Technical Note

Quantifying the multiple benefits from low-carbon actions in a greenhouse gas abatement cost curve framework

NEW CLIMATE ECONOMY PROJECT

CONTENTS

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Suggested Citation

Global Commission on the Economy and Climate. *New Climate Economy technical note: Quantifying the multiple benefits from low-carbon actions in a greenhouse gas abatement cost curve framework*. January 2015.

1. INTRODUCTION

This paper documents the assumptions and analysis that underlie the presentation and discussion of the exhibit on the Global GHG Abatement Benefit and Co-benefit Curve: 2030 in the Commission's global report *Better Growth, Better Climate*.[1] This analysis builds on the concept of a marginal abatement cost (MAC) curve, presenting this instead in terms of the marginal abatement benefits: the net financial benefits (once capital and operational costs are taken into consideration) of over 200 options for reducing greenhouse gas (GHG) emissions and their global potential. It additionally incorporates monetised valuations of co-benefits to reflect the wider benefits to society of the relevant actions. This provides a revised assessment of the global abatement potential that can have net positive benefits.[2] This analysis does not attempt to address these issues, but is intended to emphasise the importance of considering a fuller range of benefits of actions to reduce carbon emissions when comparing these with higher-carbon alternatives.

2. METHODOLOGY

A significant finding of MAC curves and other modelling of GHG mitigation is that a large volume of abatement can have "negative cost", that is, the net cost savings (for example from reduced fossil fuel use) outweigh the increase in investment and operational costs required in taking the action for a given discount rate. In this sense, these measures have "abatement benefits". For example, energy efficiency improvements can both reduce emissions and save money for businesses or consumers through reductions in energy use, once up-front capital costs and operating expenditures are taken into consideration. This finding is echoed in a wide-ranging literature on mitigation options across transport, buildings, industry and other sectors. [3]

In addition to this, many mitigation measures have the potential for multiple benefits that go beyond the immediate financial impact of the individual project. Examples include health benefits associated with lower air pollution from fossil fuels, or broad economic gains from measures such as a modal shift towards mass transportation which reduces congestion and creates fewer accidents. The New Climate Economy (NCE) project has investigated a range of such benefits, as documented in the main NCE report, *Better Growth, Better Climate*, and finds that these are often not systematically taken into consideration by decision-makers. This risks creating inconsistencies, and misrepresenting the true social value of emissions reduction initiatives and policies.

This analysis draws on a large literature that puts a monetary value to some of these benefits. These monetary estimates are, in turn, mapped onto the Global GHG Abatement Cost Curve v3.0 published by McKinsey & Company (forthcoming).[4] Specifically, the analysis covers four categories of measure:

1. The health co-benefits associated with reducing coal-related emissions;
2. The rural development benefits from measures to improve agricultural productivity and restore degraded land;
3. The benefits of improved energy security from energy efficiency measures; and
4. The combined benefits from air pollution, avoided accidents, and congestion due to transport modal shifts (in turn related to the shift towards more compact, connected cities).

A limitation of this analysis is that it operates at a global level. The level of co-benefits, as well as the potential and cost of the underlying abatement opportunities, can vary significantly given the local context. The methodology used here is intended not to give guidance about specific measures, but to show the potential scale of difference that the consideration of co-benefits can make to the assessment of options to reduce GHG emissions.

3. ASSESSING THE SCALE OF CO-BENEFITS

Tables 1a and 1b below summarise the key assumptions used for the co-benefit analysis, with the underlying rationale explained below.

Table 1a: Co-benefit assumptions by category of abatement measure 2010 dollars per tonne of carbon dioxide (CO_2) in 2030

Abatement category	Assumption
Coal-related emissions	Health co-benefit: • US$100/t CO_2 in coal-related emissions abated in developed countries • US$50/t CO_2 in coal-related emissions abated in developing countries
REDD+, degraded land restoration	Rural development co-benefit of US$10/t CO_2 for levers linked to REDD+ and restoration of degraded land **Excludes**: co-benefit from better eco-systems which could be substantial
Energy security	Energy security / reduced volatility co-benefit of US$5/t CO_2e for all energy efficiency measures for all energy-importing regions (China, India, EU, Japan and Korea)
Modal shift to buses, bus rapid transit and metro	Combined co-benefit of US$60/t CO_2 from avoided air pollution, accidents and congestion

Table 1b: Fuel price and discount rate assumptions

Variable	Assumption
Fuel prices	**Oil 2030**: US$130 per barrel **Coal 2030**: US$115 per tonne[5]
Discount rate	4% discount rate – as analysis is based on societal perspective, US long-term bond rate used as a proxy

3.1 HEALTH CO-BENEFITS FROM REDUCING COAL-RELATED EMISSIONS

Coal combustion is a major contributor to the emission of particulate matter and other local air pollution that, in turn, is associated with a wide range of negative health impacts and increased mortality. As described in Lim et al. (2012), the Global Burden of Disease project of the World Health Organization estimated the number of deaths resulting from ambient $PM_{2.5}$ exposure for all countries in 2010.[6] A background paper for the NCE (Hamilton, 2015)[7] estimated the cost of the associated mortality, expressed in terms of dollars per tonne of carbon dioxide equivalent (CO_2e) emitted in 2010, which amounts to approximately US$150/t CO_2e in developed countries and approximately US$70/t CO_2e in developing countries in 2010. The cost varies significantly by country, reflecting different levels of exposure to particulate matter (specifically $PM_{2.5}$), income levels and other factors.

These magnitudes are similar to other estimates found in the literature. West et al. (2013)[8] use a similar approach. They estimate global average co-benefits based on a moderate policy scenario for 2030 (consistent with 2.4°C warming by 2100) as US$51–293/t CO_2e in developing and emerging economies (China, Southeast Asia, Eastern Europe and the Former Soviet Union) and US$116–662/t CO_2e in developed countries (Japan, the United States and Western Europe).[9] The substantially higher values are due in part to less conservative valuation methodology for developing countries, the inclusion of additional pollutants, and the fact that higher incomes in 2030 lead to an increased willingness to pay for reduced mortality. The study by Holland et al. (2011)[10] estimates health co-benefits for the EU27 that (after aligning valuation methods with West et al., 2013) correspond roughly to US$200/t CO_2e in 2030, based on a stringent policy scenario of limiting warming to 2°C by 2100.

Using a different methodology, Parry et al. (2014)[11] estimated the health co-benefits from reducing coal use at equivalent to US$50/t CO_2e, averaged (according to emissions shares) across the leading CO_2-emitting countries, in 2010. Damages are relatively high in countries (e.g. China, Poland) with high population density and population exposure to emissions, and the converse applies in countries (e.g. Australia) with low population exposure. Damages are conservatively estimated based on country-specific emission rates at coal plants with emissions control technologies (on the assumption that deployment of these technologies will increase over time); if damages are based on average emission rates across plants with and without controls, the average damage across countries rises to US$92/t CO_2e.

As these examples indicate, estimates of the health co-benefits of reduced air pollution vary widely. Important reasons for this include uncertainties over the relationship between pollution exposure and health risk (exposure is often higher in developing countries) and uncertainty about how the willingness to pay for reduced mortality risk varies with income (it is typically assumed to be lower in developing countries with lower income levels). There is also a complication of attributing reductions in $PM_{2.5}$ to coal or other sources of pollution (notably, in the transport sector); however, this has little practical impact for our purposes, given that emissions of $PM_{2.5}$ from coal combustion are a feature of all the analyses that we draw on. For the purposes of this analysis we adopt values that are lower than those in the above literature estimates, with a value of US$100/t CO_2e in developed countries in 2030 and US$50/t CO_2e in developing countries in 2030. These are taken as illustrative numbers for global averages, used to indicate the potential magnitude of co-benefits associated with reducing coal-related emissions.

3.2 RURAL DEVELOPMENT BENEFITS FROM ENHANCING AGRICULTURAL PRODUCTIVITY AND FOREST RESTORATION AND AFFORESTATION LINKED TO REDD+

Measures to improve agricultural productivity through improved land and water management with agroforestry can have significant rural development benefits for local communities as well as climate benefits. Important categories of benefit include increased soil carbon sequestration that improves water retention and climate resilience, in addition to improving the response to artificial fertilisers. These have direct financial benefits for farmers and local communities, contributing to higher aggregate income benefits in the region. For example, a case study in Niger, looking at farmer-managed natural regeneration in Maradi and Zinder provinces, estimated that such benefits amounted to around US$25/t CO_2e abated.[12] In China, a study, made by the World Bank, of the Loess plateau rehabilitation project suggests similar benefits are worth at least US$125/t CO_2e.[13]

Forest restoration and afforestation similarly can have direct financial benefits, including the sale of selectively harvested timber and pulp, wood fuel and charcoal, and non-timber forest products like medicines. There are also indirect financial benefits, such as better crop yields from improved water management and pollinating insects. To these are added a range of other ecosystem services available from forested land. Even without including these other ecosystem services, co-benefits can amount to as much as US$75/t CO_2e sequestered.[14]

Overall, the literature indicates that the benefits can be substantial across different abatement measures that affect land use. However, data are often only available on a project basis, and there is significant uncertainty about the extrapolation to other circumstances. Moreover, it is often difficult to assess the degree of overlap between direct financial benefits captured in estimates of net marginal abatement benefit and the wider ancillary benefits.

These difficulties call for a conservative approach, and we adopt a value of US$10/t CO_2e across the main categories of abatement measures in the areas of agriculture, forestry and land use. This is lower than the individual estimates cited above, and also does not take into account other co-benefits such as protection and enhancement of vital ecosystem services, which can avoid significant public expenditures at a later date.[15]

3.3 THE BENEFITS OF IMPROVED ENERGY SECURITY FOR ENERGY EFFICIENCY MEASURES

Brown and Huntington (2010)[16] attempt to quantify the energy security externalities associated with increased oil use in the US, which derive from the expected economic losses associated with potential disruptions in world oil supply. They conclude that, for the US, the net effect for domestic oil is US$2.81 per barrel in a range of US$0.19 to US$8.70 per barrel. For imported oil the total effect is US$4.98 in a range of US$1.10 to US$14.35 per barrel. This translates to a net effect for domestic oil of 7 cents per gallon, the equivalent of US$7/t CO_2. The net effect for imported oil is estimated at 12 cents per gallon, the equivalent of US$12/t CO_2.

Similarly, Parry et al. (2007)[17] review a large US literature on the social costs of automobile transport and conclude that the costs of "oil dependency" – largely the cost of oil price volatility – is worth around 12 cents per gallon, the equivalent of US$12/t CO_2. Many of the concerns also arise directly in other oil-importing countries but there is a dearth of estimates available, as well as uncertainty about how to translate the US estimates to other contexts.

To err on the side of caution, we use a lower value of US$5/t CO_2e as an input into the MAC model. This applies to all energy efficiency measures that reduce energy demand across all sectors in net energy-importing countries only.

3.4 THE COMBINED BENEFITS FROM AIR POLLUTION, AVOIDED ACCIDENTS AND CONGESTION DUE TO TRANSPORT MODAL SHIFTS

Parry et al. (2014)[18] provide estimates of the co-benefits from reducing road fuels among large-emitting countries, expressed per tonne of CO_2. These figures reflect benefits from reduced air pollution, traffic congestion, traffic accidents and road damage – though they are net of excise taxes – which serve to reflect these costs in fuel prices. Average (net) co-benefits across countries (weighted by their emissions shares) are US$86/t CO_2 for gasoline and US$133/t CO_2 for road diesel.[19]

Earlier, Parry et al. (2007)[20] estimated the external costs of air pollution, congestion and accidents related to automobile transport in the US. The social cost of congestion is estimated at US$1.05 per gallon for congestion and a further 63 cents for accidents and 42 cents for local air pollution. The sum of this corresponds to US$210/t CO_2e. While a US example might not appear to be representative of global trends, the US exhibits very high dependency on private automobiles and a relatively undeveloped public transport system, both of which are growing characteristics of many developing countries. In 2030, the opportunity cost of time and vehicle miles travelled will be much higher, leading to higher congestion reduction co-benefits. Incomes will also be higher, which will lead to a higher valuation for the benefit of reduced accidents, while the incidence of accidents can be expected to decline with rising incomes. On balance, US co-benefits estimates from 2005 are likely to be a conservative estimate for rest of world co-benefits in 2030.

For the purposes of this analysis, we adopt a lower number than these literature estimates, and apply a co-benefit value of a modal shift to public transport (buses, bus rapid transit and metro) of US$60/t CO_2e.

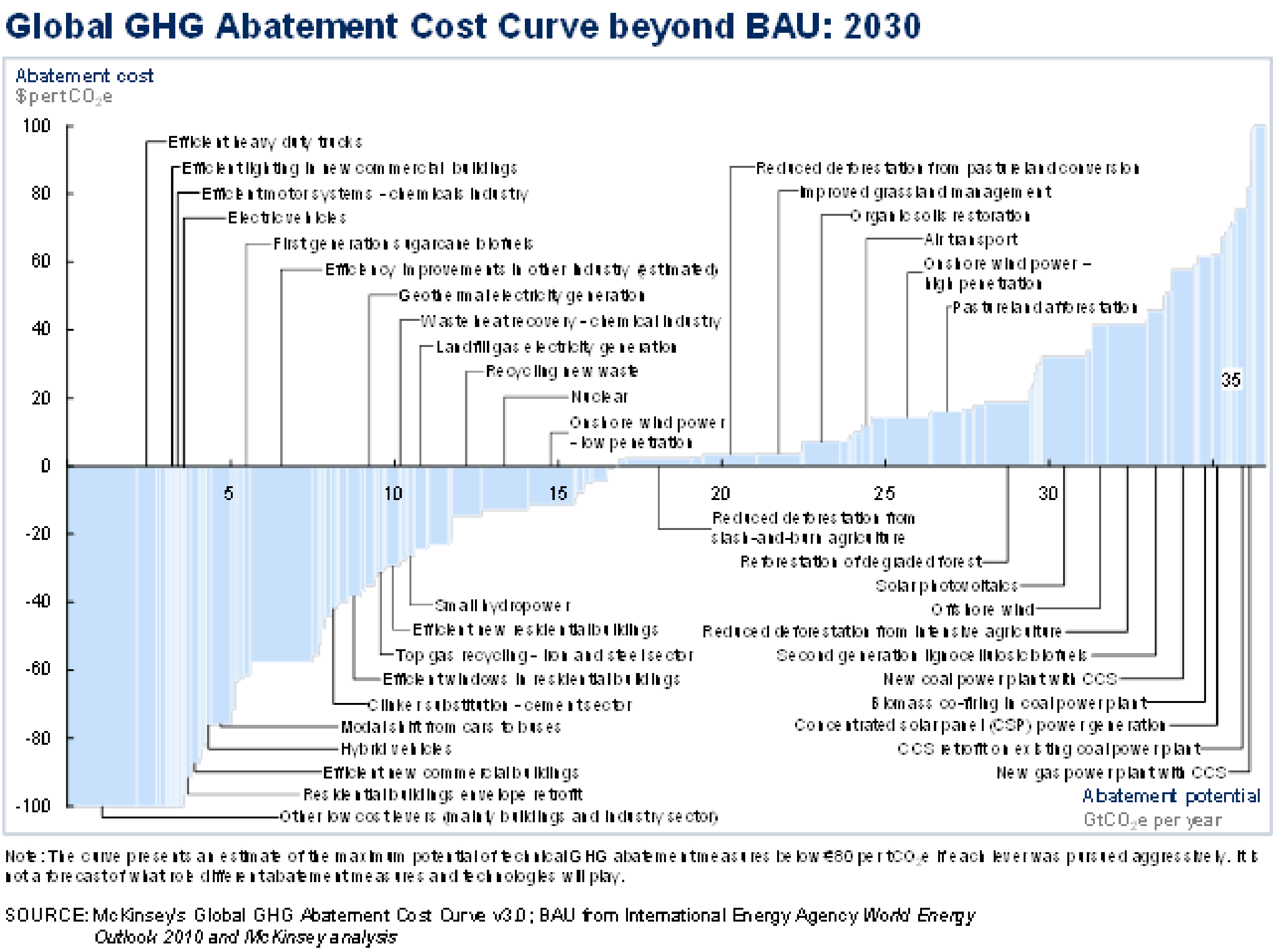
4. MCKINSEY'S GLOBAL GHG ABATEMENT COST CURVE V3.0

The starting point for the assessment is McKinsey's new Global GHG Abatement Cost Curve v3.0 (Figure 1), which provides information on the abatement potential, cost and required investment of over 200 mitigation options in 2030.[21]

The cost curve presents the technical potential of emissions abatement of a specific mitigation option and the associated marginal cost per tonne of CO_2e saved, taking into account the required upfront investments, operating costs and potential financial savings from each option, compared with the relevant high-carbon (baseline) solution. The options with a negative marginal abatement cost indicate opportunities for positive marginal abatement benefit vis-à-vis the baseline. The aggregate potential of emissions abatement and net marginal costs across the curve are measured relative to a "business-as-usual" scenario.[22]

The cost curve thus attempts to provide a quantitative basis for discussions on what actions would be most effective in delivering emissions reductions, and what they might cost.

Figure 1. McKinsey Global GHG Abatement Cost Curve: 2030



Note: The curve presents an estimate of the maximum potential of technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.[23]

5. ABATEMENT BENEFITS CURVE

We updated the McKinsey Global GHG Abatement Cost Curve in two stages. First, we inverted the cost curve to turn it into a benefits curve. In contrast to the above cost curve, measures with net benefits appear above the axis and those with net costs below. Second, we added the co-benefit estimates outlined above to the relevant underlying abatement levers. The resulting curve thus makes possible a comparison of direct net financial benefits and the value of co-benefits. The new curve in comparison to the old curve can be seen in Figure 2.[24]

Each of the blue bars shows the estimated incremental cost in 2030, relative to the high-carbon alternative, of reducing emissions by an additional tonne of CO_2e through a specific technique or action, and the total technical abatement potential it offers. The incremental cost estimate per tonne of CO_2e in 2030 is based on the difference in operating and annualised capital costs between the low- and high-GHG alternatives, net of any potential savings. The red bars show the additional co-benefit associated with various abatement options, for example the health benefits from reduced local air pollution. (These have a slightly different interpretation: the co-benefits are not necessarily available for each additional tonne of GHG emissions reductions, but in several cases are instead the average value resulting by 2030 from striking an overall lower-GHG path; today's decisions in turn determine whether that outcome is achievable, given the resulting lock-in.)

Figure 2 shows that many abatement options have a positive benefit even in narrow financial terms, even without co-benefits, but that accounting for these additional benefits reduces the average cost and increases the total potential with a net benefit (i.e., above the zero line). A number of options with net costs swing to net benefits when co-benefits are taken into account, for example reduced deforestation, recycling of new waste, and offshore wind. For energy efficiency options, the inclusion of multiple benefits in some cases triples their overall benefit, notably where they heavily reduce coal use. For clarity, the new curve can be seen alone in Figure 3.

Figure 2. Comparison: global GHG abatement benefit curve: original benefits curve and benefits curve with co-benefits

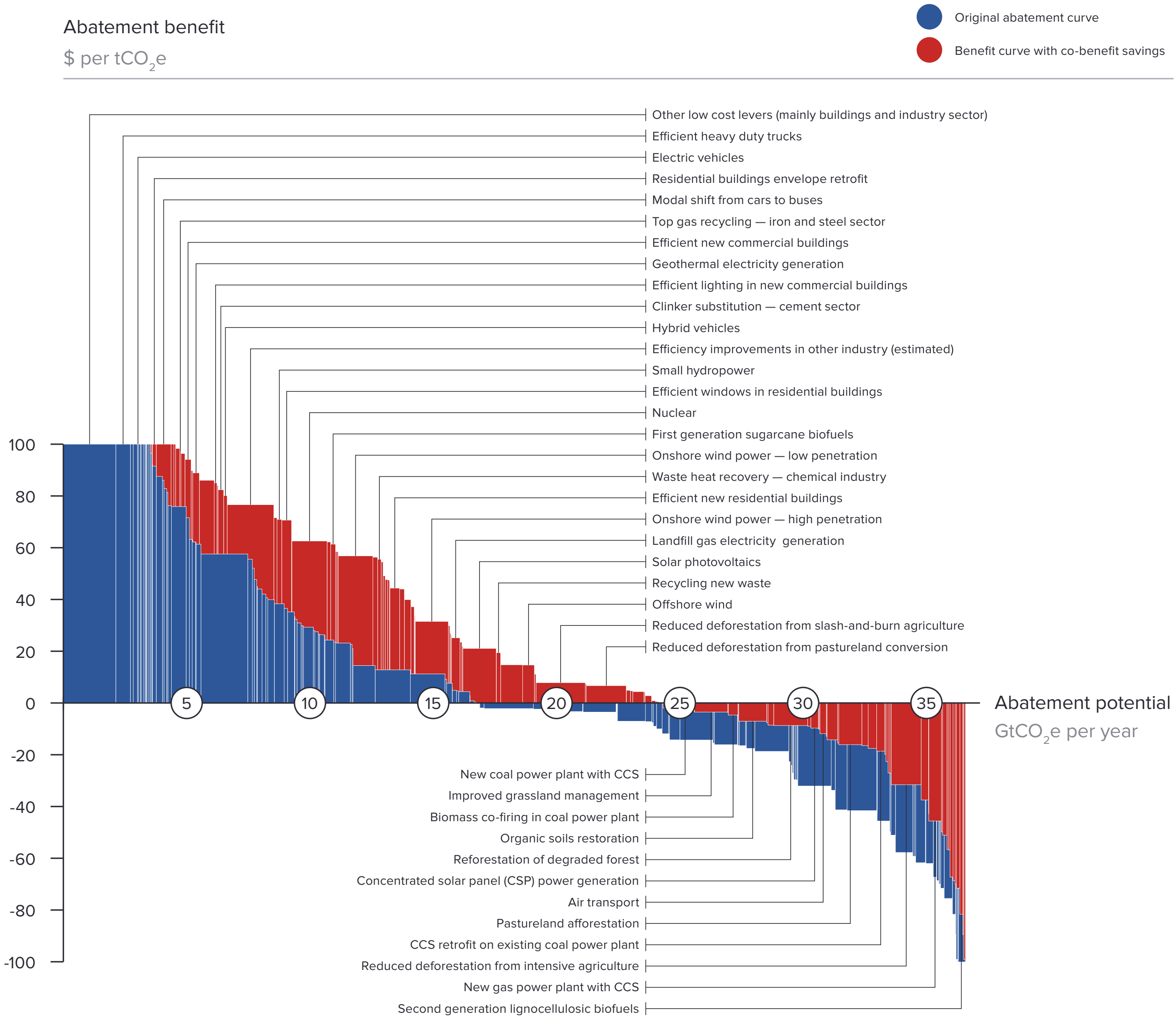
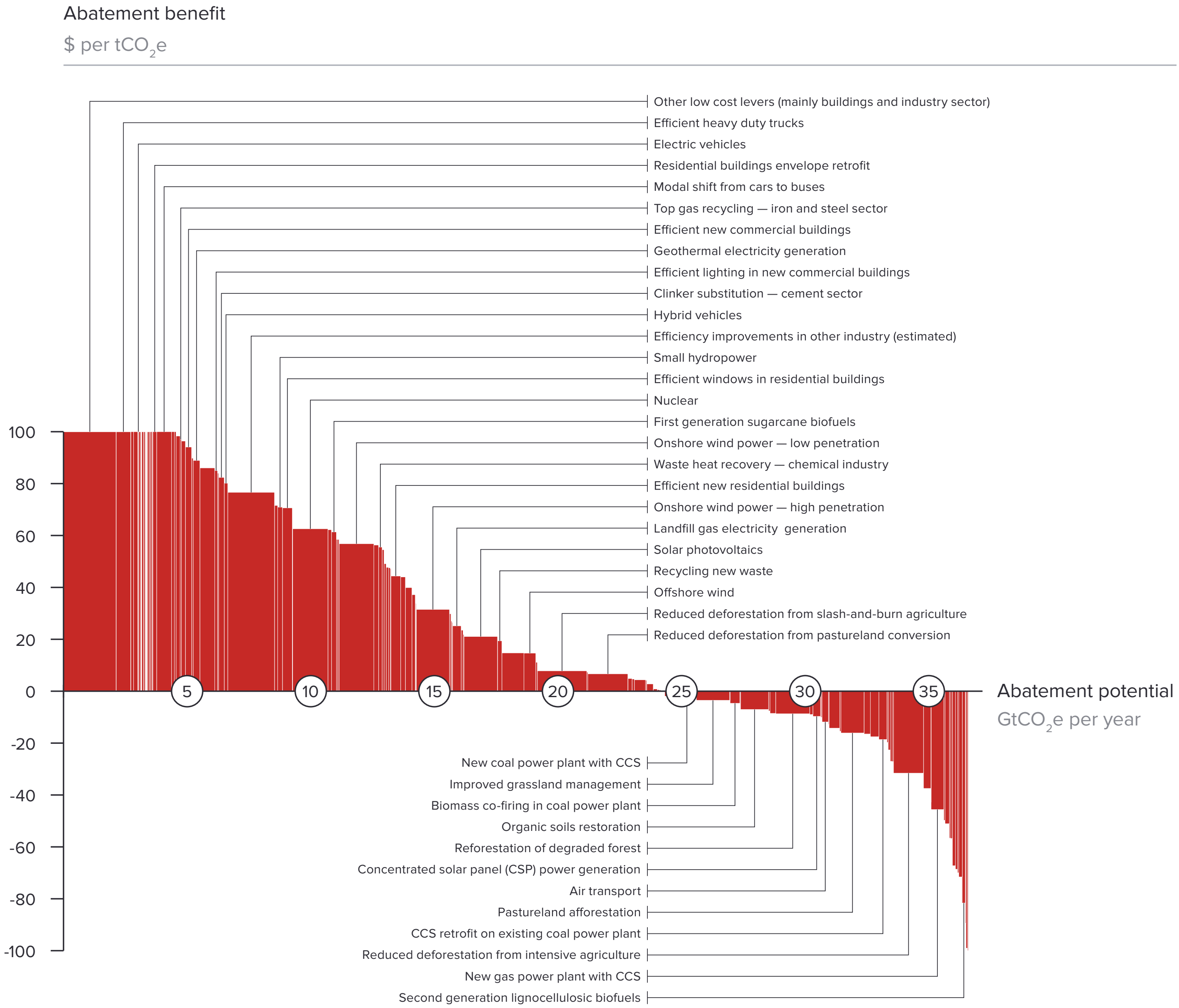


Figure 3. Global GHG abatement benefit curve including co-benefits: 2030



ENDNOTES

[1] New Climate Economy (NCE) is grateful to the individuals that provided inputs and contributions to this note. These include Stephane Hallegatte, Kirk Hamilton, Ian Parry, Simon Buckle, Michael Jacobs, Surabi Menon and Sebastian Schienle. They are, however, not responsible for the accuracy, content, findings or recommendations. The findings do not necessarily reflect their views, or those of the organisations they represent.

[2] MAC curves, for example, cannot easily take into account transaction costs and programme costs, which can be significant in some cases and prevent options being implemented. Transaction and programme costs reflect political choices about which policies and programmes to implement and vary drastically from case to case. Equally, a range of non-financial barriers exist for a wide range of mitigation options, which are not accounted for in MAC curves. Split incentives or 'agency issues', for example, exist where the consumer or company making investments does not reap the financial benefits. And financing hurdles and rapid payback requirements from investors and consumers due to high private discount rates can also act as significant barriers to investment. For further details see: Kesicki, F. and Ekins, P., 2012. Marginal abatement cost curves: a call for caution. *Climate Policy*, 12 (2), 219–236.

[3] For example, see: Seto, K.C. and Dhakal, S., 2014. Chapter 12: Human Settlements, Infrastructure, and Spatial Planning. *In Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, et al. (eds.). Cambridge University Press, Cambridge, UK, and New York. Available at: http://www.mitigation2014.org. For a contrary perspective, see, for example, Alcott, H. and Greenstone, M., 2012. Is There an Energy Efficiency Gap? *The Journal of Economic Perspectives*, 26 (1).

[4] McKinsey & Company, 2015 (forthcoming). Global GHG Abatement Cost Curve v3.0. Version 2.1 is available at: http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves.

[5] Prices are in 2010 real US$. Data are from International Energy Agency (IEA), 2010. *World Energy Outlook 2010*.

[6] Lim, S.S. et al., 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*, 380. 2224–60.

[7] Hamilton, K., 2015 (forthcoming). *Calculating $PM_{2.5}$ Damages as % of GDP for Top CO_2 Emitters: A Technical Note. New Climate Economy contributing paper*. To be available at: http://newclimateeconomy.report.

[8] West et al., 2013. Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health. *Nature Climate Change*, vol. 3, October. 885–889.

[9] West et al. use a form of environmental Kuznets curve, so developing countries are less polluting in 2030 under business as usual than they would be if no local pollution cleanup effort were made.

[10] Holland, M. et al., 2011. *Technical Policy Briefing Note 6: Ancillary Air Quality Benefits The Reduction in Air Quality Impacts and Associated Economic Benefits of Mitigation Policy: Summary of Results from the EC RTD Climate Cost Project*. European Commission, Brussels.

[11] Parry, I., Veung, C. and Heine, D., 2014. *How Much Carbon Pricing is in Countries' Own Interests? The Critical Role of Co-Benefits*. IMF Working Paper WP/14/174. Available at: http://www.imf.org/external/pubs/ft/wp/2014/wp14174.pdf.

[12] Based on NCE staff estimates. This project generated carbon savings worth 7.34t CO_2e/ha/year, and US$180/ha/year in net income benefits. See: World Resources Institute, *2008. Roots of Resilience: Growing the wealth of the poor. World Resources Report 2008*. WRI, Washington, DC. 262+viii.

See also: Sendzimir, J., Reij, C.P. and Magnuszewski, P., 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. *Ecology and Society*, 16(3):1.

Pye-Smith, C., 2013. The Quiet Revolution: how Niger's farmers are re-greening the parklands of the Sahel. *ICRAF Trees for Change no. 12*. Nairobi: World Agroforestry Center.

[13] Based on NCE staff estimates. This project generated carbon savings worth 6.25t CO_2e/ha/year and US$800/ha/year in net benefits (1994–2004). See: World Bank, 2005. Implementation Completion Report (SCL-44770 iDA-32220 TF-25677 TF-51385). *A Second Loess Plateau Watershed Rehabilitation Project*. Report No. 34612, 22 December.

[14] Based on NCE staff estimates. These activities on 300 million ha would generate 7.34t CO_2e/ha/year, and up to US$500/ha/year in net income benefits to local communities. The latter would come from a combination of sustainable management of the resource created and payments for ecosystem services. See the analysis for a likely 150 million ha of forest restoration in Verdone, M., Maginnis, S. and Seidl, A., 2015 (forthcoming). Re-examining the role of landscape restoration in REDD+. *International Union for the Conservation of Nature*. Their calculation assumes 34% of the restoration is agroforestry, 23% is planted forests, and 43% is improved secondary and naturally regenerated forests, all distributed across different biomes.

[15] See, for example: Costanza, R. et al., 2014. Changes in the global value of ecosystem services. *Global Environmental Change*, 26. 152–158. They estimate that all forests of the world in 2011 produced a net value of ecosystem services – monetised and not monetised – of US$16.2 trillion or just over US$4,000/ha/year.

[16] Brown, S. and Huntington, H., 2010. *Estimating US Oil Security Premiums*. Discussion paper 10-05. Resources for the Future, Washington, DC.

[17] Parry, I.W., Walls, M. and Harrington, W., 2007. Automobile externalities and policies. *Journal of Economic Literature*, 45 (2). 373–399. DOI: 10.1257/jel.45.2.373.

[18] Parry et al., 2014. *How Much Carbon Pricing is in Countries' Own Interests? The Critical Role of Co-Benefits*.

[19] The variation is substantial across countries; for example, net co-benefits are actually negative in cases (e.g. several European countries) where current fuel excises exceed combined pollution, congestion, accident and road damage benefits, but are strongly positive in other cases (including the United States).

[20] Parry et al., 2007. *Automobile externalities and policies*.

[21] To avoid double counting, the baseline of all energy-consuming sectors includes indirect emissions from the power sector. Similarly the transport baseline includes indirect emissions from the petroleum and gas sectors. Therefore the production output in sectors like power, petroleum and gas are reduced before any abatement measures in that sector are applied.

[22] The "business-as-usual" scenario builds on the International Energy Agency's *World Energy Outlook 2010* reference case for 2030. It amounts to emissions of ~68Gt CO_2e in 2030.

[23] From McKinsey's Global GHG Abatement Cost Curve v3.0; BAU from International Energy Agency *World Energy Outlook 2010* and McKinsey analysis.

[24] The abatement benefits denoted in Figure 2 are "capped" at US$100/t CO_2e. In the original uncapped analysis, some levers generate benefits of up to US$250/t CO_2e. We have capped the benefits to emphasise those levers for which the cost–benefit ratio changes when co-benefits are included. Levers with benefits over US$100/t CO_2e have a compelling economic case for action without consideration of broader benefits.

ABOUT THE NEW CLIMATE ECONOMY

The Global Commission on the Economy and Climate is a major new international initiative to examine the economic benefits and costs of acting on climate change. Chaired by former President of Mexico Felipe Calderón, the Commission comprises former heads of government and finance ministers, and leaders in the fields of economics, business and finance.

The New Climate Economy (NCE) is the Commission's flagship project. It provides independent and authoritative evidence on the relationship between actions which can strengthen economic performance and those which reduce the risk of climate change. It reported in September 2014 in advance of the UN Climate Summit. It aims to influence global debate about the future of economic growth and climate action.