ e	5 – 7%	3 – 5%	25 – 30% below 1990 emissions	50 – 65% below 1990 emissions
USA	None based on air pollution co-benefits alone				

- The only exception is the USA, where the value of co-benefits from reduced air pollution already offsets its mitigation costs, according to each of the analysis approaches employed.
- Nevertheless, for all emitters, there are additional co-benefits that could pay for the cost of even stronger mitigation efforts. These may include job creation, improved energy security, reduced impacts of air pollution on ecosystems, and

² In this assessment, we use a globally uniform Value of Statistical Life, ruling out regionally weighted VSL. VSL is set uniformly based on the principle that all human lives are of equal value (Bayles, The Price of Life, 1978, http://www.jstor.org/stable/2380129).

http://www.jstor.org/stable/2380129). ³ These findings reflect the high and low results of the three methods used for each country. Within each country, where there is a high and a low estimate of the cost-effective mitigation potential, we take the low end of the range.

⁴ China has set out two unconditional types of pledges in its INDC: a non-fossil share target and an emissions intensity target. We have expressed the potential here as a proportion of both targets. How the targets jointly reflect the additional mitigation potential would need to take into account the nature and size of the available mitigation measures. Not all mitigation potential (e.g. energy efficiency, industrial process emissions) can necessarily be delivered through an increase in the non-fossil energy target.

increases in rural electrification. However we don't quantify these additional cobenefits in this briefing.

- We also exclude the actual costs human, economic, environmental, and social of climate change, such as those due to sea level rise, extreme weather events, reduced crop yields, and the need for adaptation. If they were taken into consideration, the cost-effectiveness of mitigation in many regions would likely become even more attractive.
- This briefing looks at co-benefits at an economy-wide level, without undertaking new or detailed modelling of the impacts of specific domestic climate policies. The cost of specific climate policies (and by how much their costs could be offset by co-benefits) will vary, depending on their location, strength, and scope.
- Co-benefits can have very significant non-monetary value in encouraging support at a domestic level, with empirical studies showing that people "are more likely to support climate action if they know about the many extra benefits of doing so".⁵
- Since there is uncertainty about countries' projected levels of emissions in 2030, we test the sensitivity of our findings to higher or lower projections to demonstrate the robustness of our conclusions.

⁵ Bain et al., Co-benefits of Addressing Climate Change can Motivate Action Around the World, 2015, <u>http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2814.html</u>.

Table of contents

Summary1
Acknowledgements
Table of contents
1 Introduction
2 Methodology7
2.1 How do we determine the available mitigation potential?7
2.2 What approaches do we take to assess mitigation costs?
2.3 How do we assess co-benefits?11
2.4 Comparison with national pledges and the 2°C goal13
3. Results
3.1 China14
3.2 European Union
3.3 India
3.4 Japan
3.5 Russia
3.6 USA
Appendix A: Assessment of measure-by-measure costs
Appendix B: Consideration of key assumptions in the analysis
References

Acknowledgements

Gunnar Luderer and Christoph Bertram (Potsdam Institute for Climate Impact Research) for providing REMIND scenarios as well as much assistance, Michael Westphal (World Resources Institute) for providing AIM Enduse scenarios, Markus Amann (International Institute for Applied Systems Analysis) and Fabian Wagner (Princeton University) for providing GAINS mitigation efforts calculator data and Jason West (University of North Carolina), Steven Smith (Pacific Northwest National Laboratory) and Raquel Silva (University of North Carolina) for providing co-benefits data and assistance in interpreting some of the results.

1 Introduction

This analysis aims to identify the cost-effective level of greenhouse gas (GHG) mitigation potential available in 2030 in six major emitting countries: China, the European Union, India, Japan, the United States of America⁶ and the Russian Federation. Together, these five countries and the EU accounted for around 60% of global emissions in 2010. The cost of mitigation increases with increasing stringency, and the co-benefits of mitigation vary in value (as described in Section 2.3). By offsetting the costs of mitigation against the co-benefits, the mitigation potential in each country can be separated into three categories, reflecting its net cost to the country or region undertaking the mitigation: "net economic benefits," "co-benefits balance costs" and "net economic costs". These categories are shown in Figure 1.



Figure 1: Separating mitigation potential into cost categories

"Net economic benefits" mitigation measures are those for which the costs of the measures are lower than their associated economic benefits - the most common example of which is energy efficiency improvements, which can reduce fuel or utility costs even in the absence of climate change policies such as a carbon price or renewable energy subsidies. However, despite being financially attractive, this potential may not be realised due to barriers such as high upfront investments, transaction costs or lack of technical and institutional capacity.

A level of emissions that falls within the "co-benefit balances costs" category implies that the costs of climate policy may be fully offset by their accompanying benefit of reducing air pollution.

The "net economic costs" captures those measures whose costs exceed the monetary benefits of reducing air pollution and therefore result in net economic impact.

Measuring the economic impact of climate change mitigation in a holistic way, taking into account all of the direct and indirect costs of climate change and all of the direct and indirect benefits of avoiding it, is a challenging task. The fact that a full accounting of the costs of climate change is not always performed was acknowledged by the IPCC in its AR5 report:

"The total economic effect at different temperature levels would include mitigation costs, co-benefits of mitigation, adverse side-effects of mitigation, adaptation costs and climate damages."

⁶ Throughout this briefing, emissions and mitigation potential are projected to 2025 in the case of the USA, not 2030, to enable a comparison with their INDC, which sets out a pledge for 2025, not 2030.

How these costs fit into a holistic cost-benefit analysis is shown in Figure 2.



Figure 2: Illustration of mitigation benefits and costs.

While substantial efforts have been made to assess the cost of climate policies, less emphasis has been placed on quantifying their associated benefits. In spite of decades worth of research on co-benefits, and substantial literature on the value and existing scope of co-benefits,⁷ conventional approaches to assessing mitigation costs are restricted to assessing the costs of mitigation, compared to the costs of business-as-usual development. Because climate policies typically impose additional direct costs on economies, mitigation costs almost always turn out to cost more than 'doing nothing.'

Analysis by the Climate Action Tracker has shown that most governments' climate change pledges, made in advance of the Paris climate change conference in November/December 2015, are inadequate. Based on the best available science, they would fail to shift the world onto a pathway that would limit global warming to 2° C, let alone 1.5° C – the existential limit for many small island states.⁸ This briefing provides an illustrative accounting of the value of a single co-benefit – reduced air pollution – and demonstrates that the costs of mitigation are overstated, and that many major emitters could increase the strength of their pledges without imposing additional burdens on their national economies.

Economy-wide estimates of the extent to which co-benefits can offset mitigation costs are subject to uncertainty, because the precise value of co-benefits will vary according to the specific geographic, economic, financial, and technical characteristics of the mitigation measure being implemented. However, they illustrate a powerful point about the need for a holistic approach to assessing the cost of minimising climate change.

The economic impacts of dealing with 3 or more degrees Celsius of global warming, which is the likely estimate based on the latest available projections, are beyond the scope of this briefing.⁹ Climate change will require significant investment in adaptation measures to deal with its effects, ranging from development of new drought-resistant crops, to reinforced buildings to deal with extreme weather events, to stronger flood defence structures. These costs are not taken into account in this analysis.

⁸ Climate Action Tracker, INDCs lower projected warming to 2.7°C: significant progress but still above 2°C, October 2015, <u>http://climateactiontracker.org/publications/briefing/223/INDCs-lower-projected-warming-to-2.7C-significant-progress-but-still-above-2C-.html</u>, accessed 30/10/15.

⁷ IPCC AR5, Chapter 6, 2014.

The impacts of climate change – even if global warming is held to below 2°C – are likely to result in irreversible and permanent economic damages, such as reduced agricultural yields and property loss due to sea level rise. These damages are not taken into account in this analysis either; if they were properly accounted for, the cost-effectiveness of mitigation (depending on the region) would likely become even more attractive.

2 Methodology

Our methodology for assessing how major emitters could strengthen their mitigation commitments is described in the following sections.

2.1 How do we determine the available mitigation potential?

Projecting emissions to 2030 based on current policies

The first step in determining the available mitigation potential for each major emitter is to project emissions from 2012 (the most recently available actual emissions data in most cases) to 2030. These baseline projections consist of three elements: energy-related CO_2 emissions, industry-related CO_2 emissions, and non- CO_2 GHG emissions.

Projecting how countries' emissions change over time to 2030, which is necessary in any assessment of future mitigation costs, is in itself subject to significant uncertainty because it depends on assumptions about how countries' regulatory, economic and energy environments will change over time. We take existing projections, using the most recently available data, to project emissions to 2030, assuming countries undertake no further action beyond currently implemented policies.

The methodology we employ is well-established, and forms the basis for many of the Climate Action Tracker country assessments available at <u>www.climateactiontracker.org</u>. Our projections draw predominantly on projections contained in the International Energy Agency World Energy Outlook 2014¹⁰ and are supplemented by historical data from the EDGAR database and projected growth rates for non-CO₂ emissions from the US Environmental Protection Agency and for non-energy (i.e. industrial and process) CO₂ emissions from the IEA Energy Technologies Perspectives (ETP) 2010 report¹¹.

Determining how much mitigation can be delivered for a given cost

The cost of mitigation in a given country or region depends on a wide range of diverse factors. Significant factors include the type of mitigation activity undertaken, the sector in which it is implemented, and the existing carbon and energy-intensity of the national economy. It is challenging to capture all of these considerations in a single analytical approach.

We set out three methods for assessing mitigation costs, each of which has advantages and disadvantages. The methods are: measure-by-measure, analysis of marginal abatement cost curves (MACCs) and macroeconomic modelling. By undertaking three distinct methods we generate more confidence in our results by understanding how different methodological approaches and assumptions impact the results.

Determining the mitigation effort to limit global warming to 2°C

The available mitigation potential varies depending on the type of approach and the level of carbon price assessed. The higher the carbon price, the more mitigation potential is unlocked. To enable a consistent analysis of mitigation potential between approaches, we assume the upper limit of mitigation potential for each major emitter is the corresponding emissions range in 2°C compatible scenarios from the LIMITS model inter-comparison

¹⁰ At the time of finalising the analysis supporting this briefing, the IEA WEO 2015 had not yet been released.

¹¹ The 2010 edition of the ETP is the latest version in which process CO₂ emissions are projected on a regional/country level.

study.¹² The uncertainty range largely reflects differences between the models that took part in the study.

We extend or limit the mitigation potential in each approach relative to the range from the LIMITS study. This involves extending the out of pocket cost mitigation potential range, for each approach, to the global cost-optimal range modelled in the LIMITS study. This mitigation potential is different to what would be considered 'fair' according to principles of equity and climate justice, but rather focuses on technically-feasible and globally cost-effective emissions reductions.

2.2 What approaches do we take to assess mitigation costs?

2.2.1 Measure-by-measure approach

The measure-by-measure approach involves assessing distinct mitigation activities – such as improving the energy efficiency of buildings, or investing in renewable energy – and allocating the mitigation potential between the three cost categories: '*net economic benefits*', '*co-benefit balances costs*', and '*net economic costs*'. Our assessment of the costs and benefits of each mitigation activity are supported by references to published literature, where possible.

Methodology

For CO₂ emissions from fossil fuel combustion, we assess the available mitigation potential on a sector-by-sector basis in 2030 by looking at the difference between the International Energy Agency World Energy Outlook (WEO) Current Policy Scenario and the WEO 450 ppm scenario. For other emissions we estimate the potential using other literature, as described in Appendix A. We aggregate the potentials to determine the mitigation potential that needs to be realised in each country to hold global warming below 2°C above pre-industrial levels.

To arrive at an assessment of mitigation costs, we separate the mitigation task into sectors and activities, based on the underlying energy data in the WEO data set. We distribute the available potential between the '*net economic benefits*', '*co-benefit balances costs*', and '*net economic costs*' cost categories based on the evaluation of the project team. The 19 activities we assess, and the basis on which the costs of each activity are estimated, are described in Appendix A.

Advantages

One of the biggest advantages of the measure-by-measure approach is that the mitigation potential in 2030 is based on the latest available projections of country emissions and mitigation potential. This incorporates many recent policy developments and provides a robust foundation for assessing mitigation costs. The WEO produces projections on a country-by-country basis and hence avoids the need for downscaling regional results to a country level, which introduces uncertainty into the analysis. The WEO also incorporates explicit modelling of country climate policies at a sectoral level, which enables a closer assessment of the mitigation potential of specific sectors of an economy.

Disadvantages

However, a downside of this approach is the lack of empirical foundation for assessing mitigation costs. This could limit its effectiveness in informing the policy-making process, because it does not rely on quantitative estimates of the cost of individual mitigation activities. Further, the analysis is conducted on a global basis – differences between

¹² Kriegler et al., What does the 2°C target imply for a global climate agreement in 2020? The LIMITS study on Durban Platform scenarios, 2014, <u>http://www.feem-project.net/limits/03_outreach_01_02.html</u>, accessed 10/11/15.

countries (e.g. energy prices) in the valuation of mitigation costs and benefits cannot be explicitly addressed. As the other approaches show, these regional variances can be significant.

2.2.2 Analysis of marginal abatement cost curves (MACs)

Mitigation costs can also be assessed on country- and activity-specific basis using a MAC. In a MAC, the mitigation potential of each activity is assessed based on assumptions about future capital costs, which are in turn influenced by technology costs, operating costs (predominantly fuel prices), technology learning rates and the cost of capital. This approach is popular because of its easy-to-visualise representation of the cost of different mitigation measures, from least expensive, to most expensive.

Methodology

Since undertaking an activity and sector-specific analysis for each major emitter is a significant undertaking, we performed a literature review to identify the most recent MAC analysis for each major emitter. Each MAC sets out the quantity of mitigation potential available at given marginal abatement cost levels.

Advantages

One of the biggest advantages of this approach is that mitigation potentials and costs are country-specific and the cost of mitigation measures reflects the cost environment in which they are undertaken. It also permits close inspection of the available mitigation potential in specific sectors and activities. A notable characteristic of MACs (and the measure-bymeasure approach) is the explicit representation of 'net economic benefit' (i.e. money saving) mitigation activities, even in the absence of climate policies such as a carbon price, usually due to targeted energy efficiency measures which lower fuel consumption and in turn fuel costs.

It should be noted that mitigation potential with a net economic benefit may be smaller than expected because of a 'rebound effect', where energy savings from implementing energy efficiency measures fall short of expected savings because of behavioural changes or other factors (e.g. buying a fuel-efficient car but driving further).¹³ For this reason, the 'net economic benefit' mitigation potential we assess in these approaches might be more appropriately characterised as an upper bound to the possible potential in this category.

Disadvantages

On the other hand, analysis of existing MACs has several limitations. Since the analyses we obtained were at least two - and sometimes up to five - years old, the baseline projections that they used are no longer necessarily as realistic as they were when they were generated. This is particularly relevant for countries in which significant mitigation has already occurred, or in which the projected growth in emissions is significantly different from what was expected previously.

This approach also fails to consider interdependencies between mitigation measures: for example, increased deployment of renewables decreases the emissions intensity of the power grid and hence reduces the cost-effectiveness of other mitigation activities. MACs also fail to incorporate macro-economic feedbacks such as the impact of climate policies on investment, trade and other macro-economic indicators.

The marginal value of mitigation activities, particularly those that displace fossil fuels, is particularly sensitive to assumptions about future fossil fuel prices. Different MACs also

¹³ International Energy Agency, Box 1.1, Capturing the Multiple Benefits of Energy Efficiency, <u>http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf</u>, 2014.

apply different discount rates to investments to reflect public versus private funding of mitigation activities, which can have a material impact on the cost of mitigation in each country.

2.2.3 Macroeconomic modelling approach

Macroeconomic modelling of climate policies relies on computationally-intensive tools to project the evolution of an economy over a period of time with respect to key macroeconomic indicators such as investment, consumption and trade. This is typically undertaken with the use of an Integrated Assessment Model. Because comprehensive macroeconomic modelling of countries' INDCs is beyond the scope of this briefing, we use existing scenarios from the inter-temporal general equilibrium REMIND model at the Potsdam Institute for Climate Impact Research, which are described in Luderer et al. (2013).¹⁴

Methodology

The six countries we assess correspond with discrete REMIND regions, which avoids downscaling effects. For each country we assess six different technology choices (e.g. nuclear phase out) to display the difference in costs associated with the type of decarbonisation pathway chosen. We assume that climate policies to achieve the 2030 targets are implemented immediately upon the conclusion of a global climate deal in Paris in December 2015. Each scenario from the model represents how the global economy responds to the introduction of an implicit carbon price. To estimate the marginal abatement cost in each region, we plot marginal cost against mitigation and derive a relationship between the two using an exponential function.

Advantages

The use of macroeconomic modelling scenarios has benefits, which are not found in the other approaches employed. Since the same model generates all the scenarios, the results are comparable between countries – we are comparing "apples with apples". This means that differences in the cost of mitigation between countries can be clearly attributed to their inherent economic characteristics, rather than differences in methodologies or assumptions. The seven different technology 'assumptions' used to generate the scenarios also enable an explicit representation of the uncertainty in mitigation costs due to different technology development pathways, which is not available in the other two approaches. These scenarios also provide information about mitigation costs in five-yearly intervals, so mitigation costs in 2025 for the USA are available (unlike with the MAC approach).

Disadvantages

However, as with any projection of future levels of emissions, these scenarios do not reflect changes in policies, technology costs and other factors that have occurred since they were developed. For this reason, the scenarios – which were produced in 2013, were last calibrated to historical emissions in 2005, and which only reflect climate policies put forward during the Copenhagen climate conference in 2009 – do not reflect the most recent projections of emissions. This could introduce some uncertainty into the analysis. We address this uncertainty by measuring mitigation as a relative reduction from the baseline projection, rather than an absolute reduction; this process is described in more detail in Appendix B.

A disadvantage of the economic modelling approach is its failure to explicitly represent noregret mitigation activities, in contrast to the measure-by-measure and MAC approaches. While the REMIND model incorporates endogenous improvements in energy efficiency (e.g.

¹⁴ Luderer et al., Economic mitigation challenges: how further delay closes the door for achieving climate targets, Environmental Research Letters, 2013.

due to rising fossil fuel prices), it fails to consider energy efficiency measures that don't require an implicit carbon price, but can be delivered through other kinds of policy instruments, for example the EU Energy Efficiency Directive, the (now abolished) Australian Energy Efficiency Opportunities program, or the China 5 vehicle emissions standard.

2.3 How do we assess co-benefits?

Co-benefits are defined by the IPCC AR5 as the positive side-effects of a government policy intended to achieve a mitigation objective.¹⁵ There are challenges in quantifying, not to mention monetizing, co-benefits, as they can depend heavily on local circumstances as well as on implementation practice, pace and scale.¹⁶ Nevertheless, they are an important element of assessing the true cost of climate action.

Using co-benefits to offset mitigation costs

Numerous co-benefits of mitigation have been identified in all sectors where mitigation is needed to limit global warming. Examples include (but are not limited to):¹⁷

- **Energy:** Reduction in air pollution, improved access to electricity, local employment impact, energy security;
- **Buildings:** Higher asset values, increased productivity, employment impact;
- **Industry:** Competitiveness and productivity, new business opportunities, safety, working conditions and job satisfaction;
- Agriculture and land use: Diversification of income and access to market, food crops production and ecosystem resilience.

Co-benefits can be difficult to quantify. They are omitted from many policy and program evaluations because there is a lack of data, uncertainty in measurement and evaluation, institutional barriers and/or perceived credibility risk.^{18 19} However, while they are subject to high uncertainty, it is arguably more inaccurate to omit them entirely from a cost-benefit assessment. Failure to quantify the value of co-benefits of mitigation measures is likely to overstate the cost of action to minimise climate change.

Reduced air pollution as a co-benefit of mitigation

The benefits of reducing air pollution in terms of their impact on human health "are nontrivial and have been observed across varied geographies, time periods and sectors".²⁰ Reducing air pollution lowers the risk of premature deaths from heart and respiratory diseases, blood vessel conditions and strokes and lung cancer.²¹

In the measure-by-measure approach, sector-specific estimates of the value of reducing air pollution are not readily available. Unless otherwise stated in Appendix A, we use the global value of \$49 USD2010/tCO $_2e^{22}$ to determine how much mitigation potential is available at break-even cost and how much is considered to be out-of-pocket. This value is based on the mean value of estimates for the air quality benefits of climate change mitigation from Nemet, Holloway & Meier (2010) as referenced in the IPCC AR5 (Chapter 5, page 392).

¹⁵ IPCC AR5, Box TS.11.

¹⁶ Tables TS.4 to TS.8, IPCC AR5, 2014.

¹⁷ Tables TS.4 to TS.8, IPCC AR5, 2014.

¹⁸ IEA, Capturing the Multiple Benefits of Energy Efficiency, 2014,

http://www.iea.org/topics/energyefficiency/energyefficiencyiea/multiplebenefitsofenergyefficiency/. Nemet et al., Implications of incorporating air-quality co-benefits into climate change policymaking, 2010, http://iopscience.iop.org/article/10.1088/1748-9326/5/1/014007/pdf.

²⁰ Nemet et al., Implications of incorporating air-quality co-benefits into climate change policymaking, 2010,

http://iopscience.iop.org/article/10.1088/1748-9326/5/1/014007/pdf. ²¹ World Health Organisation, Air pollution costs European economies US\$ 1.6 trillion a year in diseases and deaths, new WHO study says, <u>http://bit.ly/1g5XeGe</u>, April 2015. ²² This value was converted to different currencies and years when interpreting information from various MAC-

curves.

In the MAC and macroeconomic modelling approaches, we base our assessment of the value of reducing air pollution on peer-reviewed literature. West et al. (2013)²³ present the benefits of avoided air pollution on a regional basis, with a mean global value of around US $\frac{90}{tCO_2}$ in 2030. Air pollution in this study refers to anthropogenic PM2.5 (particulate matter emissions) and ozone, and the benefits relate to human health, and not reduced impacts on agriculture or ecosystems.

The values from West et al. are generated using a global chemical transport model MOZART-4 and emissions pathways from the Global Change Assessment Model (GCAM). They therefore reflect several interdependent effects, including long-range transport of air pollutants, demographic change, and the influence of climate change on air quality. The geographic resolution of the study illustrates the variation in the air pollution co-benefit between countries, which can be significant. For example, the marginal benefit of reduced air pollution in China is estimated to be around ten times the value of reducing air pollution in Latin American countries. These regional variations are illustrated in Figure 3.



Figure 3: Value of avoided air pollution by region, 2030, using a globally uniform VSL, from West et al. (2013). This briefing adopts the conservative estimate of VSL indicated by the blue lines.

The marginal benefits assessed by West et al. are based upon a value of a statistical life of \$1.8 million, which is taken from the lower end of the range of \$1.8 to \$5.4 million estimated by the OECD for valuing mortality risk in environment, health and transport policies.²⁴ The value employed is therefore a conservative estimate.

For this briefing we work under the ethics principle that all human lives are of equal value and we therefore define VSL at the same level across countries and regions. This means that the statistical value of life is the same in each region. However, a globally uniform VSL significantly under-estimates regionally-weighted VSLs in developed country regions.

To correct for this understatement we calculate the mean of the underestimate ratio between regionally-weighted and uniform VSLs, for developed country regions, weighted by population. Consistent with the aforementioned ethics principle and based on this average ratio, we scale-up the uniform VSL in all country regions (developed and

²³ West et al., Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health, Nature Climate Change, 2013, http://www.gfdl.noaa.gov/cms-filesystemaction/user_files/van/publications/west_etal_nclimate.pdf.

OECD, Mortality Risk Valuation in Environment, Health and Transport Policies, 2012,

http://www.oecd.org/env/tools-evaluation/mortalityriskvaluationinenvironmenthealthandtransportpolicies.htm.

developing) by this factor to address underestimates in developed country regions. This increases the VSL for all countries/regions by 56%, from US\$1.8 million to around US\$2.8 million. Despite this correction, the VSL for the US still remains largely below the VSL commonly used in cost-benefits analysis in the US, which is about US\$7 million.²⁵

We use this VSL of around \$2.8 million in the MAC and macro-economic modelling approaches to estimate the quantity of mitigation potential that can be realised by offsetting the costs of mitigation against the benefits of reduced air pollution. This contrasts with the measure by measure approach, which does not require a region specific estimate of the marginal benefits.

2.4 Comparison with national pledges and the 2°C goal

To compare the available cost-effective mitigation potential with the policies and pledges put forward by major emitters, we take existing analysis from the Climate Action Tracker (CAT). We plot each country's INDC mitigation pledge ('Paris pledge') against their projected emissions level in 2030 (as described in Section 2.1). The methodology for arriving at each of these projections is described on the CAT website, as are each of the country assessments.²⁶

For those countries' INDCs that contain a binding and non-binding component, we base our analysis on the most stringent component. This affects China, because China's pledge to increase renewable and nuclear power generation capacity leads to greater emissions reductions than its pledge to limit the carbon intensity of its economy. For countries that have both unconditional and conditional pledges, we use the unconditional pledge to assess mitigation potential. This means India's target of a 40% share of non-fossil fuels is excluded, since it is conditional on international finance (although we consider it briefly in Section 3.3).

We also show the emissions level in 2030 for each country that represents the level of climate action consistent with limiting global warming to 2°C. This takes into consideration various indicators of equity, such as historic responsibility and current capability. Such a level of emissions corresponds to the beginning of the 'sufficient' category in each of the CAT country assessments (see the CAT website for further details). By adopting a Paris pledge that achieves this level of emissions, the country is doing the minimum of what could be considered to be its fair contribution to global efforts to hold warming below 2°C with a 'likely' probability²⁷.

 ²⁵ Viscusi, The Value of Life, 2006, http://www.law.harvard.edu/programs/olin_center/papers/pdf/Viscusi_517.pdf.
²⁶ Climate Action Tracker, Methodology, 2014, <u>http://climateactiontracker.org/methodology.html</u>, accessed
15/11/15.
²⁷ Climate Action Content of the second sec

²⁷ Greater than or equal to 66% (see the CAT website)

3. Results

3.1 China

Basis for measure-by-measure approach

The cost of mitigation in different sectors of the Chinese economy using the measure-bymeasure approach is shown in Figure 4.



Figure 4: Projected China mitigation potential and costs by sector in 2030^{28}

Most mitigation potential in China in 2030 is in the industry sector – almost as much as the energy sector and the buildings sector combined. Much of this mitigation potential can be delivered through money-saving measures, which is supported by estimates in the literature on the size of the potential for energy efficiency in China. A recent publication estimated the potential for energy efficiency in China's industrial sector to be 3100 Mt CO_2e in 2030 - over double the value arrived at here.²⁹

Basis for marginal abatement cost and macroeconomic modelling approaches

The cost of mitigation in China was assessed by Westphal et al. (2013) for the Asian Development Bank³⁰ and is shown in Figure 5, as well as the mitigation cost profile developed by the REMIND macro-economic model.

Figure 5, left panel, shows a relatively low quantity of mitigation potential with net economic benefits, but significant potential at low cost in wind power and more efficient industrial plant and machinery.

²⁸ Note that while the absolute values from the analysis are presented here, as described earlier in the briefing all mitigation is expressed in our analysis as relative reductions from a baseline. Therefore the absolute values in this Figure will be larger than those presented Figure 6.

Zhou et al., Quantifying the potential impact of energy efficiency and low carbon policies for China, 2013, p 20, https://china.lbl.gov/sites/all/files/quant_ee_lc_eceee.pdf, accessed 11/11/15. ³⁰ Westphal M., Asian Development Bank, Economics of Climate Change in East Asia, 2013.



Figure 5: Left panel, ADB marginal abatement cost curve, China in 2030; right panel, projected mitigation cost profile generated by macro-economic modelling, China, 2030. Different colours in the right panel in this and subsequent figures represent different decarbonisation pathways.

For several years, China has experienced increasingly severe air pollution as a result of the expansion of fossil fuel industries and private car ownership. Recent studies have found particulate matter emissions to cause, on average, 1.6 million deaths per year.³¹ This is reflected in the high economic value of reducing air pollution in China, which was found by West et al. (2013) (adjusted per Section 2.3) to be \$237-505 ($\leq 214-454$)/tCO₂e in 2030. China exhibits the highest value of the co-benefit in 2030 of all countries assessed in this briefing.

Results

The results of the analysis of Chinese mitigation costs are shown in Figure 6.

All three approaches demonstrate that China's INDC fails to capture the full economic value of undertaking stronger climate action. While it represents a deviation from its current policy trajectory, and captures some mitigation activities with net economic benefits, the full potential of the mitigation co-benefit from avoided air pollution has not been realised.

China could increase its mitigation effort by $1.8 - 6.5 \text{ GtCO}_2 \text{e}$ in 2030, at no additional economy-wide cost (according to the measure-by-measure and macro-economic modelling approaches respectively). This is equivalent to raising the non-fossil fuel component of its INDC target from a 20% reduction by 2030 to around 40 - 65% reduction, or the emissions intensity target from a 60 - 65% reduction from 2005 levels to around 65 - 85%. As shown in Table 2, these results are not affected by uncertainty in the projected level of emissions in 2030.

³¹ Rohde et al. (2015), Air Pollution in China: Mapping of Concentrations and Sources, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0135749



Projected China mitigation potential and costs in 2030

Figure 6: Projected mitigation potential and costs in China in 2030

Table 1: Sensitivity of category, within which the Chinese INDC falls, to selected parameters (bold indicates results shown in the graph above)

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro- economic modelling
+5%	No change	No change	No change
0%	As per figure	As per figure	As per figure
-5%	No change	No change	No change

3.2 European Union Basis for measure-by-measure approach

As shown in Figure 7, the large mitigation potential available in the energy sector increases the overall cost profile of mitigation in the EU, because a large proportion of mitigation potential in the energy sector cannot be offset by the co-benefit of avoided air pollution (green bar). While significant mitigation potential appears to remain in the buildings and industry sectors, the EU's implementation of effective energy efficiency policies is likely to have reduced the no regret potential available in this sector in the EU, compared with other countries/regions.



Figure 7: Projected EU mitigation potential and costs by sector in 2030

Basis for marginal abatement cost and macroeconomic modelling approaches

The Ecofys assessment of the cost of mitigation in Europe in 2009 is shown in Figure 8, along with the mitigation costs implied by the REMIND macroeconomic model.³²



*Figure 8: Left pane, marginal abatement cost curve of EU mitigation potential in 2030; right pane, macroeconomic modelling of EU mitigation potential in 2030.*³³

The quantity of available mitigation potential with net economic benefits suggested by the MAC analysis is likely to be overstated, predominantly because the underlying methodology assumed no 'learning by doing' technology cost or energy efficiency improvements over time. Such improvements could be important because the cost many mitigation measures is sensitive to the technology cost, as well as the choice of discount rate (in this case 4%) and projected fuel prices.

In the EU, emissions have declined over the past ten years, and faster than some projections have predicted. This is likely to be due to the impact of the European economic downturn from around 2009 onwards, as well as the effect of targets for 2020 in GHG emissions, renewable energy and energy efficiency. In addition, the EU Emissions Trading System was launched in 2005, and is now in its third phase.

 ³² Ecofys, Sectoral Emission Reduction Potentials and Economic Costs for Climate Change, 2009, available at http://www.ecofys.com/files/files/serpec_executive_summary.pdf, accessed 15/10/15.
³³ Note: the implied marginal abatement cost shown here is a poor fit for reductions below around 15%, but as the

³³ Note: the implied marginal abatement cost shown here is a poor fit for reductions below around 15%, but as the EU's mitigation commitment is equivalent to a reduction greater than 15% this has no impact on the analysis.

These measures combined are likely to have had an impact on both the quantity and cost of the remaining mitigation potential in the region. Without additional analysis, how the mitigation cost profile has evolved over time in Europe is unclear, but recent reductions in emissions imply that the cost of mitigation estimated by both of these methods is likely to be somewhat overstated and, in turn, the quantity of mitigation that can be offset by the co-benefit is also likely to be an overestimate.

The mitigation benefits of avoided air pollution in the European Union alone are estimated by West et al. (2013) (adjusted per Section 2.3) to be US\$78-166 (\notin 70-149)/t CO₂e in 2030.

Results

The results of each approach are shown in Figure 9.



Projected EU mitigation potential and costs in 2030

Figure 9: Projected EU mitigation potential and costs in 2030

Figure 9 shows a mixed picture of mitigation costs in the European Union. It highlights the challenges of relying solely on the marginal abatement cost approach, which is likely to substantially overstate the quantity of mitigation potential available at a net economic benefit. Additionally, since the marginal abatement cost curve analysis and the macroeconomic modelling analysis may overstate the costs (and hence the co-benefit) of achieving a given level of mitigation, it is difficult to draw a robust conclusion from these two methods.

Taking the measure-by-measure approach as the most conservative estimate of the three approaches, it is plausible that the EU's target could be increased from its current 40% reduction below 1990 levels by 2030 by up to 300 Mt CO_2e to around a 45% reduction below 1990 levels without incurring additional net economic costs. The results also indicate that, to contribute its minimum fair share of mitigation, the EU needs to both strengthen its domestic reduction target (the green sections) and fund cost-effective mitigation activities in other regions (grey sections), such as through market mechanisms.

As shown in Table 3, these results are unaffected by the uncertainty in the baseline projection of emissions in 2030.

Table 2: Sensitivity of category, within which the EU INDC falls, to selected parameters (bold indicates results shown in the graph above)

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro- economic modelling
+5%	No change	No change	No change
0%	As per figure	As per figure	As per figure
-5%	No change	No change	No change

3.3 India

Basis for measure-by-measure approach

The mitigation cost profile for India, estimated using the measure-by-measure approach, is shown in Figure 10.



Figure 10: Projected mitigation cost profile using measure-by-measure approach, India, 2030

The largest share of mitigation potential in India is found in the energy sector, followed by the industry and building sectors. While mitigation measures with net economic benefits are available in the industry and buildings sectors, the energy sector stands to deliver significant mitigation at break-even cost if the air pollution co-benefit is taken into consideration.

Basis for marginal abatement cost analysis and macroeconomic modelling approaches

The most recent bottom-up assessment of mitigation costs in India that we could identify was undertaken by McKinsey³⁴ and is shown in Figure 11, along with the mitigation cost profile for India in 2030 generated using the REMIND macro-economic model.

³⁴ McKinsey, Environmental and Energy Sustainability – An Approach for India, 2009.



Figure 11: Left panel, marginal abatement cost analysis of India in 2030; right panel, macroeconomic modelling of mitigation costs in India in 2030.

The MAC analysis shows significant money-saving potential across a variety of sectors.³⁵ Around half of the mitigation potential assessed can be delivered through money-saving measures, with further gains available at break-even levels, predominantly in the power sector.

West et al. estimates the marginal air pollution-related co-benefit of mitigation in 2030 in India (adjusted per Section 2.3) to be up to \$45 (\leq 41)/tCO₂e, but also finds under some conditions that the co-benefit fails to materialise. We consider this to be a transient (i.e. short-term) response in the model, given that the benefits of reducing air pollution rise to between \$175-\$356/tCO₂e in 2050 as the widespread deployment of low carbon technologies rapidly drives down greenhouse gas emissions.

Empirical evidence suggests that even today, let alone in 2030, the value of the mitigation co-benefit in India is substantial, largely as a result of the severe levels of particulate matter emissions found in major cities. The World Health Organisation reported recently that 13 of the 20 most polluted cities in the world (in terms of PM2.5 emissions) are located in India, with resultant severe human health and economic impacts. Therefore the quantity of available mitigation potential in 2030 for which the co-benefit balances costs, according to the marginal abatement cost and macroeconomic modelling approaches, is likely to be understated.

Results

The results of each approach are shown in Figure 12.

³⁵ Note that since our analysis excludes land use and forestry emissions, we exclude mitigation potential in these sectors from our assessment of mitigation costs in India.



Projected India mitigation potential and costs in 2030

Figure 12: Projected Indian mitigation potential and costs in 2030

The measure-by-measure approach shows that India could increase its unconditional Paris mitigation commitment by employing more mitigation measures in the 'co-benefit balances costs' category. The lack of any potential for such measures in results from the second and third methods (i.e. the absence of solid orange areas in Figure 12) highlights the transient effect described above.

Taking into consideration all three approaches, India could commit to up to $1200 \text{ MtCO}_2\text{e}$ of mitigation on projected 2030 emissions levels at a cost that would be fully balanced by the co-benefit of avoided air pollution. This is equivalent to raising India's unconditional emissions intensity target of 33 - 35% below 2005 levels to up to 47 - 49%. Figure 12 also shows that there is scope for India's conditional INDC target of a 40% share of non-fossil fuel technologies to be strengthened at no additional net cost.

Across all three approaches, a significant proportion of India's contribution to holding global warming below 2°C could be achieved through measures in the 'co-benefit balances costs' catoegy, indicating that it would make economic sense, and be consistent with limiting warming to 2°C, for India to adopt stronger climate policies than those currently in place.

As shown in Table 4, these conclusions are not affected by uncertainty in India's projected level of emissions in 2030. Note that in each case, the Indian unconditional target is still higher than the most recent projected emissions level in 2030.

Table 3: Sensitivity of category, within which the Indian INDC falls, to selected parameters (bold indicates results shown in the graph above)

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro- economic modelling
+5%	No change	No change	No change
0%	As per figure	As per figure	As per figure
-5%	No change	No change	No change

3.4 Japan

Basis for measure-by-measure approach

Figure 13 shows that the largest amount of Japan's mitigation potential is found in the energy sector, followed by the industry and buildings sectors. The replacement of current fossil fuel-fired power plants by alternatives with lower emissions would lead to a large cobenefit of avoided air pollution. This explains the large potential in the 'co-benefit balances costs' category for Japan. Significant potential also exists in the buildings and industry sectors for mitigation with net economic benefits. However, it should be noted that the relatively low value of reducing air pollution in Japan compared to other countries (described below) means that this approach is likely to over-estimate the amount of potential for which the co-benefit balances the costs.



Figure 13: Projected Japan mitigation potential and costs by sector in 2030

Basis for marginal abatement cost analysis and economic modelling approaches

Estimates for marginal abatement costs in Japan are taken from Westphal et al (2013)³⁶ and the REMIND macro-economic model, and are shown in Figure 14 in the left and right panels respectively.

³⁶ Westphal et al, Asian Development Bank, Economics of Climate Change in East Asia, 2013.



Figure 14: Left panel, ADB marginal abatement cost curve, Japan, 2030; right panel, Implied mitigation costs from the REMIND macro-economic model, Japan, 2030.

Consistent with the measure-by-measure approach, the MAC analysis identifies a significant amount of potential for measures with net economic benefits. It should be noted that since the Fukushima disaster in 2011, emissions have risen by approximately 10 per cent compared with previous projections, largely due to the increased use of LNG, coal and oil. This has created more mitigation potential in 2030, implying that there is likely to be more potential available in the 'co-benefit balances costs' category than these methods demonstrate (depending on future LNG fuel costs).

West et al. (2013) estimates the value of reduced air pollution in Japan in 2030 (adjusted per Section 2.3) to be US\$62-137 (\leq 56-123)/tCO₂e. This is lower than most other countries assessed in this briefing.

Results

The results of each approach are shown in Figure 15.



Projected Japan mitigation potential and costs in 2030

Figure 15: Projected Japan mitigation potential and costs in 2030

Figure 15 shows that according to the measure-by-measure and marginal abatement cost approaches, Japan has failed to grasp the opportunity to increase its mitigation commitment in a cost-effective manner. Most of its current Paris commitment can already be delivered at a net economic benefit through measures such as energy efficiency (red sections). Incorporating savings associated with reduced air pollution could allow Japan to increase its Paris commitment by $100 - 400 \text{ MtCO}_2 \text{e}$ in 2030 (macroeconomic modelling and measure-by-measure results respectively). This is equivalent to increasing its target from $26\%^{37}$ below 2013 levels to 30 - 55% at no additional net economic burden on the economy.

The results of the sensitivity analysis are shown in Table 5. Of the six countries and regions assessed in this briefing, Japan is one of the more sensitive to changes in projected emissions in 2030. However, the conclusions we draw are unaffected; even assuming 5% higher emissions in 2030, the INDC still fails to capture the entire cost-effective mitigation potential available.

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro-economic modelling
+5%	Break even	Break even	Break even/ Out of pocket
0%	As per figure	As per figure	As per figure
-5%	No change	No change	No change

Table 4: Sensitivity of category, within which the Japanese INDC falls, to selected parameters (bold indicates results shown in the graph above)

³⁷ Climate Action Tracker, Japan, <u>http://climateactiontracker.org/countries/japan.html</u>, July 2015, accessed 15/11/15.

3.5 Russia

Basis for measure-by-measure approach

Figure 16 shows that the majority of the potential mitigation with net economic benefits in Russia can be achieved through reducing emissions in the buildings and industry sectors. Most break-even potential is found in the energy sector (orange section).



Figure 16: Projected Russia mitigation potential and costs by sector in 2030

Basis for marginal abatement cost and macro-economic modelling approaches

An economy-wide MAC was produced by McKinsey in 2009³⁸, and is shown in Figure 17 along with the implied mitigation costs from the REMIND macro-economic model.



Figure 17: Left panel, marginal abatement cost curve for Russia in 2030; right panel, macroeconomic modelling for Russia in 2030

The MAC study by McKinsey estimates a significant amount of mitigation potential with net economic benefits. West et al. reports the value of avoided air pollution in Russia (adjusted as per Section 2.3) to be US\$5-185 (₹76-166)/tCO₂e.

Results

Figure 18 shows that Russia is missing a substantial opportunity to increase its mitigation efforts and at the same time achieve net economic benefits through targeted

³⁸ McKinsey, Pathways to an Energy and Carbon Efficient Russia, 2009.

improvements in energy efficiency. Russia's current INDC, corrected for land use emissions, suggests an emissions pledge that is actually higher (shaded grey bar) than the latest projections of its emissions in 2030, and therefore does not represent a decrease in emissions.



Projected Russia mitigation potential and costs in 2030

Figure 18: Projected mitigation potential and costs in Russia, 2030

Russia's current INDC is equivalent to a 25 - 30 per cent reduction below 1990 levels by $2030.^{39}$ Both the first and second approaches show that Russia could increase its mitigation commitment by realising the ~0.4 GtCO₂e of mitigation potential in 2030 associated with net economic benefits. This is equivalent to an emissions reduction target of 36 - 41 per cent below 1990 levels by 2030, and can be achieved while generating net economic benefits at the same time.

The three approaches also identify substantial potential for mitigation for which the cobenefit of avoided air pollution balances the costs. If realised, this would enable Russia to increase its mitigation commitment in 2030 in a cost-effective manner by 0.8 - 1.2 GtCO₂e. This is equivalent to strengthening its target to around 50 - 65 per cent below 1990 levels.

The sensitivity analysis in Table 6 shows that the conclusions are unaffected by uncertainty in the projected level of Russia's emissions in 2030. Note that for all cases in the sensitivity analysis, the Russian target is still higher than the most recent projected emissions level (excluding land use) in 2030.

Table 5: Sensitivity of category, within which the Russian INDC falls, to selected parameters (bold indicates results shown in the graph above)

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro-economic modelling
level in	Measure-by-	abatement	Macro-economic
2030	measure	cost curve	modelling

³⁹ Climate Action Tracker, Russian Federation, <u>http://climateactiontracker.org/countries/russianfederation.html</u>, April 2015, accessed 15/11/15.

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro-economic modelling
+5%	No change	No change	No change
0%	As per figure	As per figure	As per figure
-5%	No change	No change	No change

3.6 USA

Basis for measure-by-measure approach

Figure 19 shows that significant potential for mitigation with net economic benefits exists in the buildings and industry sectors. The potential in the 'co-benefit balances costs' category is spread evenly between the energy and industry sectors.



Figure 19: Projected mitigation potential and costs by sector in the USA in 2025

Basis for marginal abatement cost and macro-economic modelling approaches

The cost of mitigation in the USA was assessed using the GAINS Mitigation Efforts Calculator⁴⁰ and the REMIND macro-economic model, both of which are shown in Figure 20. No literature was identified that contains a MAC based on projections of USA emissions in 2025; therefore we assume that the cost profile developed using GAINS for 2020 is applicable to the USA's emissions in 2025.

⁴⁰ Amann et al., GAINS, 2008, <u>http://gains.iiasa.ac.at/gains/reports/AnnexI-methodology.pdf</u>.



Figure 20: Left panel, GAINS marginal abatement cost curve for USA in 2020; right panel, macro-economic modelling of USA mitigation costs, 2025

The GAINS marginal abatement cost curve displays limited potential with net economic benefits. However, there is significant potential available at very low cost through improved energy efficiency measures, efforts to mitigate non-CO2 gases, and the collection of high global warming potential refrigerant gases.

West et al. estimates the value of avoided air pollution in the USA in 2030 (adjusted per Section 2.3) to be US\$46-102 (\leq 42-92)/tCO₂e. No corresponding value is available for 2025, so we assume that the value of reduced air pollution in 2030 can be applied to mitigation potential in 2025. As a result, the amount of mitigation potential in the 'co-benefit balances costs' category may be an over-estimate..

Results

The results of each approach are shown in Figure 21.



Projected USA mitigation potential and costs in 2025

Figure 21: Projected mitigation potential in the USA in 2025

As seen in Figure 21, all three approaches indicate that the USA's INDC captures the majority, if not all, of the available air pollution co-benefit. This is especially the case if the potential for mitigation with a balance between costs and co-benefits found using the second and third approaches is overstated for the reasons described above.

This is not to say that the USA has captured all of the available co-benefits. A recent report by New Climate Institute found that strengthening the USA's INDC to one that is consistent with a 2°C target would generate savings of \$160 billion per year in reduced fossil fuel imports, and create 180,000 jobs in the wind, solar and hydro energy industries.⁴¹ These benefits could pay for additional mitigation efforts.

The results also show that to achieve its fair share of the global mitigation effort, the USA would need to undertake deep mitigation efforts domestically (green shading), and would potentially need to look beyond the USA to purchase mitigation elsewhere at lowest cost (grey shading).

The sensitivity analysis shown in Table 7 demonstrates the robustness of these conclusions to changes in the USA's projected level of emissions in 2025.

⁴¹ New Climate Institute, More climate change action, more co-benefits. Analysis of the INDCs for EU, US and China, <u>http://newclimate.org/2015/03/30/more-climate-change-action-more-co-benefits-analysis-of-the-indcs-for-eu-us-and-china/</u>.

Table 6: Sensitivity of category, within which the USA INDC falls, to selected parameters (bold indicates results shown in the graph above)

Emissions level in 2030	Measure-by- measure	Marginal abatement cost curve	Macro- economic modelling
+5%	No change	No change	No change
0%	As per figure	As per figure	As per figure
-5%	No change	No change	No change

Appendix A: Assessment of measure-by-measure costs

Mitigation activities	Net economic benefits	Co-benefit balances costs	Net economic costs	Comments
Buildings				
Fuel savings in new buildings	30%	70%	0%	WEO mitigation potential is distributed over the three categories according to the potential distribution in MACCs from McKinsey (2009). Since
Fuel savings existing buildings	70%	30%	0%	WEO does not cover the full potential, we extended the available potential using ambitious energy efficiency improvement rates taken from IEA Global Energy Assessment. This is allocated to the 'out of pocket' category.
Electricity savings in buildings	100%	0%	0%	WEO potential is distributed over the three categories according to the potential distribution in MACCs from McKinsey (2009).
Renewable energy use in buildings	40%	40%	20%	We assumed 40% to be 'net economic benefits', 40% to be 'co-benefit balances costs' and 20% to be 'net economic costs'. Since the costs depend strongly on local energy prices and the type of renewables (e.g. solar thermal, solar PV or biomass) there is uncertainty here. However CAT estimates that the co-benefit balances costs for at least 80% of renewable energy generation. The uncertainty has a limited impact on the total potential.
Tran	sport			
Energy efficiency in transport	75%	25%	0%	Estimated based on McKinsey (2009) Road Transport MAC-curve.
Electrification of transport	45%	45%	10%	Estimated based on McKinsey (2009) Road Transport MAC-curve.
Biofuels use in transport	50%	50%	0%	Estimated based on McKinsey (2009) Road Transport MAC-curve. However, abatement costs are very sensitive to the oil price, where lower oil prices lead to higher mitigation costs.
Ind	ustry			
Fuel efficiency in industry	50%	50%	0%	Here we assumed 50% of the WEO potential to be have net economic benefits, and 50% to have a co- benefit that balances the costs. Since WEO does not cover the full potential, we extended the available potential using ambitious energy efficiency improvement rates taken from IEA Global Energy Assessment. This is allocated to the 'out of pocket' category.
Electricity savings in industry	100%	0%	0%	Based on Waide & Brunner (2011) and McKinsey (2009). This pre-dominantly involves electric motors and variable speed drives. Given their relatively low investment costs compared to lower efficiency motors, and taking into account the lower electricity bill, the cost of this measures is negative.
Biofuel use in industry	50%	25%	25%	We assume about 50% of the potential can be harvested at negative cost by utilizing waste streams. The other half of the potential is distributed equally over the 'co-benefit balances costs' and 'net economic costs' categories. Again, the abatement costs are sensitive to conventional fuel prices.

Mitigation activities	Net economic benefits	Co-benefit balances costs	Net economic costs	Comments
Reduction in process emissions	0%	60%	40%	Based on the mitigation potential in cement production according to IPCC AR5 (2015) scenarios. The emission reductions by 2030 (median value) in the '450' scenarios are allocated to the 'co-benefit balances costs' category, and the additional emission reductions by 2050 are allocated to the 'net economic costs' category. The 'net economic costs' category thus reflects an acceleration of emission reduction efforts compared to the IPCC scenarios. ⁴²
Carbon capture and storage (CCS) in industry	0%	0%	100%	Based on ETP (share of baseline emissions). The entire potential is assigned to the 'net economic costs' category as CCS is not commercially available at a large scale before 2030.
Power				
Renewable energy in the power sector	0%	50%	50%	According to McKinsey (2009), most potential is in the break even category. Since WEO does not cover the full potential, we extended the potential, based on growth rates in renewable energy in the Global Energy Assessment Supply scenario. The potential resulting from this additional growth rates (differentiated per region) rate is allocated to the 'out of pocket' category.
Nuclear power	0%	100%	0%	According to McKinsey (2009), most potential is in the break even category.
CCS in the power sector	0%	0%	100%	Based on ETP (share of baseline emissions). Entire potential assigned to the out of pocket category as CCS is not commercially available at a large scale before 2030.
Other				
Mitigation of non- CO ₂ emissions	2 Varies by region			Potential and distribution of the three categories is based on US EPA (2013) MAC-curves. ⁴³

⁴² IPCC, AR5, 2014, <u>http://www.ipcc.ch/report/graphics/index.php?t=Assessment%20Reports&r=AR5%20-%20WG3&f=Chapter%2010</u>, accessed 1/11/15.
⁴³ US EPA, Global Mitigation of Non-CO2 Greenhouse Gases: 2010–2030, 2014, <u>http://www3.epa.gov/climatechange/EPAactivities/economics/nonco2mitigation/execsumm/index.html#reports</u>, accessed 1/11/15.

Appendix B: Consideration of key assumptions in the analysis

Consistency of baseline projections from different sources

The marginal abatement costs derived from a cost analysis are specific to the emissions baseline and reference projections used to derive them. As national emissions projections are updated over time to reflect recent developments, cost estimates from past studies may be less accurate than those based on recent projections. However, it should also be noted that even emissions projections produced at the same time can vary, depending on the underlying assumptions.

We use existing studies on mitigation costs which, while not reflecting the most recent projections of emissions and mitigation measures, still provide valuable insights into the present mitigation cost profile of the countries we assess in this briefing, because:

- small deviations from the emissions projections underpinning the cost profiles are tolerable and within the range of uncertainty in other elements of the analysis (e.g. the valuation of reduced air pollution)
- where the deviation is attributable to significant economy-wide shocks, such as the GFC in 2009, we assume that the mitigation potential is reduced across all sectors of the economy, more or less equally, so the 'shape' of the cost profile is not affected.

To reduce the impact of inconsistent baselines on the analysis, and since it is not feasible to investigate how the mitigation potential has evolved in each country and sector, the mitigation potential is calculated in this briefing at an economy-wide level as a percentage reduction from projected baseline emissions. This minimizes the effect of recent changes in emissions projections on the conclusions of the analysis. We also conduct a sensitivity test for each country by varying the projected 2030 emissions by +/- 5 per cent to test how robust the results are to changes in the baseline projection.

In some instances, changes in the baselines can be directly attributed to the effectiveness of domestic climate policies. This has the potential to change the mitigation cost profile of the country, depending on which mitigation measures have been implemented. In these instances we investigate relevant country policies and evaluate the impact of those policies on our findings.

Uncertainty in the valuation of avoided future air pollution

The monetized value of future mitigation benefits is influenced by several factors. For example, the magnitude of co-benefits is often large initially, but becomes smaller as emissions reductions become more aggressive. This is especially in rapidly developing countries. However, the opposite effect occurs in those developing countries that have yet to undertake rapid development, since population and economic growth lead to increase pollution-related health risks, and hence greater co-benefits over time.⁴⁴ Significant factors that affect the value of reducing future air pollution include: the relationship between pollution and mortality (the concentration-response function), population growth projections, and the value of a statistical life (VSL).

The value of co-benefits also depends on the baseline projections and GHG abatement scenarios used to generate the marginal benefit. The West et al. paper derives the value of air pollution by comparing a reference case without climate policy to a scenario targeting 525ppm CO_2 (equivalent to a 66% chance of holding warming below 2.6°C). For the purposes of this briefing we assume the value can be applied to the baseline projections for each country set out in this briefing.

⁴⁴ US EPA, Global Mitigation of Non-CO2 Greenhouse Gases: 2010–2030, 2014,

http://www3.epa.gov/climatechange/EPAactivities/economics/nonco2mitigation/execsumm/index.html#reports, accessed 1/11/15.

Treatment of land use emissions

Consistent with the CAT methodology, the cost and fairness of country emissions are assessed on the basis of fossil fuel and industrial emissions only. Land use emissions are excluded from the assessment because land use emissions have a much higher level of uncertainty attached to them and their treatment under the anticipated Paris agreement is still unclear.

Where macroeconomic modelling is used to generate estimates of mitigation costs, the cost of mitigation in other sectors depends on the level of mitigation being achieved in the land use sector: if there is less mitigation in the land use sector than modelled, more – and potentially higher cost – mitigation is required in other sectors.

References

Amann et al. (2008). Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Model, http://gains.iiasa.ac.at/gains/reports/AnnexI-methodology.pdf.

Bain et al. (2015). Co-benefits of addressing climate change can motivate action around the world, http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2814.html.

Bayles (1978). The Price of Life, http://www.jstor.org/stable/2380129).

Climate Action Tracker (2014). Methodology, http://climateactiontracker.org/methodology.html.

Climate Action Tracker (2015). Briefings, http://climateactiontracker.org/publications/briefing.html.

Climate Action Tracker (2015). Rating countries, http://climateactiontracker.org/countries.html.

Ecofys (2009). Sectoral Emission Reduction Potentials and Economic Costs for Climate Change, 2009, <u>http://www.ecofys.com/files/files/serpec_executive_summary.pdf</u>.

Global Environment Centre Foundation (2014). Joint Crediting Mechanism, http://gec.jp/jcm/about/index.html.

Green Climate Fund (2014). Initial Results Management Framework of the Fund, http://gcfund.net/fileadmin/00_customer/documents/MOB201406-7th/GCF_B07_04_Initial_Results_Management_Framework__fin_20140509.pdf.

IEA. (2010). Energy Technology Perspectives 2010. http://www.iea.org/publications/freepublications/publication/energy-technologyperspectives-2010.html.

IEA. (2014). CO2 Emissions from fuel Combustion. IEA Statistics. https://www.iea.org/publications/freepublications/publication/name,32870,en.html\nhttps ://www.iea.org/co2highlights/co2highlights.pdf

IEA. (2014). Energy Technology Perspectives. http://www.iea.org/etp/etp2014/.

IEA. (2014). World Energy Outlook 2014. http://www.worldenergyoutlook.org/weo2014/.

IEA. (2014). World Energy Statistics and Balances 2014, http://www.iea.org/statistics/.

IIASA (2012). Global Energy Assessment, http://www.iiasa.ac.at/web/home/about/news/Global-Energy-Assessment-nowavailable.en.html.

International Energy Agency (2014). Capturing the Multiple Benefits of Energy Efficiency, <u>http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_of</u> <u>EnergyEficiency.pdf</u>.

IPCC. (2014): Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment. Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/report/ar5/wg3/.

Jewell et al. (2014). Energy security under de-carbonization scenarios: An assessment framework and evaluation under different technology and policy choices, Energy Policy, http://www.sciencedirect.com/science/article/pii/S0301421513010744.

JRC/PBL. (2012). Edgar Version 4.2 FT2010. Retrieved from http://edgar.jrc.ec.europa.eu/index.php

Kriegler et al. (2014). What does the 2°C target imply for a global climate agreement in 2020? The LIMITS study on Durban Platform scenarios, <u>http://www.feem-project.net/limits/03_outreach_01_02.html</u>.

Latvia and the European Commission (2015). SUBMISSION BY LATVIA AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES, INDC of EU and its Member States,

http://www4.unfccc.int/submissions/INDC/Published%20Documents/Latvia/1/LV-03-06-EU%20INDC.pdf.

Luderer et al. (2013). Economic mitigation challenges: how further delay closes the door for achieving climate targets, Environmental Research Letters, http://iopscience.iop.org/article/10.1088/1748-9326/8/3/034033/pdf.

McKinsey (2009). Environmental and Energy Sustainability – An Approach for India, <u>http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_ab</u> <u>atement_cost_curves</u>.

McKinsey (2009). Pathways to an Energy and Carbon Efficient Russia, <u>http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_ab</u> <u>atement_cost_curves</u>.

McKinsey&Company. (2009). Pathways to a Low-Carbon Economy, <u>http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_ab</u> <u>atement_cost_curves</u>.

Nemet, G. F., Holloway, T., & Meier, P. (2010). Implications of incorporating air-quality cobenefits into climate change policymaking. Environmental Research Letters. <u>http://doi.org/10.1088/1748-9326/5/1/014007</u>

New Climate Institute (2015). More climate change action, more co-benefits. Analysis of the INDCs for EU, US and China, <u>http://newclimate.org/2015/03/30/more-climate-change-action-more-co-benefits-analysis-of-the-indcs-for-eu-us-and-china/</u>.

OECD (2012). Mortality Risk Valuation in Environment, Health and Transport Policies, <u>http://www.oecd.org/env/tools-</u>evaluation/mortalityriskvaluationinenvironmenthealthandtransportpolicies.htm.

OECD (2013), Exploring Climate Finance Effectiveness, Climate Change Expert Group Paper No. 2013(4), http://www.oecd-

ilibrary.org/docserver/download/5jzb44nmnbd2.pdf?expires=1443195903&id=id&accname =guest&checksum=C2F2402940E8262023819B33C872EC93.

Potsdam Institute for Climate Impact Research (2015). PRIMAP4 database, <u>https://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/research/rd2-flagship-projects/primap/emissionsmoduledocumentation/primap-iv-2013-sar-gwp-crf-edgar-weo-cdiac-poles-match-baseline.</u>

Rohde et al. (2015). Air Pollution in China: Mapping of Concentrations and Sources, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0135749.

Sawhney A. (2015). Renewable Energy Policy in India: Addressing Energy Poverty and Climate Mitigation, http://reep.oxfordjournals.org/content/7/2/296.full.pdf+html.

UCL Energy Institute (2011). Marginal Abatement Cost Curves: A call for caution, https://www.bartlett.ucl.ac.uk/energy/news/documents/ei-news-290611-macc.pdf. UNESCAP (2015). Valuing the sustainable development co-benefits of climate change mitigation actions,

http://www.unescap.org/sites/default/files/Valuing%20the%20Sustainable%20Dev%20Co-Benefits%20(Final).pdf.

United Nations Industrial Development Organisation (2011). Barriers to Industrial Energy Efficiency,

http://www.unido.org//fileadmin/user_media/Publications/Research_and_statistics/Branch_publications/Research_and_Policy/Files/Working_Papers/2011/WP102011%20Barriers%2006%20Industrial%20Energy%20Efficiency%20-%20A%20Literature%20Review.pdf.

US EPA. (2012). Global Anthropogenic Non-CO2 Greenhouse Gas Emissions : 1990 - 2030. http://www.epa.gov/climatechange/Downloads/EPAactivities/EPA_Global_NonCO2_Projections_Dec2012.pdf

US EPA. (2014). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Environmental Protection.

http://www.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2014-Exec_Summ.pdf

Viscusi (2006). The Value of Life, http://www.law.harvard.edu/programs/olin_center/papers/pdf/Viscusi_517.pdf.

Waide, P., & Brunner, C. U. (2011). Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems. International Energy Agency.

West et al. (2013). Co-benefits of Global Greenhouse Gas Mitigation for Future Air Quality and Human Health, Nature Climate Change, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4051351/.

Westphal et al. (2013). Asian Development Bank, Economics of Climate Change in East Asia, <u>http://www.adb.org/sites/default/files/publication/30434/economics-climate-change-east-asia.pdf</u>.

World Health Organisation (2014), Ambient (outdoor) air pollution in cities database 2014, http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.

World Health Organisation (2015). Air pollution costs European economies US\$ 1.6 trillion a year in diseases and deaths, new WHO study says, <u>http://www.euro.who.int/en/media-centre/sections/press-releases/2015/04/air-pollution-costs-european-economies-us\$-1.6-trillion-a-year-in-diseases-and-deaths,-new-who-study-says.</u>

Zhou et al. (2013). Quantifying the potential impact of energy efficiency and low carbon policies for China, <u>https://china.lbl.gov/sites/all/files/quant_ee_lc_eceee.pdf</u>.









The Climate Action Tracker is an independent science-based assessment that tracks the emission commitments and actions of countries. It is a joint project of the following organisations:

Climate Analytics

Climate Analytics is a non-profit institute based in Berlin, Germany, with offices in Lomé, Togo and New York, USA, that brings together inter-disciplinary expertise in the scientific and policy aspects of climate change with the vision of supporting science-based policy to prevent dangerous climate change, enabling sustainable development. Climate Analytics aims to synthesise and advance scientific knowledge in the area of climate, and by linking scientific and policy analysis provide state-of-the-art solutions to global and national climate change policy challenges. Contact: Dr. h.c. Bill Hare, +49 160 908 62463

www.climateanalytics.org

Ecofys – Experts in Energy

Established in 1984 with the mission of achieving "sustainable energy for everyone", Ecofys has become the leading expert in renewable energy, energy & carbon efficiency, energy systems & markets as well as energy & climate policy. The unique synergy between those areas of expertise is the key to its success. Ecofys creates smart, effective, practical and sustainable solutions for and with public and corporate clients all over the world. With offices in Belgium, the Netherlands, Germany, the United Kingdom, China and the US, Ecofys employs over 250 experts dedicated to solving energy and climate challenges. Contact: Prof. Kornelis Blok, +31 6 558 667 36

www.ecofys.com

Potsdam Institute for Climate Impact Research (PIK)

The PIK conducts research into global climate change and issues of sustainable development. Set up in 1992, the Institute is regarded as a pioneer in interdisciplinary research and as one of the world's leading establishments in this field. Scientists, economists and social scientists work together, investigating how the earth is changing as a system, studying the ecological, economic and social consequences of climate change, and assessing which strategies are appropriate for sustainable development. Contact: Dr. Louise Jeffery, louise.jeffery@pik-potsdam.de

www.pik-potsdam.de

NewClimate Institute

NewClimate Institute is a non-profit institute established in 2014. NewClimate Institute supports research and implementation of action against climate change around the globe, covering the topics international climate negotiations, tracking climate action, climate and development, climate finance and carbon market mechanisms. NewClimate Institute aims at connecting up-to-date research with the real world decision making processes. Contact: Dr. Niklas Höhne, +49 173 715 2279

www.newclimate.org