The potential of scaling up proven low-carbon solutions

Final report

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1. Executive summary

The world is entering the time of implementation of actions to reduce greenhouse gas emissions. For more than 20 years, nations have been negotiating solutions to tackle climate change, and though progress has been made, it is clearly not enough to reach the 2 degrees Celsius target. The COP21 in Paris calls for a historic turning point. Prior to the COP more than 150 countries have submitted Intended Nationally Determined Contributions (INDCs) covering around 87% of global emissions in 2010 (excluding LULUCF) and 88% of global population (CAT 2015). Implementing these INDCs would still not be enough to bring the world to a trajectory of 2°C warming. In fact, the latest UNEP emissions gap report estimates the emissions gap in 2030 as 14 Gt CO_2e[1] (range 12-17Gt). Clearly, ambitions need to increase and implementation of the pledges need no delay.

The argument that decoupling emissions from the economy is difficult, expensive, and compromises economic development no longer holds. This report shows that there are low-carbon solutions that have been successfully implemented in both developed and developing countries, which are not only reducing emissions but also contributing to sustainable development, economic growth and poverty reduction. We show that scaling up or replicating proven solutions in other countries is feasible and could lead to substantial global emission reductions. Moreover, we show that many of these solutions are cost-effective.

The potential mitigation impact of scaling up proven low carbon solutions provides strong arguments to the international climate community to act quickly. By showing what is already achieved at national levels, we hope to encourage national governments to pledge more ambitious commitments and start implementation sooner than later.

What are low carbon solutions?

In this report we define low carbon solutions as policy packages and/or bundles of technologies and policies that enable countries to reduce greenhouse emissions in a specific sector of the economy. Low carbon solutions also deliver benefits linked to sustainable economic growth and/or poverty reduction. Our study focuses on concrete examples of low-carbon solutions that have been tested by individual countries (or regions in the case of the EU) and that have proven mitigation impacts and positive co-benefits to the environment and society. Table 1 below shows the low-carbon solutions that were considered in this study.

[1] UNEP (2015). The Emissions Gap Report 2015. United Nations Environment Programme (UNEP), Nairobi

Table 1 Solutions assessed in the study

Wind power (Denmark)
Wind power (Brazil)
Solar PV (Bangladesh)
Solar PV (Germany)
Bioenergy for heating (Finland)
Solar water heating (China)
Vehicle fuel efficiency (EU)
Bus rapid transit (Colombia)
Reducing methane from fossil fuel production (USA)
Industrial efficiency improvements (China)
Efficiency standards for electric motors (USA)
Appliance efficiency (Japan)
Building energy efficiency (Germany)
Building energy efficiency (Mexico)
Efficient cookstoves (China)
Low Carbon Agricultural Programme (Brazil)
Reducing deforestation (Brazil)
Payments for ecosystem services (Costa Rica)
Cutting food waste (Denmark)

How are the mitigation impacts and costs estimated?

We estimate the potential greenhouse gas emission reductions of replicating the solutions in selected countries and regions for the year 2025 and 2030 compared to current policies or trends baseline.

We use two methods to estimate the emission reductions: (i) share of potential achieved and (ii) historic development. The methodology is tailored to individual solutions; therefore, the selection of each method depends on the characteristics of the solution and data availability. For example, for some solutions there is published information on what has been achieved in relation to their mitigation potential; whereas for other solutions these data is not available, but rather the historic development of the solution.

To calculate the abatement costs of upscaling the low-carbon solutions we use marginal abatement costs either per unit of implementation or per unit of emission reduction, and apply these to the estimated impact of scaling-up the solutions. We differentiate the emission reduction factors by country or region when data is available. The main challenge of estimating the abatement costs is the limited data available on abatement costs per solution/per country. Considering this limitation, we use the marginal abatement costs from MAC-curves already developed by McKinsey in 2009. The forecasted McKinsey abatement costs to 2030 include an estimated learning experience from 2009 to 2030; for example, they assumed 18% learning rate for renewable energy (RE) solutions. For the solar and PV solutions in our analysis, the learning rate could be even higher since we scale up very successful country solutions to the whole world, leading to a RE deployment in 2030 beyond the McKinsey's forecast. This could also result into lower abatement costs than those estimated by McKinsey.

What will these solutions contribute in 2025 and 2030?

Our analysis shows that replicating these proven low carbon solutions alone could save an average of 9 Gt CO_2e in 2025 and 12 Gt CO_2e in 2030, with an uncertainty of about 20%. This is equivalent to about 60% of the emissions gap between current policies and the 2°C path in 2030[2]. Figure 1 shows the estimated emission reductions from the low-carbon solutions assessed in this study. The range of greenhouse gas emissions reductions delivered by the solutions we have analysed is quite large. However, even solutions with relatively limited reductions in our analysis, may deliver significant societal benefits through co-benefits or have a higher potential if implemented in a different way.

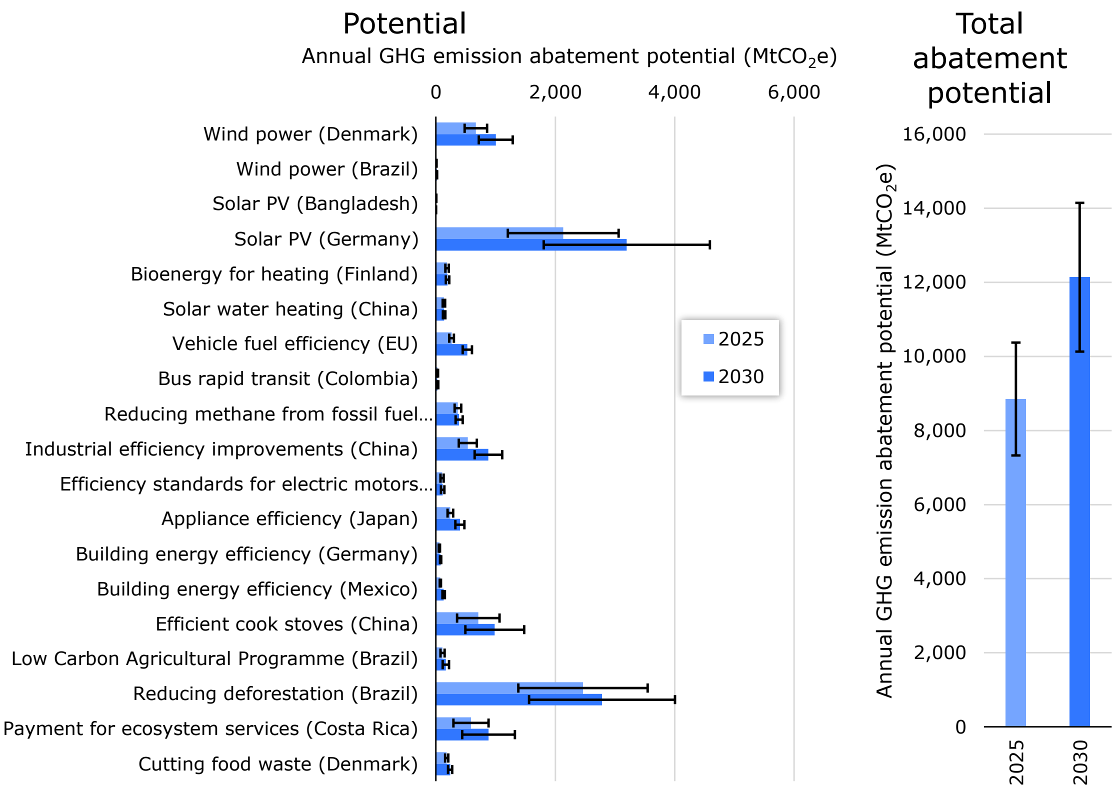

Figure 1. Aggregate and disaggregate emission abatement potential of low carbon solutions

The study also shows that low-carbon solutions not only avoid emissions but also provide co-benefits to natural resources, society and the economy. Among the benefits, we highlight positive effects in employment, enhancement of health conditions and livelihoods, increasing access to clean energy

[2] UNEP (2015). The Emissions Gap Report 2015. United Nations Environment Programme (UNEP), Nairobi

and enhancing ecosystem services. We expect that by scaling up these low carbon solutions these co-benefits will also be achieved. Figure 2 summarises the co-benefits per solution. The grey boxes in the bioenergy solution indicate that scaling would need to account for proper management of biomass sources to prevent soil and biodiversity degradation.

Solutions	Enhanced air quality	Economic benefits	Cost reduction in waste treatment	Enhanced indoor air quality	Health and associated cost benefits	Increased electrification rate	Increased education opportunities	Increased gender equality	Increased energy security	Increased safety	Water and soil protection	Forest and biodiversity protection
Wind power (Denmark)	■	■							■			
Wind power (Brazil)	■	■							■			
Solar PV (Bangladesh)	■	■		■	■	■	■	■		■		
Solar PV (Germany)	■	■			■							
Bioenergy for heating (Finland)		■									grey	grey
Solar water heating (China)	■	■								■		
Vehicle fuel efficiency (EU)	■	■			■				■			
Bus rapid transit (Colombia)	■	■			■							
Reducing methane from fossil fuel production (USA)	■	■			■				■	■		
Industrial efficiency improvements (China)	■	■			■					■		
Efficiency standards for electric motors (USA)	■	■			■							
Appliance efficiency (Japan)	■	■			■							
Building energy efficiency (Germany)		■		■	■							
Building energy efficiency (Mexico)					■						■	
Efficient cook stoves (China)	■			■	■			■				■
Low Carbon Agricultural Programme (Brazil)		■									■	■
Reducing deforestation (Brazil)											■	■
Payment for ecosystem services (Costa Rica)		■									■	■
Cutting food waste (Denmark)	■	■	■								■	■

Figure 2. Co-benefits to natural resources, society and the economy

For many of the cases, the costs of scaling up the solutions are less than the direct financial benefits they deliver. The aggregate abatement costs are on average $-18.2 billion in 2025 and $-38.5 billion in 2030 (Figure 3). Scaling up all solutions would result in approximate costs of $-2/ton$CO_2$e in 2025 and $-3/ton$CO_2$e in 2030. These costs figures should be considered conservative as they do not include the co-benefits, nor the avoided climate change damages caused by business-as-usual options.

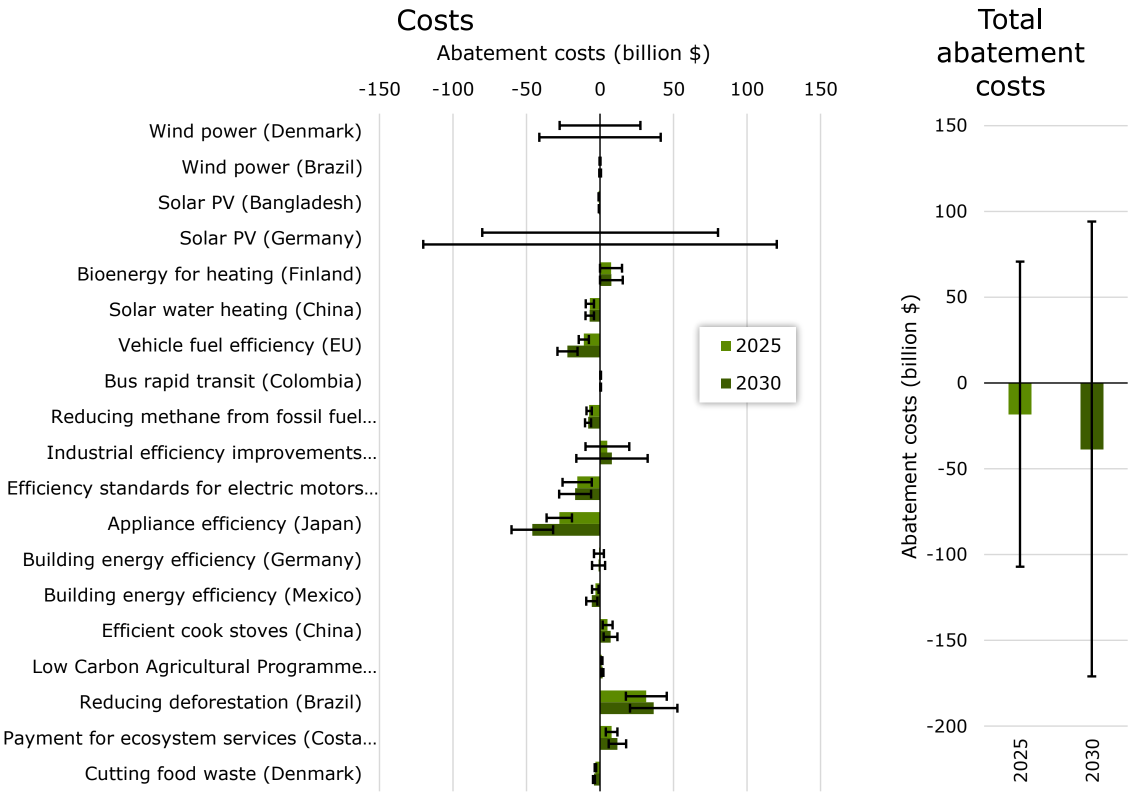

Figure 3. Aggregate and disaggregate abatement costs of low-carbon solutions

2. Introduction

A group of countries from developed and developing regions are demonstrating that decoupling emissions from economic growth is possible. By implementing low-carbon solutions through policy packages and technologies, these countries demonstrate concrete ways to mitigate climate change. How much emissions could the world collectively cut if other countries replicate these proven low-carbon solutions?

The latest analysis of government climate pledges reveals that national commitments thus far are not enough to limit the increase of global average temperature to below 2°C. There is still a large emissions gap in 2030 of 11 to 22 $GtCO_2e$ between the aggregate effect of the pledges in the Intended Nationally Determined Contributions (INDC) submitted to 1st October 2015 and the level consistent with 2ºC (UNFCCC, 2015). This state of affairs calls not only for increasing the level of ambition but also for a rapid implementation of pledges. It is imperative to move from discussing mitigation potentials to actions on the ground to quickly get back on a 2 degree Celsius trajectory.

With the Paris conference, we are indeed entering the era of implementation and proven low-carbon solutions become one of the most concrete options available to accelerate mitigation action. These solutions, already applied in both developed and developing countries, cover multiple sectors, such as renewable energy, transport, buildings, industry, agriculture and forestry. They often consists of policies that enable changes in a specific sector, mostly by applying specific technologies. Scaling up already proven low-carbon solutions can contribute to additional emissions reduction and can trigger incentives to increase climate mitigation ambition at the national level.

In this report we present a quantitative assessment of the greenhouse gases (GHG) mitigation impact in 2025 and 2030 of scaling up selected solutions within particular country groups. We focus on low-carbon solutions already implemented in specific countries, which have successfully reduced GHG, and define the groups of comparable countries capable of replicating the successes. We also present an analysis of the barriers and key drivers for scaling up the mitigation impact, as well as the co-benefits that each solution provides.

The report illustrates the scaling potential of proven-low carbon solutions and present an estimation of how much GHG emissions could be cut if these would be replicated in specific country groups. We hope that these examples will inspire national governments to act and contribute to reduce the emissions to the level needed to get the world back to the 2ºC trajectory.

3. Methodological approach

1. Identification and characterisation of low-carbon solutions

We identified existing and tested low carbon solutions that are considered examples of best practices in climate change mitigation, both in developed and developing countries. We aimed at having a broad coverage of economic sectors, including energy, industry, land use, land use change and forestry (LULUCF), buildings, transport and agriculture. We began with identifying and scoping out more than 50 solutions applying three main conditions: (i) solutions are proven to be working on the ground, (ii) solutions have significant mitigation impact, and (iii) solutions have high potential for replicability. The analysis was based on both literature review, in-house expert knowledge, and inputs from project partners. The scoping analysis resulted in the selection of 30 solutions which were further characterised. The characterisation, also based on a literature review, provided a qualitative description of the solutions in view of five categories: (i) climate mitigation effects, (ii) financial characteristics, (iii) environmental co-benefits, (iv) socio-economic co-benefits, and (v) implementation characteristics. Altogether, the characterisation presented the key features of the solutions, the emission reduction achieved, the abatement costs, the impacts to natural resources and society, and the factors that determined their successful implementation. This qualitative assessment served to select the most promising cases from the sample, taking into account a balance between the potential mitigation impact and the co-benefits. These cases are the ones presented in this report.

2. Estimation of the mitigation impact and costs of low carbon solutions

Based on the characterisation of the solutions we identify the conditions for scalability of each solution; namely what are the various conditions that a country should have in place, or could easily fix to implement the solution (e.g. development status, climatic conditions, specific policies, other enabling conditions). Based on these conditions we select a group of countries or regions in which the solution could be replicated. This selection is made on a solution by solution basis, and the same country or region can be included in the selection for multiple solutions. For example, for some solutions we use country groupings based in income level (low, medium and high income countries). These country groupings partly overlap with groupings used for other solutions (e.g. based on climatic conditions).

Overlap between solutions is not assessed in the study; however, we selected the countries and regions in such a way that overlap is minimised. The country groupings for each solution are in Annex 1.

We assess the potential greenhouse gas emission reductions of replicating the solutions in the selected countries and regions for the year 2025 and 2030 compared to a current policies or trends baseline. We only include direct emissions (scope 1) and emissions related to the use of electricity or heat (scope 2) in our analysis. Indirect emissions, such as emissions related to material production or end-of-life treatment, are not included in the analysis.

Given the variety in the low-carbon solutions analysed, there is no general methodology that can be applied for all solutions. However, for each we select one of the following two options, based on, A) share of potential achieved, or B) historic development. These general methodologies are schematically shown in Figure 4. For each solution, we select the most suitable approach—taking into account the characteristics of the solution and data availability. The general methodologies are further customized for each of the solutions. The specific methodology applied for each solution is described individually in the following sections.

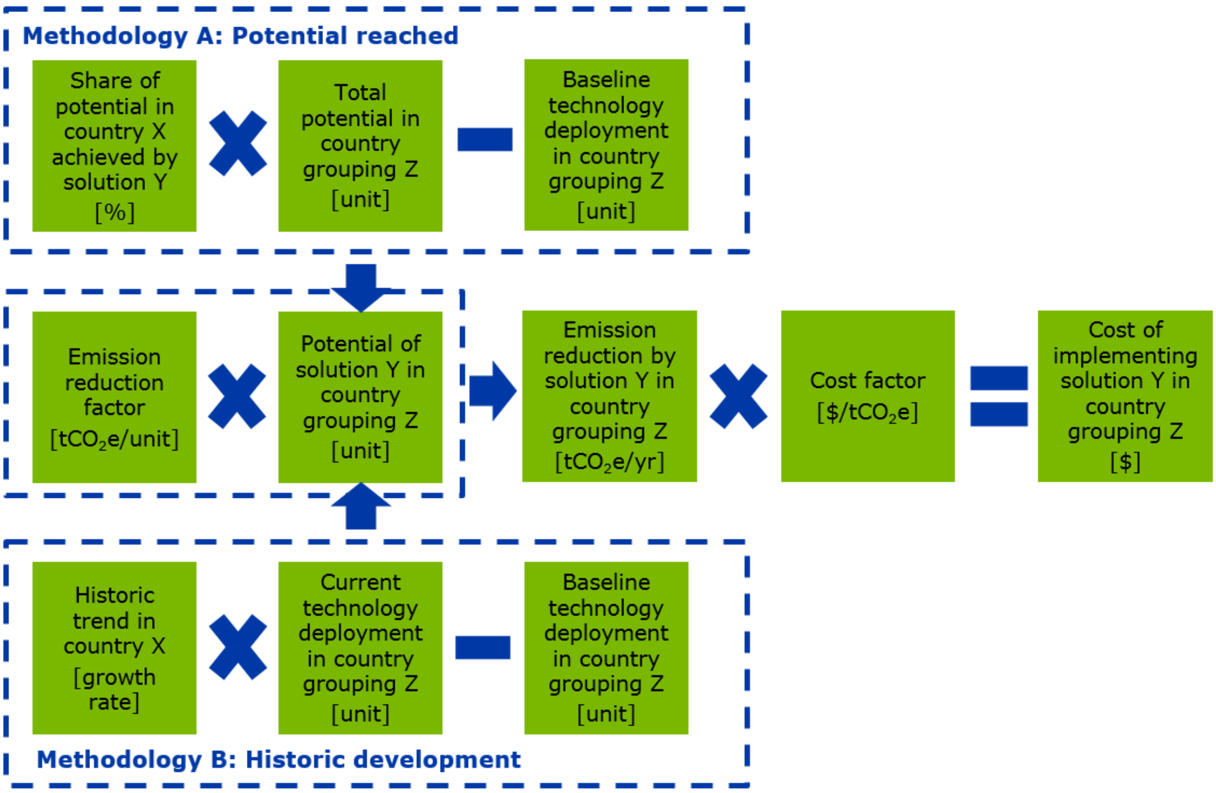

Figure 4 Schematic representation of the general methodology

The general methodologies, shown in *Figure 4*, consists of the following steps:

- We select an appropriate unit of implementation of the solution. Examples of a unit implementation are gigawatts installed capacity for the solutions in wind and solar energy and hectares of land for solutions in reforestation. For some solutions, the unit of implementation is a unit per capita.
- We determine the deployment of the unit of implementation in 2025 and 2030 if the solution is replicated in the selected countries and regions. Note that with both approaches, this does not

reflect the full potential of the technology or measure applied by the solution but is based on achieving the proven success rate.

  - Methodology A: We determine the total potential for this unit of implementation in both the country the solution is applied in and the country grouping selected for upscaling. We then apply the share of the (technical) potential achieved by the solution to the potential in the country grouping for upscaling.
  - Methodology B: We analyse the historic development of the unit of implementation achieved by the low-carbon solution and apply this development to the current status in the country grouping for upscaling.
- We determine the baseline deployment of the unit of implementation in the country grouping in 2025 and 2030. Whenever possible, we do this based on existing scenarios (e.g. IEA current policy scenarios). If no existing scenario can be used, we assume the historic trend continues until 2030. The additional deployment from scaling-up the solution is the difference between this baseline and the deployment determined based on methodology A or B.
- To calculate the associated emissions reduction, we define specific emission reduction factors based on literature per unit of implementation of the solution (e.g. $MtCO_2e$ / GW solar power). Where relevant these emission reduction factors are differentiated by country or region (e.g. to reflect differences in power generation fuel mix or efficiency).

To calculate the costs of upscaling the low-carbon solutions to the country groupings we determine specific marginal abatement costs either per unit of implementation or per unit of emission reduction based on literature (e.g. MAC-curves) and apply these to the estimated impact of scaling-up the solutions. Where relevant these emission reduction factors are differentiated by country or region. All marginal abatement costs are converted to USD2010[3].

[3] We used 2010 dollars to be able to compare more easily with other publications on the topic and which are mainly using 2010 dollars

4. Low carbon solutions in the renewable energy sector

1. Wind power, Denmark and Brazil

In both Denmark and Brazil, the government has adopted policies to increase the generation of, amongst others, wind power generation.

In 1985, the Danish parliament decided not to build any more nuclear power plants. Today, Denmark is among the world leaders in wind power technology. In 2014, Denmark had an installed capacity of 855 W/capita of wind power, which supplied 39% of the Danish electricity consumption in 2014. Denmark has very ambitious energy targets. Among those are[4]:

- Energy consumption covered 100% by renewable sources in 2050
- Power and heat supply covered 100% by renewable sources in 2035
- Coal totally phased out by 2030 (fossil free target)

Interim targets for 2020 which are expected to be achieved are the following:

- 35% renewable energy in final energy consumption
- 50% of electricity consumption covered by wind power

Wind energy in Denmark is supported thought a premium tariff. The amount of the tariff is variable and comprised of a guaranteed bonus, but limited by a statutory maximum amount. Onshore wind plants commissioned on or after January 2014 obtain a guaranteed bonus of approximately €ct3/kWh, but the maximum amount which is equivalent to the bonus plus the market price may not be higher than €ct8/kWh for the sum of 6,600 full load hours[5]. Plant operators receive the amount from Energienet.dk, which owns the Danish electricity and gas transmission system. Furthermore, expansion of the electricity grids will be financed through a Public Service Obligation (PSO) scheme via the Energy Bill.

In addition to the government action, cooperatives have played an important role in the development of wind power by increasing public acceptance, through ensuring that communities directly benefitted from wind power development. Especially in the form of profit-sharing from electricity generation from renewable energy sources and from lower energy taxes[6].

In Brazil, the promotion of wind energy is part of a general auction system for electricity. Since reforming its electricity market in 2004, electricity auctions have played an important role in Brazil

[4] Greenpeace (2014), Denmark's commitment to 100% renewable energy, available at: http://www.greenpeace.org/international/Global/international/briefings/climate/2014/BRIEFING-Denmarks-commitment-to-100pct-renewable-energy.pdf
[5] Greentech (2015), available at http://greentech.dk/country/denmark/
[6] IRENA-GWEC: 30 YEARS OF POLICIES FOR WIND ENERGY, available at https://www.irena.org/documentdownloads/publications/gwec_denmark.pdf

and have resulted in the contracting of 72 GW of new capacity[7], of which 29% consists of NCRE including wind energy. The new regulatory framework seeks to ensure adequate system expansion to meet demand growth and maintain security of supply. In order to encourage diversification among renewables, contracts were designed in such a way that was attractive to technologies other than hydro, which led to highly competitive auction involving a variety of public and private actors.

In Brazil all energy auctions are organized by the government. Once an auction committee is formed, the main auction tasks are distributed among various entities. The auction committee is also responsible for determining different aspects of the auction, including the type of auction, suggested price caps, preparing the tender and coordinating the planning of transmission. With regards to promoting the development of renewable energy, two types of auction have been most important: the regular new energy auctions and the reserve auctions. Regular new energy auctions are carried out biannually to ensure adequate system expansion. Reserve auctions are carried out at the government's discretion with the aim of increasing the reserve margin of the electricity system.
In countries other than Brazil and Denmark successful wind solutions have also already been implemented. For example in China, a strong growth in wind energy is seen and in the USA policies including production tax credit (PTC) and Renewables Portfolio Standards (RPS) have also contributed to a strong growth.[8]

In Denmark in 2013, in total 3,749,412 tons of coal were saved and 8.6 $MtCO_2e$ (776 g/ kWh) avoided by this solution[9]. In Brazil an emission reduction of approximately 1.1 $MtCO_2e$/year is realized. This number has been calculated based on Brazil's average emission factor of power generation of 94tCO_2e/GWh[10] and a wind energy production of 12,210 GWh[11]. Although the total emission reduction by wind energy in Brazil is lower than in Denmark, this doesn't say anything about the effectiveness of the measures since the wind energy market in both countries have a different stage of maturity. The solutions that have been implemented in Brazil have been very effective, resulting in a growth rate of wind energy generation as high as 71% in the period between 2008 and 2013[12].

Environmental and social co-benefits

Implementing wind energy brings about positive environmental and social co-benefits. For example, the replacement of fossil fuels by clean energy reduces air pollution. In effect, in Brazil renewables have almost fully displaced thermal generation (coal and gas) in auctions since 2009.
Furthermore it has positive impact on employment. Denmark's transition to 100% renewable energy, for which wind power plays a crucial part, is expected to generate at least 30 to 40,000 new jobs

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[7] CIGRE (2014), Lessons learned from the auction-based approach to integrate wind generation in the Brazilian electricity market, available at http://digilib.monenco.com/documents/10157/2530512/C5_303_2014.pdf
[8] Irena (2012), 30 years of policies for wind energy. Available at: http://www.irena.org/DocumentDownloads/Publications/IRENA_GWEC_WindReport_Full.pdf
[9] IEA (2014), Wind 2013 Annual Report, available at: https://www.ieawind.org/annual_reports_PDF/2013/2013%20AR_small_090114.pdf
[10] McKinsey & Company, Pathways to a Low-Carbon Economy for Brazil
[11] EPE (2015), Balanço Energético Nacional, available at https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2015.pdf
[12] EPE (2015), Balanço Energético Nacional, available at https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2015.pdf

(gross) in a country of 5.5 million people[13]. For Brazil, it is estimated that wind power growth will generate 90,000 gross jobs from 2012 to 2016[14]. In a case study estimating job creation by wind energy in Brazil, estimating both direct jobs (e.g. in manufacturing and operations & management) and indirect jobs (e.g. in upstream supply chains for materials and inputs for manufacturing), a job potential of 13.5 persons-year equivalent for each MW installed between manufacture and first year of operation of a wind power plant, and 24.5 persons-year equivalent over the wind farm lifetime have been estimated[15].

Other economic co-benefits of wind energy are: bringing economic activity to project sites and supply chain entities, stimulating domestic manufacturing, and enhancing export of wind turbines, components and consulting expertise. For example in Brazil, with wind farms, financial benefits go to the owners of the land upon which the farms are installed, providing land owners (in often rural areas) an extra monthly or yearly income.

Increasing the share of wind energy can also make a country less dependent on imported fossil fuel (or allow more fossil fuel exports if it is a producing country) and less dependent on fossil fuel price increases.

Upscaling methodology

The potential of the wind energy strategies of Denmark and Brazil have been analysed based on scaling it up to multiple countries. As shown in the table below, two options for upscaling have been assessed. In the first option, the wind energy solution of Denmark is scaled up to high and upper middle income countries and the wind energy solution of Brazil is scaled up to lower income countries. In the second option, the wind energy solution of Denmark is scaled up to all countries. The specific countries are listed in the annex.

	Upscaling to relative wind energy level of Denmark	**Upscaling to relative wind energy level of Brazil**
Option 1	• High income countries • Upper middle income countries	• Lower middle income countries • Low income countries • Countries with no income data available (limited group)
Option 2	• All countries	

To assess the upscaling potential, first the share of the total realistic on shore wind power potential in Denmark and Brazil has been determined by dividing their current onshore wind energy generation[16] by their realistic on shore wind power potential[17]. This potential has been determined by an Ecofys

[13] Energy Supply (2011), available at: http://www.energy-supply.dk/article/view/64607/eksperter_40000_jobs_i_nye_energijobs?ref=newsletter=e6zjtvnp#.VcSqSvmqqkq

[14] Journal of Sustainable Development of Energy, Water and Environment Systems (2013), Socio-economic Benefits of Wind Power in Brazil, available at: http://dx.doi.org/10.13044/j.sdewes.2013.01.0003

[15] Simas and Pacca (2014), assessing employment in renewable energy technologies: A case study for wind power in Brazil. Renewable and Sustainable Energy Reviews. doi:10.1016/j.rser.2013.11.046

[16] IEA database 2014, 2012 numbers. For Brazil no offshore wind energy assumed, for Denmark offshore wind energy taken from IEA wind annual report 2013

[17] Confidential Ecofys analysis (2014)

project in 2015 and takes into account available amount of land (including limitations such as land-use competition and acceptance), resource quality and technology of wind turbines. Realistic on shore wind potentials are available as a range for each country and local capacity factors are not taken into account.

To estimate how much wind energy will be generated in other countries in 2030, this share of the total realistic on shore wind potential in Denmark and Brazil is scaled up to other countries by multiplying it with their realistic on shore wind potential[18]. As each potential is expressed in a range, we take low and high estimates based on the realized share of the lowest point in the range in Denmark or Brazil and at the highest point of the range. However, for some countries with high potential compared to electricity generation, the estimate might produce (unrealistic) high values so we constrain it to 50% of the total electricity generation in each country in 2030[19]. Another potential methodology might be to extrapolate the growth rate of wind energy in Brazil to other countries. However, since wind energy in Brazil in absolute values is still relatively small compared to the total amount of land available, it seems unrealistic to assume that the same growth rate can be achieved in other countries where there may already be significant wind energy generation.

To estimate the upscaling potential, an amount of wind energy in business as usual scenario has been deducted from the total wind energy estimate. This base case wind production has been calculated by extrapolating the current wind energy production in a country[20] based on the growth rate of wind energy in that country[21], or region if country data is not available. Since this amount of wind energy includes offshore, a share of offshore wind energy varying between 0 (highest potential scenario) and 90% (lowest potential scenario) has been deducted, contributing to an uncertainty range in the outcomes.

The resulting upscaling potential in energy has been multiplied by an emission factor of energy generation per country[22]. For the few countries where no emission factor is known, the world average of 533 gCO_2/kWh has been used. Although, in the early stages of development of wind energy it is most likely to displace marginal electricity, as we include amounts of wind energy generation up to 50% of the total electricity generation the average emission factor is preferred. The marginal emission factor in countries like Brazil, where hydro power makes up a large share of the electricity generation, can be significantly lower than the average emission factor.

For each country a minimum and maximum value of emission reduction by upscaling the solutions of Denmark and Brazil has been calculated. The following inputs contribute to the difference between these values:

[18] Confidential Ecofys analysis (2014)
[19] IEA database 2015, 2012 numbers extrapolated to 2030 based on growth rate WEO new policies scenarios 2014. Where available (USA, Russia, Japan, China, India and Brazil) 2030 number in WEO new policies scenarios taken directly. . In case no IEA data available, CIA database has been used, available at https://www.cia.gov/library/publications/the-world-factbook/rankorder/2232rank.html#so
[20] IEA database 2014, 2012 numbers
[21] WEO new policies scenarios 2014
[22] IEA database 2014, 2012 numbers

- The realistic on shore wind power potential in a specific country is given as a range of which both extremes are used
- For very few small countries, no electricity generation data is available. For these countries the minimum potential is assumed to be zero and the maximum potential is not capped by 50% of the total electricity generation
- For a few small countries, no wind energy generation data is available. For these countries the minimum potential is assumed to be zero and the maximum potential is assumed to be the total potential by upscaling the solutions of Denmark and Brazil, assuming zero wind energy production in a business as usual scenario
- The amount of wind energy in a base case scenario includes offshore wind energy. A share of offshore wind energy varying between 0 and 90% has been deducted to estimate a base case scenario for onshore wind energy

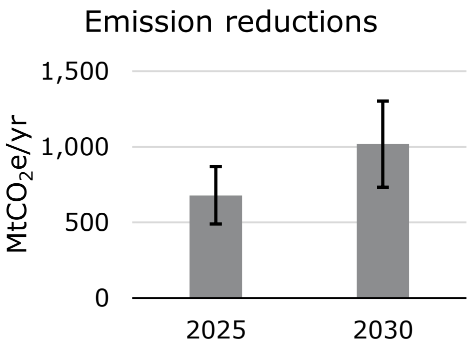
UPSCALING RESULTS

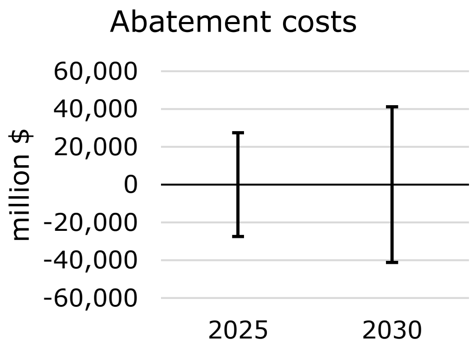
In option 1, if the wind energy solution of Denmark is scaled up to high and upper middle income countries and the wind energy solution of Brazil is scaled up to lower income countries, the resulting upscaling potential is estimated at 730-1310 $MtCO_2e$ in 2030.

The abatement costs for renewable energy in this report (solar and wind), have been based on the global GHG abatement cost curve beyond business-as-usual for projects implemented in the period up to 2030, as prepared by McKinsey. For wind energy, abatement costs of around $22-32 have been estimated for 2030. Since this abatement costs are a forecast, a learning rate has been taken into account. For example for solar PV a learning rate of 18% has been taken into account, which results in power generation costs going down from €180 per MWh in 2005 to €36 per MWh in 2030. However, since we analyse upscaling the renewable energy generation in very successful countries to the whole world, the amount of renewable energy in 2030 in our scenario, exceeds beyond the forecast of McKinsey. Therefore it is plausible, that also a higher learning rate can be reached and that costs for renewable energy drop below the values that McKinsey estimated.
To illustrate the effect of the price for renewable energy on the abatement costs, we'd like to introduce a high level example. In the case that renewable energy costs 1 cent per kWh more to produce than that of fossil energy, and given the avoided emissions are 500g CO2 per kWh, this yields abatement costs of 2 cents per kg CO2, or €20 per ton CO2. However, in case the renewable energy costs are 1 cent per kWh less than that of fossil energy, abatement costs would go down to -€20 per ton CO2. This shows how sensitive the mitigation costs are to the difference in electricity generation costs between conventional power and renewable power.
Due to the high amount of upscaling potential for wind energy that we assume in this analysis, it's plausible that the high scale of wind energy will cause wind energy to become cheaper than assumed by McKinsey. Therefore we include cost figures based on the abatement costs as assessed by McKinsey as a maximum ($22-32 per ton CO2[23]) and -$22-32 per ton CO2 as minimum. Due to the total volume of renewable energy, this leads to a large difference in total abatement costs. Please

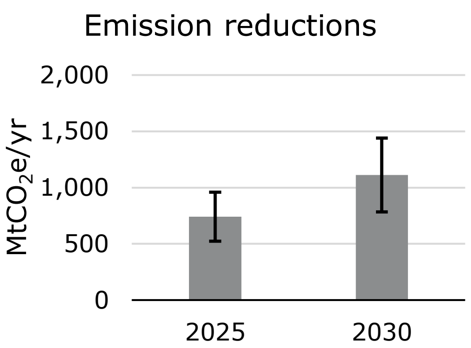
[23] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves

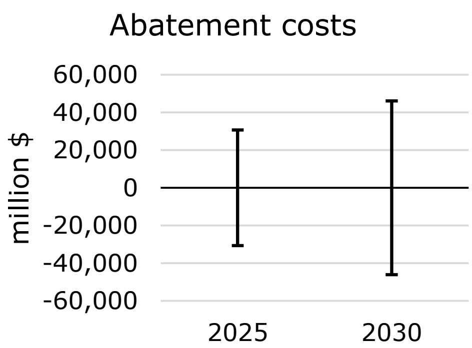
note that this is highly driven by volume and it's caused by only a 1 cent per kWh difference in cost assumptions.
Based on this assumed range for plausible abatement costs for wind energy, the abatement costs of scaling up this solution can be estimated at -$42,000 up to $42,000M per year in 2030.





In option 2, if the wind energy solution of Denmark is scaled up to all countries, the resulting upscaling potential is estimated at 780-1440$MtCO_2e$ in 2030. Based on the abatement costs of low and high penetration wind energy[24] (-$32-$32/tCO_2e) the abatement costs of scaling up this solution can be estimated at -$46,000-$46,000M per year in 2030.





KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

Some key drivers for implementation have been noted for both the wind energy solutions in Denmark and Brazil, which can also be expected in other countries to which the solution would be scaled up.

- The infrastructure needed for upscaling this solution can also be a major barrier for implementation: Two critical pillars for integration of wind power are system operation and a well-functioning power market. System operation means that accurate wind forecasts as well as adequate reserve capacity of other electricity sources exist, which are automatically managed by demand side. A well-functioning power market means that a balance is achieved (i.e. supply equals projected demand and power is well balanced), in Brazil this has been

[24] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves

achieved by giving fewer capacity certificates to wind power producers, so as to better reflect their contribution to the supply and demand balance. Transmission infrastructure must also be built to connect new power production site to the transmission and distribution network. Many countries also have policies that give preferential access to the grid for renewable energy compared to fossil based electricity and this can also help overcome transmission capacity limitations.

- In general public attitudes towards renewables are positive, yet local opposition to wind farms also exists. For example, there could be local opposition due to visual impacts of windfarms or fear of noise[25,26]. In this case countries could take Denmark's example of the Danish Renewable Energy Act (2009), which introduced specific measures for greater citizen involvement and the generation of local economic benefits which helped to ensure a more widespread acceptance of onshore wind. In particular, the Act contains four instruments to promote acceptance of onshore wind farms:
    - a fund to support the financing of preliminary investigations by local wind turbine owners' associations or groups;
    - a mandatory auctioning of a minimum 20 per cent of the shares in a wind turbine to neighbours living within a 4.5 km limit of the wind farm project;
    - a right of property owners to full compensation for loss of value to real property due to the siting of wind turbines in their vicinity; and
    - a fund to enhance local scenic and recreational values, such as nature restoration projects or the installation of renewable energy sources in public buildings.[27]
- The availability of wind resources is a pre-condition for good wind power production; hence the scalability of this solution should consider measures to provide power when wind does not blow.
- The geographic conditions need to be suitable for wind development.
- Reaching a high penetration level (up to 50%) of variable renewable energy sources might be a barrier in upscaling countries. Due to fluctuation of energy generated by these sources countries need solutions to cover for this, such as the possibility to export and import electricity from neighbouring countries or sufficient energy storage (e.g. pumped hydro, large scale battery storage, underground compressed air, etc.)

2. Solar PV, Bangladesh

The Government of Bangladesh has set up a national programme to subsidise the use of solar home systems (SHS) as a source of electricity in areas of Bangladesh where grid development is slow. The program is managed by the government owned Infrastructure Development Company (IDCOL). IDCOL certifies SHS equipment and so-called partner organisations (POs). The 47 eligible POs (like

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[25] Colby et al. (2009). Wind Turbine Sound and Health Effects, an Expert Panel Review
[26] Lima et al. (2013). Strategic impact management of wind power projects. Available at: http://www.sciencedirect.com/science/article/pii/S136403211300261X
[27] Olsen (2013)

BRAC, Grameen Shakti, RSF and other private sector companies) act as equipment dealers, install and maintain the SHS and provide consumer credit which reduces the monthly credit tranches to a level that is affordable for the rural customers. The POs offer a range of product sizes from 10 watts to 135 watts, so poorer customers can choose smaller systems that cost less. IDCOL receives funding from the Government of Bangladesh or directly from donor organisations. Funds are used to reduce the price of solar home systems for the end consumer (grants) or to refinance the consumer credit of the PO. Approximately 3.8 million of 36 million houses use Solar Home Systems in Bangladesh today. In a few months, 65,000 new connections were made, serving today 13 million beneficiaries[28] (24% of the off-grid population, 9% of the total population).

Since its inception in 2002, it is estimated that SHS has replaced ca. 220 million litres of kerosene, corresponding to approx. 580,000 tCO_2e[29].

In countries other than Bangladesh, examples of policies for electrification of rural areas can also be found. For example, in Brazil the PRODEEM project is a governmental sponsored project which promotes electrification of off-grid villages. It is sponsored by international donors and implemented through Brazilian utilities in the villages where they have started a pilot project using PV, wind and hybrid systems.[30]

Environmental and social co-benefits

The replacement of kerosene lamps by solar home systems induces environmental and social co-benefits. On the environmental side, the replacement of kerosene lamps reduces indoor air pollution. A reduction of respiratory diseases of woman (aged 16 and above) of 1.2% due to less indoor pollution was noted. According to a World Bank report, no negative environmental impacts are expected, but the improper disposal of lead-acid storage batteries poses a potential environmental hazard. However, since this type of battery has been used in SHS projects for over 10 years, there is evidence to suggest that good disposal practices are widely implemented.

Other social co-benefits exist, for example around 115,000 people are employed by SHS, principally in sales, installations and maintenance. Changes have been noted in the rural economy, for example snack shops stay open late, telephone facility booths are able to cater to more customers in the evening, therefore increasing income, and the reduced fear of thefts and robberies or burning incidents as fewer kerosene lamps are used. Furthermore the SHS programme has increased the electrification rate by 9% since 2002. Additionally, study hours in the evening have increased as a result of the SHS expansion, with a positive effect on education.

In addition, the installation of SHS empowers women and increases gender equality. Close to 17,000 technicians have been trained with more than 1,000 women technicians, many of them are assembling SHS accessories at local Grameen Technology Centres, others are providing after sales

[28] The daily start (2015), available at: http://www.thedailystar.net/op-ed/the-potential-solar-home-systems-bangladesh-82837

[29]Tiedemann, Silvana (2015) The Bangladeshi Solar Home System (SHS) Programme: Relevance and Development of the Supply Side in CISD Yearbook of Global Studies (2) May 2015. CISD yearbook of global studies (2015), available at http://www.cisd.soas.ac.uk/Files/docs/52944583-cisd-yearbook-of-global-studies-vol-2-with-intro.pdf

[30] Goldemberg et al, Expanding Access to Electricity in Brazil. Available at http://www.afrepren.org/project/gnesd/esdsi/brazil.pdf

service. Additionally, women can spend more time on leisure and social activities, as their sense of security after dark increases.

Upscaling methodology

The upscaling potential of the solar home systems in Bangladesh has been based on scaling it up to the current off-grid population of all other countries. For specific countries refer to *Table 5. Renewable energy solutions and country groupings*. The off-grid population has been calculated by using the share of population with grid access[31] and the total population[32] of each country. It has been assumed that, as in Bangladesh, solar home systems are installed for 24% of this off-grid population.

To estimate the resulting emission reduction of installing these solar home systems, the amount and emissions of kerosene that will be replaced by SHS has been analysed. Therefore the following assumptions have been made[33]

- An average kerosene lamp is used for 4 hours per day
- An average kerosene lamp uses 7.5 ml of kerosene per hour
- An average off-grid household consists of 5 people
- An average off-grid household uses 3 kerosene lamps

These assumptions result in an annual amount of kerosene used of 6.6l per year per off-grid person. Based on the emission factor of kerosene[34] and this kerosene usage, the emission reduction of replacing this amount of kerosene by solar home systems has been estimated.

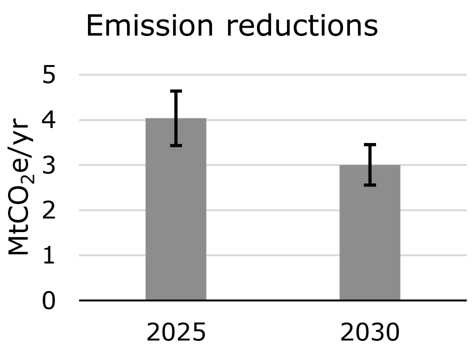
In a business as usual scenario, no building of solar home systems is assumed. However, the business as usual development of the off-grid population has to be taken into account. To estimate the off-grid population in each country in 2025 and 2030, the historical trends in share of people with grid access[35] has been extrapolated linearly to these years and the resulting share of people without grid access has been multiplied by the forecast population[36] in 2025 and 2030. The maximum emission reduction potential from installing solar homes systems is this estimated off-grid population in 2025 and 2030.

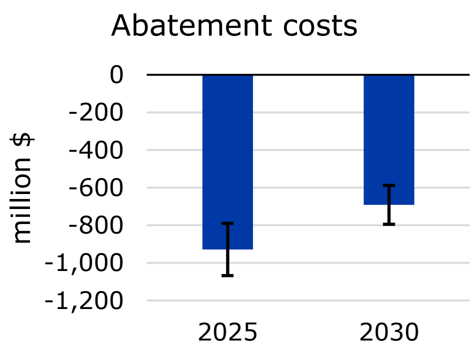
Upscaling results

If the solar home system solution of Bangladesh is scaled to the off-grid population of other countries, this yields an emission reduction of 4 $MtCO_2e$/yr in 2025 and 3 $MtCO_2e$/yr in 2030. In the situation where this solution is scaled up, around 200 million people gain access to electricity by solar home systems. The potential in 2030 is lower than in 2025, because in a business as usual scenario, in 2030 more people have been connected to a grid.

[31] World bank 2015, available at http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
[32] World bank 2015, available at http://data.worldbank.org/indicator/SP.POP.TOTL
[33] Renewable Energy & Energy Efficiency Partnership (2009), 50 ways to end kerosene lightning, available at: http://global-off-grid-lighting-association.org/wp-content/uploads/2013/09/Fifty-Ways-to-End-Kerosene-Lighting-in-Developming-Countries-REEP.pdf
[34] IPCC 2006, available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html
[35] World bank 2015, available at http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
[36] World bank 2015, available at http://data.worldbank.org/indicator/SP.POP.TOTL

Based on the abatement costs of replacing kerosene lamps by renewables of (-230$/t$CO_2$e), the avoided costs of scaling up this solution can be estimated at $930M per year in 2025 and $690M per year in 2030.





KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- The largest barriers for upscaling that countries can expect are limited access to capital and access to a financing facility to purchase solar panels. In Bangladesh, a solution has been found in a local company, IDCOL, which was set up as well as partner organisations (POs) which obtained finance from the World Bank and other donors to devise a financing scheme for marketing SHS. Moreover, insufficient awareness in rural households presented a difficult barrier for which IDCOL had to spend a lot of money to convince villagers of SHS.
- An infrastructure to support the programme is needed. In Bangladesh IDCOL provides grants to POs, subsidising the cost of SHS. With this, the POs purchase and install SHS for consumers. IDCOL additionally provides technical assistance (logistics and promotion) as well as capacity building.
- A key driver for solar home systems is the awareness and attitude of the people in upscaling countries towards SHS. In Bangladesh, civil society had a positive resonance as there is a reduced fear of thefts and robberies or burning incidents as fewer kerosene lamps are used. However, more information campaigns are still needed to increase public awareness.

3. Solar PV, Germany

The expansion of solar PV in Germany has been driven by the Renewable Energy Act (EEG), which entered into force in 2000 and was reformed in 2014. The objective of the EEG has been to promote renewable energy technologies like solar and wind through a fixed remuneration rate and guaranteed purchase for producers as well as a priority feed-in to the grid ("Feed-in Tariff scheme"). The EEG established the basis for the expansion of renewable energies in Germany and transformed them to one of the main pillars of power supply in Germany. Today, the share of renewable energy in

Germany's electricity supply amounts to 25%, and the share of PV in particular to 6%. In 2013, 35 GW of PV were installed in Germany[37].

As PV is replacing natural gas and coal in the German electricity mix, the consumption of 28 TWh PV[38] electricity in 2012 avoided greenhouse gas emissions of 18.6 million tons of CO_2e. Hard coal-fired power plants emit roughly 949 g CO_2/kWh of electricity, while lignite-fired power plants emit approximately 1153 g CO_2/kWh of electricity[39].

In countries other than Germany, other policies are also in place to promote the use of solar PV. The most recent case is France, which in August 2015, adopted a new law to promote the development of renewable energies, including solar energy.[40] Other examples are China, where feed-in tariff support is in place for solar PV, and the United States, where the US climate action plan includes the following ways to accelerate clean energy permitting[41]

- Directing the US Department of the Interior to permit 10 gigawatts (GW) of renewables on public lands by 2020
- Setting a goal to install 100 megawatts of renewables in federally assisted housing by 2020
- Deploying 3 GW of renewables in military installations

Environmental and social co-benefits

Implementing solar PV energy brings about positive environmental and social co-benefits. The impact of solar PV in use on air quality is positive, as PV systems emit no emissions of any kind during normal operation. Air pollutants produced by fossil fuel combustion contribute to health-damaging smog and acid rain. By replacing fossil fuels, particularly coal, PV has a positive impact on health. Furthermore, the expansion of solar PV correlates positively with employment. In 2013, there were 56,000 jobs in the PV industry in Germany in the investment, installation and use of solar PV. However, this number dropped from 100,000 in 2012[42]. This is mainly because the production of solar panels decreased by a third in the same time. In general, the European PV market has lost market shares over the past years, especially to China.

Upscaling methodology

[37] Fraunhofer ISE (2015), Recent facts about photovoltaics in Germany, available at https://ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf

[38] Fraunhofer ISE (2015), Recent facts about photovoltaics in Germany, available at https://ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf

[39] Fraunhofer ISE (2015), Recent facts about photovoltaics in Germany, available at https://ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf

[40] Gouvernment.fr (2015), La transition énergétique pour la croissance verte. Available at http://www.gouvernement.fr/action/la-transition-energetique-pour-la-croissance-verte

[41] IEA/IRENA joint policies and measures database, accessed November 2015

[42] Marlene O'Sullivan et al (2014), Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2013. Available at http://www.bmwi.de/BMWi/Redaktion/PDF/B/bericht-zur-bruttobeschaeftigung-durch-erneuerbare-energien-jahr-2013,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

The potential of the solar PV energy strategy of Germany has been analysed based on scaling it up to multiple countries. Three options for upscaling have been assessed

- To other high income countries
- To high and upper middle income countries
- To all countries

The upscaling potential has been calculated excluding countries with <10TWh solar potential (equivalent to ~1% of the potential in the USA), due to data limitations. The specific countries included in the upscaling potential are listed in Table 5 in the annex.

To assess the upscaling potential, first the share of the total realistic solar PV power potential in Germany has been determined by dividing their solar PV energy generation[43] by their realistic solar PV potential[44]. This potential has been determined by an Ecofys project in 2014 and keeps in mind available amount of land (including limitations such as land-use competition and acceptance), the amount of available rooftops and facades, resource quality and technology of solar PV. The world has been analysed using a 1 km^2 grid analysis covering the whole world at country level. Realistic solar PV potentials are available as a range for each country.

To estimate how much solar PV energy will be generated in other countries in 2030, this share (10-15%) of the total realistic solar PV potential in Germany is scaled up to other countries by multiplying it with their realistic solar PV potential[45]. As each potential is expressed in a range, we take low and high estimates based on the realized share in Germany of the lowest point in the range and at the highest point of the range. However, for some countries with high potential compared to its electricity generation, the estimate might produce (unrealistic) high values, so we constrain it to 50% of the total electricity generation in each country in 2030[46].

To estimate the upscaling potential, an amount of solar PV energy in business as usual scenario has been deducted from the total solar PV energy estimate. This base case solar PV production has been calculated by extrapolating the current solar PV energy production in a country[47] based on the growth rate of solar PV energy in that region[48]. Where it is available (USA, Russia, Japan, China, India and Brazil), the 2030 solar PV generation has been taken directly from the WEO new policies scenarios 2014.

The resulting upscaling potential in energy has been multiplied by an emission factor of energy generation per country[49]. For the few countries where no emission factor is known, the world average

[43] IEA database 2014, 2012 numbers
[44] Confidential Ecofys analysis (2014). Confidential
[45] Confidential Ecofys analysis (2014). Confidential
[46] IEA database 2015, 2012 numbers extrapolated to 2030 based on growth rate WEO New Policies scenarios 2014. Where available (USA, Russia, Japan, China, India and Brazil) 2030 number in WEO new policies scenarios taken directly. In case no IEA data available, CIA database has been used, available at https://www.cia.gov/library/publications/the-world-factbook/rankorder/2232rank.html#so
[47] IEA database 2014, 2012 numbers expanded to 2030, based on growth rate in WEO new policies scenarios 2014.
[48] WEO new policies scenarios 2014
[49] IEA database 2014, 2012 numbers. We use average fossil.

of 533 gCO_2/kWh has been used. Although, in the early stages of development of solar energy it is most likely to displace marginal electricity, as we include amounts of solar energy generation up to 50% of the total electricity generation the average emission factor is preferred.

For each country a minimum and maximum value of emission reduction by upscaling the solution of Germany has been calculated.[50]

Upscaling results

The upscaling potential depends heavily on the assumption of in which countries the level of solar PV energy can be scaled up to the level of Germany, as is shown in the table below.

Table 2

Country group	Emission reduction by scaling up to level of Germany ($MtCO_2$)	
	Min	Max
High income: non OECD	276	535
High income: OECD	445	799
Upper middle income	1,084	3,253
Lower middle income	645	1,524
Low income	37	49
Unknown	-	8

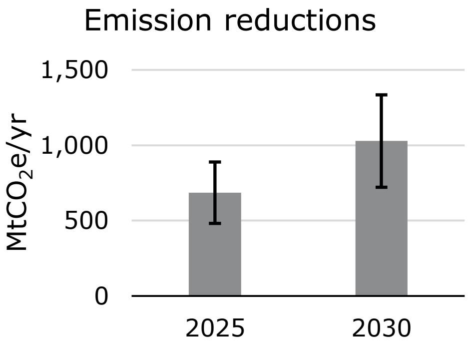
In option 1, if the solar PV energy solution of Germany is scaled up to high income countries, the resulting upscaling potential is estimated at 720-1330$MtCO_2e$ in 2030.

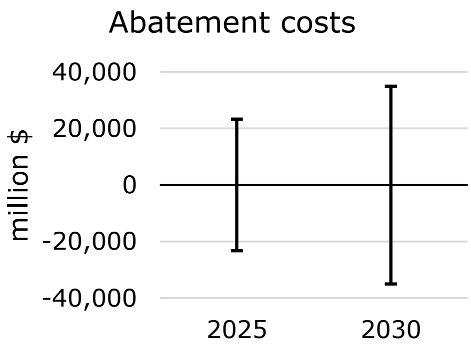
As we also discussed in the solution for wind in Denmark and Brazil, the abatement costs for renewable energy in this report (solar and wind), have been based on the global GHG abatement cost curve beyond business-as-usual for projects implemented in the period up to 2030, as prepared by McKinsey. For solar energy, abatement costs of $26 have been estimated for 2030. Since this abatement costs are a forecast, a learning rate has been taken into account. For example for solar PV a learning rate of 18% has been taken into account, which results in power generation costs going down from €180 per MWh in 2005 to €36 per MWh in 2030.

However, since we analyse upscaling the renewable energy generation in very successful countries to the whole world, the amount of renewable energy in 2030 in our scenario, exceeds beyond the forecast of McKinsey. Therefore it is plausible, that also a higher learning rate can be reached and that costs for renewable energy drop below the values that McKinsey estimated.

[50] The following inputs contribute to the difference between these values:
-The realistic solar PV power potential in a specific country is given as a range of which both extremes are used
-For very few small countries, no electricity generation data is available. For these countries the minimum potential is assumed to be zero and the maximum potential is not capped by 50% of the total electricity generation
-For a few small countries, no solar PV energy generation data is available. For these countries the minimum potential is assumed to be zero and the maximum potential is assumed to be the total potential by upscaling the solution of Germany, assuming zero solar PV energy production in a business as usual scenario

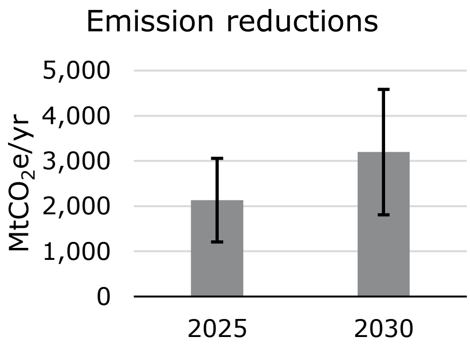
To illustrate the effect of the price for renewable energy on the abatement costs, we'd like to introduce a high level example. In the case that renewable energy costs 1 cent per kWh more to produce than that of fossil energy, and given the avoided emissions are 500g CO2 per kWh, this yields abatement costs of 2 cents per kg CO2, or €20 per ton CO2. However, in case the renewable energy costs are 1 cent per kWh less than that of fossil energy, abatement costs would go down to -€20 per ton CO2. This shows how sensitive the mitigation costs are to the difference in electricity generation costs between conventional power and renewable power.
Due to the high amount of upscaling potential for solar energy that we assume in this analysis, it's plausible that the high scale of solar energy will cause solar energy to become cheaper than assumed by McKinsey. Therefore we include cost figures based on the abatement costs as assessed by McKinsey as a maximum ($26 per ton CO2[51]) and -$26 per ton CO2 as minimum. Due to the total volume of renewable energy, this leads to a large difference in total abatement costs. Please note that this is highly driven by volume and it's caused by only a 1 cent per kWh difference in cost assumptions.
Based on this assumed range for plausible abatement costs for solar energy, the abatement costs of scaling up this solution can be estimated at -$35B up to $35B per year in 2030.

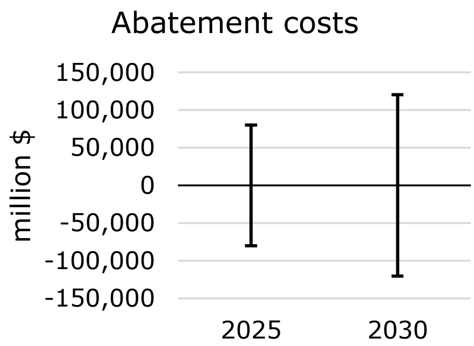




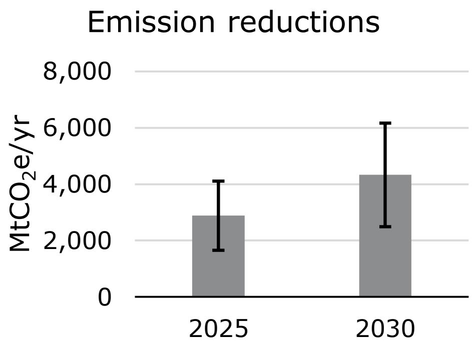
In option 2, if the solar PV energy solution of Germany is scaled up to high and upper middle income countries, the resulting upscaling potential is estimated at 1800-4590$MtCO_2e$. Based on the assumed abatement costs for solar PV[52] (-$26-$26/tCO_2e) the costs of scaling up this solution can be estimated at -$120B-$120B per year in 2030.

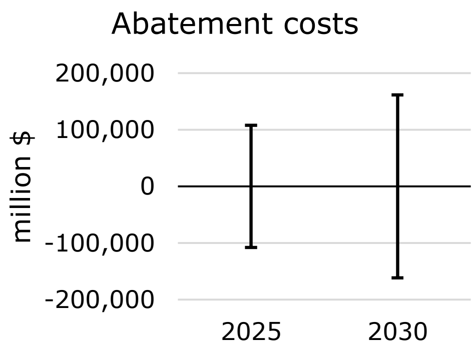
[51] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[52] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves





In case it is assumed that the solar PV energy solution of Germany can be scaled up to all countries in the world, in option 3, the resulting upscaling potential is estimated at 2490-6170$MtCO_2e$ in 2030. Based on the assumed abatement costs for solar PV[53] (-\$26-\$26/tCO_2e) the costs of scaling up this solution can be estimated at -\$160B-\$160B per year in 2030.





KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

Some key drivers and barriers for implementation have been noted for the solar PV energy solution in Germany.

- Countries may face barriers to PV expansion in terms of high upfront investment costs. In Germany, these were effectively addressed by the feed-in-tariff system under the EEG, which sets economic incentives for PV power producers and has brought the price for PV down dramatically.
- In infrastructure, barriers for implementation may also be faced, for example PV-related adjustments to low-voltage networks. In Germany, the costs of these adjustments will amount to about 1.1 billion EUR until 2020. This corresponds to ca. 10% of projected routine network adjustments[54].
- While in general civil society acceptance of renewable energy is high, electricity end-consumers generally have to pay a surcharge under the EEG to compensate for the difference between the wholesale market price for power on the electricity exchange and the higher

[53] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[54] BSW-Hintergrundpapier – März 2012, available at http://www.solarwirtschaft.de/fileadmin/media/pdf/bsw_hintergr_netzausbau.pdf

fixed remuneration rate for renewable energies. In Germany, there has been public discussion about the EEG surcharge, particularly after a nearly 50% increase between 2012 and 2013[55]. In 2014, the German government reformed the EEG to curb the cost increase of further renewable energy expansion.

- Another key driver for the success of solar PV energy is the climate in the implementing country. Local weather conditions affect the electricity production from a PV array. The most obvious factor is the amount of sunlight hitting the panels, but air temperature, humidity and wind regime also have an impact on energy production as they affect the degree to which panels become dusty or fouled. Do note, that the amount of solar irradiation in Germany is not ideal and that many countries exist with higher irradiation.
- Reaching a high penetration level (up to 50%) of variable renewable energy sources might be a barrier in upscaling countries. Due to fluctuation of energy generated by these sources countries need solutions to cover for this, such as the possibility to export and import electricity from neighbouring countries or sufficient energy storage (e.g. pumped hydro, large scale battery storage, underground compressed air, etc.)

4. Bioenergy for heating, Finland

Bioenergy accounts for 20% of primary energy consumption and 10% of electrical demand in Finland. However, more opportunities have been identified to increase the use to 35% over the next decade, including the use of bioenergy for heating. Wood pellets are increasingly used to heat homes and other buildings instead of oil or electricity. Pellets can also be used in place of oil in the peak boilers of district heating networks, which supply half of the country's space heating. In Finland, bioenergy heating cooperatives take three forms – the most common is a network of forest companies looking to turn their existing forest waste into profit; the second is owned by the heating customers themselves and the third is municipality-owned. Three sorts of subsidies are in place in Finland to promote wood energy: a feed-in tariff dependent on the EU-ETS allowance price for electricity from forest chips, a feed-in tariff for small CHP plants using wood energy, and an energy subsidy for small diameter wood from young forests[56]. Bioenergy for heating in Finland avoids approximately 6.8 $MtCO_2e$ annually.

In other countries than Finland successful bioenergy solutions have also already been implemented. For example in Austria, 85% of woody biomass goes to heat, while 15% goes to electricity. This is facilitated by district heating plants and distributions grids that are built in rural areas. Also, houses not connected to district heat, use pellets for heating. In Austria biomass heating plants for private use are subsidized[57].

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[55] Forbes 2014, available at http://www.forbes.com/sites/williampentland/2014/10/16/germanys-renewable-energy-surcharge-declines-as-subsidy-reforms-take-effect/

[56] Finland Ministry of Employment and the Economy (2012). Energy policy in Finland – how will we reach the RES targets. Available at www.feed-in-cooperation.org/wDefault_7/download-files/9th-workshop/presentations/session-3/RES-Finland.pdf

[57] Schilcher & Schmidl (2009). WP 4.2.2 Austria - Country Study on Political Framework and Availability of Biomass. Available at http://www.central2013.eu/fileadmin/user_upload/Downloads/outputlib/4biomass_country_study_Austria.pdf

Environmental and social co-benefits

Bioenergy heating can have a negative impact on soil and biodiversity if robust sustainability criteria are not implemented. For example, the practice of harvesting stumps reduces the carbon stock in the soil and poses a threat to coarse woody dependent species. The use of bioenergy for heating has a positive impact on employment. By 2020, jobs in the forest fuel supply chain and in related machinery supply in Finland are expected to increase five times[58].

Upscaling methodology

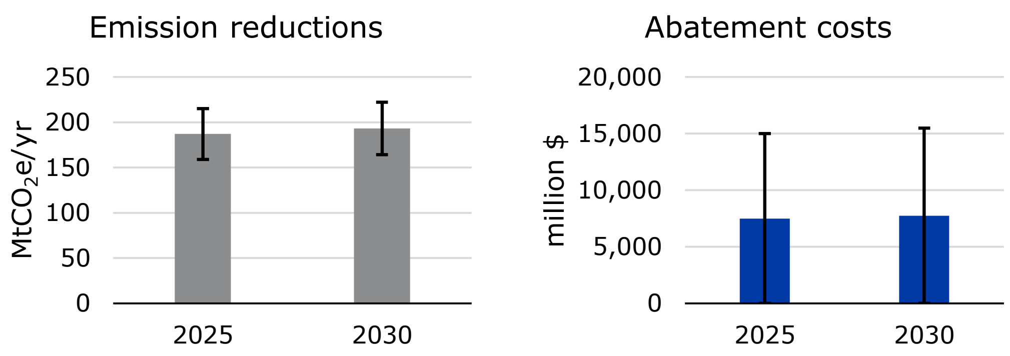
The applicability of bioenergy for heating purposes is dependent on two main variables: a high heat demand and a high biomass availability. To select countries, therefore, two indicators are assessed: heating degree days (HDDs) and amount of forested area per capita. The solution is only scaled up to countries that have more than 3,000 HDDs[59] and that have at least 80% of Finland's wood residue production per capita[60]. The countries that comply with both criteria are Canada, Mongolia, and Russia. For these countries, the energy balances are used to calculate the share of bioenergy in non-electricity energy consumption of buildings (both direct bioenergy consumption in buildings and heat from heat plants generated from bioenergy). The *World Energy Outlook* is used to calculate baseline non-electricity energy consumption in buildings. Subsequently, the difference between Finland's bioenergy share and that of the country is multiplied by the baseline energy consumption to calculate the energy savings. These energy savings are multiplied by the emission factor of natural gas, assuming that the heat would otherwise be generated using natural gas.

In the McKinsey abatement cost curve for Russia the abatement cost of usage of biomass is around 80 $/ton CO_2e. This is used as the upper end of the cost range. The lower end is 0 $/ton CO_2e, assuming that the solution can be implemented cost effectively in the selected countries. District heating costs are excluded.

Upscaling results

If the same bioenergy share that is used for heating in Finland is scaled up to other countries with cold climates and high wood residue production, this yields an emission reduction of 193 $MtCO_2e$ per year in 2030. Based on the abatement costs of bioenergy for heating (0-80$/$tCO_2e$) the costs of scaling up this solution ranges from $0 to $15 billion per year in 2030.

[58] Luxmore (2010). District Heating and Beyond. Available at http://www.renewableenergyworld.com/articles/2010/03/district-heating-and-beyond.html
[59] Baumert, K. and Selman, M. (2003). Data Note: Heating and Cooling Degree Days. World Resources Institute.
[60] Wikipedia (2015). List of countries by forest area. Available at https://en.wikipedia.org/wiki/List_of_countries_by_forest_area
World Bank (2015), world development indicators, population, available at http://databank.worldbank.org/data/reports.aspx?source=2&country=&series=SP.POP.TOTL&period=



KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

Some key drivers and barriers have been identified for bioenergy for heating in Finland:

- Infrastructure is needed to use bioenergy for heating effectively. The efficient, large-scale application of bioenergy for heating appliances requires district heating systems. For some countries or regions, district heating may not be applicable because buildings are not concentrated geographically.
- District heating systems are increasingly cost-effective in colder climates. Therefore, this is accounted for in the upscaling. In the selected countries a similar business case to that in Finland can be made.
- The availability of a sustainable supply of biomass is needed. In Finland, the large forestry sector provides this. In other countries, possibly other sectors might play a role in this too.

5. Solar water heating, China

Solar collectors for water heating have experienced a massive deployment in China in the recent years. In 2013, the vast majority of the total capacity of solar collectors in operation was located in China (262.3 GW_{th}, or 70% of global installed capacity). Per inhabitant, China ranks 8^{th} worldwide, with 194 kW_{th}/1,000 inhabitants. And in the year 2013, a total capacity of 44.5 GW_{th} was installed in China (80% of total global installation).[61]

This rapid deployment is mainly driven by the low cost of Solar Thermal Systems (STS) and several dedicated policies. Mandates for compulsory STS installation in urban areas are in place since 2006 with more than 11 provinces and 23 cities, including Beijing, now mandating installation of STS in buildings. In addition, at the end of 2014, all new buildings had to install solar water heating systems in the areas where sunshine hours are higher than 2200 hours. Further factors for STS uptake are a subsidy scheme to inhabitants in rural areas equalling 13% of capital costs since 2009, and a goal to install 300 million m^2, or 328 GW_{th}, of STS by 2020, of which 65% will be in residential applications.[62]

[61] Solar Heating & Cooling Programme (2015). Solar Heat Worldwide – Markets and Contribution to the Energy Supply 2013. Available at http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2015.pdf

[62] IRENA (2015). *Solar Heating and Cooling for Residential Applications – Technology Brief*. Available at

Finally, the Chinese Government supports a number of demonstration projects for "New Energy" cities with financial support for solar heating and cooling systems.[63] According to the IEA SHC programme, the Chinese Solar Thermal Systems led to emissions reduction of around 76 $MtCO_2e$ in 2013.[64] Along with a number of European and Mediterranean countries (Germany, Austria, Turkey, Israel, Cyprus), China has the most advanced policies on STS deployment.

Environmental and social co-benefits

The large-scale deployment of solar water heaters has several environmental and social co-benefits. By replacing water heating systems based on fossil fuel, solar collectors improve air quality, especially in dense urban areas, where heating using fossil fuels may increase the concentration of pollutants.[65] Solar water heaters are also relatively labour-intensive and therefore create local jobs: the solar water heating industry employs around 600,000 people in China according to IRENA (figure from 2014).[66] Solar heater replacing fossil fuel heating systems also have a positive impact on health, by reducing the risk of hazardous accidents. Finally given its' lower price per kWh_{th} and the fact that it can be installed in places that are not linked to the electricity or gas network (for instance, remote rural areas), solar water heating may contribute to improved energy access.

Upscaling methodology

IEA data on regional consumption of solar heating and cooling has been used to scale up this solution. The Chinese consumption of 2012, amounting to 150 TWh was used to determine the consumption per million inhabitant per year (0.1 TWh). This consumption was set as the 2030 potential of other regions with similar or higher solar radiation: Asia excluding China, Non-OECD Americas, Middle East and Africa. This is a rather conservative potential, as Chinese consumption has continued to grow at a fast pace since 2012. Non-OECD Europe and Eurasia was not selected as it has lower solar radiation. Using UN population projections, we applied the Chinese level of consumption per inhabitant to the 2025 and 2030 population figures of these regions[67]. The value for baseline consumption in 2030 was taken from the reference scenario of Greenpeace report "Energy revolution 2015" for each region.[68] The value for baseline consumption in 2025 is obtained by assuming a linear interpolation of consumption growth between 2012 and 2030.

Upscaling results

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http://www.irena.org/DocumentDownloads/Publications/IRENA_ETSAP_Tech_Brief_R12_Solar_Thermal_Residential_2015.pdf

[63] Ruicheng Z., Tao H., Xuan W. (2014).*The Roadmap Research of China Solar Thermal Development* in Energy Procedia 48, pp. 1642 – 1649. Available at http://www.sciencedirect.com/science/article/pii/S1876610214004470

[64] Solar Heating & Cooling Programme (2015). Solar Heat Worldwide – Markets and Contribution to the Energy Supply 2013. Available at http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2015.pdf

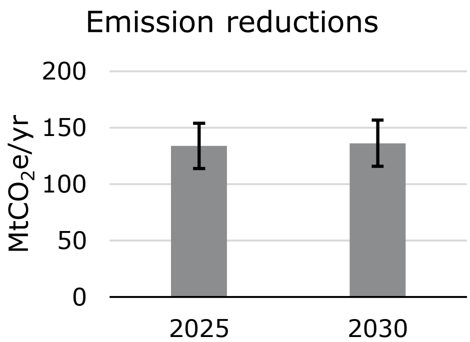
[65] IRENA (2015). *Solar Heating and Cooling for Residential Applications – Technology Brief*. Available at http://www.irena.org/DocumentDownloads/Publications/IRENA_ETSAP_Tech_Brief_R12_Solar_Thermal_Residential_2015.pdf

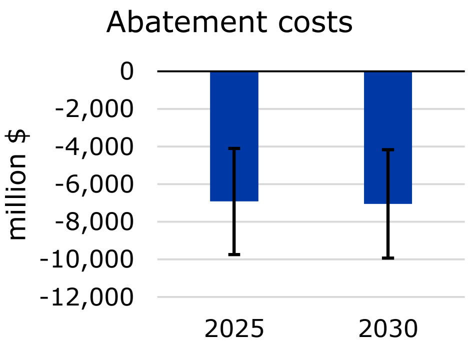
[66] IRENA (2015). *Renewable Energy and Jobs – Annual Review 2015*. Available at http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2015.pdf

[67] UN statistics, available at http://esa.un.org/unpd/wpp/

[68] Greenpeace (2015). *Energy Revolution 2015*. Available at http://www.greenpeace.org/international/Global/international/publications/climate/2015/Energy-Revolution-2015-Full.pdf

This methodology provides us with a total potential of 140 $MtCO_2e$/yr in 2030. Regions with the largest potential are Asia excluding China (74 $MtCO_2e$/yr) and Africa (48 $MtCO_2e$/yr). For the EU-28 and non-OECD Americas, the values of the reference scenario were higher than the values obtained by upscaling the Chinese deployment. These regions are not included in the upscaling.
Abatement costs, based on the McKinsey abatement cost curve that set the saving at $31 to 73/$tCO_2e$[69], result in savings of $4 to 10 billion per year. These costs are of course estimates that may vary according to technology advances and price of fossil fuels.





KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- Solar Thermal Systems (STS) deployment has been hampered by a lack of quality control. China has around 30 standards for STS engineering and installation but, to date, no performance standard. China is now developing and streamlining standards to ensure quality of the products and proper functioning.[70] Establishing performance standards, along with a monitoring structure to ensure that they are implemented, may help increase even more the production of solar heating and cooling.
- Capital costs (US$200) are higher than electric water heaters (US$50) or gas water heaters (US$100).[71] While their low operational costs allow quick return on investments, these capital costs were a barrier to the development of solar thermal systems. The Chinese government set up a subsidy scheme to support poorer population (rural inhabitants) to afford the upfront costs.
- Another barrier is the large number of players in the solar thermal system manufacturing sector, with more than 5 000 companies among which only 10 could be considered to be major companies in 2009.[72] This impedes price reduction and widespread standardisation.
- No specific infrastructure is needed, as solar thermal system are a rather simple product. Production lines are relatively easy to set up, requiring only low capital expenditure, and the

[69] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[70] IRENA (2015). *Solar Heating and Cooling for Residential Applications – Technology Brief*. Available at http://www.irena.org/DocumentDownloads/Publications/IRENA_ETSAP_Tech_Brief_R12_Solar_Thermal_Residential_2015.pdf
[71] Idem
[72] Idem

systems can be installed in off-grid areas. However, support to education for better installation and after sale service is needed.

- Public acceptance is high in China, especially in rural areas, where solar water heating systems are considered a sign of modernity, similar to cell phones and air conditioning. There is no opposition to installation of rooftop solar heating systems, contrary to other regions in the world, where reluctance to change homes' external appearances may impede solar heating systems deployment.[73]
- Given the variety of technologies, solar thermal systems can be deployed under almost all latitudes, from equatorial areas to northern European countries. However, investment costs are lower, and efficiency is higher in countries with higher solar radiation, thus facilitating uptake and scaling up. In areas with low radiation, PV-powered heat pumps may be a more efficient option.[74]

[73] Lee, L., Jie, L., (2013). *Why is China the world's leader of solar water heater production and consumption?* In American Journal of Environmental Science, 9 (2): 182-187. Available at http://thescipub.com/PDF/ajessp.2013.182.187.pdf

[74] IRENA (2015). *Solar Heating and Cooling for Residential Applications – Technology Brief*. Available at http://www.irena.org/DocumentDownloads/Publications/IRENA_ETSAP_Tech_Brief_R12_Solar_Thermal_Residential_2015.pdf

5. Low carbon solutions in the transport sector

1. Vehicle fuel efficiency, EU

The European Union, with a production output of over 17 million vehicles per year, is the second largest producer of automobiles globally. One quarter of the vehicles sold globally has been produced in Europe or is imported into the European Union[75]. Europe already started programmes to reduce the emission of vehicle fleet in the mid-1990s. This took the form of voluntary targets for manufacturers. These targets became mandatory in 2009 when a target of 130 gCO_2/km was set for the fleet average of new vehicles in 2015. Progress towards the target has been jointly monitored by the European Automobile Manufacturers Association (ACEA) and the European Commission. Mandatory targets exist for passenger vehicles and light commercial vehicles. Manufacturers of two and three-wheeled vehicles are required to calculate and report CO_2 emissions, but no specific targets have been set. In 2013, the passenger car standards were set at 95 g/km of CO_2, phasing in for 95 percent of vehicles in 2020 with 100 percent compliance in 2021, while light-commercial vehicle standards were set at 147 g/km of CO_2 for 2020[76].

Manufacturers who do not comply with the set standards are subject to penalties. These are €5 per vehicle for the first g/km of CO_2; €15 for the second gram; €25 for the third gram; € 95 from the fourth gram onwards. In 2019 the penalties will increase to €95 for each g/km that is beyond the target[77]. There are other policies supporting vehicle fuel efficiency such as the Energy Taxation Directive which gives minimum tariffs of heating and motor fuels, the Eurovignette Directive which established a harmonised EU framework for charging heavy goods vehicles on European motorways and fiscal measures in individual EU Member States. With the existing 2015 target for passenger cars, the average CO_2 emission level of new cars has dropped by 17%, from about 160 g/km to 132 g/km, in the period 2006–2012, measured over the European driving cycle[78].

Many other countries have policies in place to improve vehicle fuel efficiency for example Japan, US and Canada[79].

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[75] Transport Policy Net (2015). EU: Light-duty GHG. Available at: http://transportpolicy.net/index.php?title=EU:_Light-duty:_GHG
[76] ICCT (2014). EU CO_2 Emission Standards for Passenger Cars and Light-commercial Vehicles. International Council on Clean Transportation. Available at: http://theicct.org/sites/default/files/publications/ICCTupdate_EU-95gram_jan2014.pdf
[77] European Commission (2012). Impact Assessment Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO2 emissions from new passenger cars. Available at: http://eur-lex.europa.eu/resource.html?uri=cellar:70f46993-3c49-4b61-ba2f-77319c424cbd.0001.02/DOC_1&format=PDF
[78] ICCT (2014). EU CO_2 Emission Standards for Passenger Cars and Light-commercial Vehicles. International Council on Clean Transportation. Available at: http://theicct.org/sites/default/files/publications/ICCTupdate_EU-95gram_jan2014.pdf
[79] ICCT (2015) POLICIES TO REDUCE FUEL CONSUMPTION AIR POLLUTION, AND CARBON EMISSIONS FROM VEHICLES IN G20 NATIONS http://www.theicct.org/sites/default/files/publications/ICCT_G20-briefing-paper_Jun2015_updated.pdf

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ENVIRONMENTAL AND SOCIAL CO-BENEFITS

Fuel efficiency standards are beneficial in terms of energy security, as the fuel savings result in a lower demand for (imported) fuels. According to EC impact assessment[80] there is negligible impacts for employment between sectors (e.g. metal industries and automotive parts suppliers). When standards are further extended, other studies estimate up to 443,000 new jobs by 2030[81].

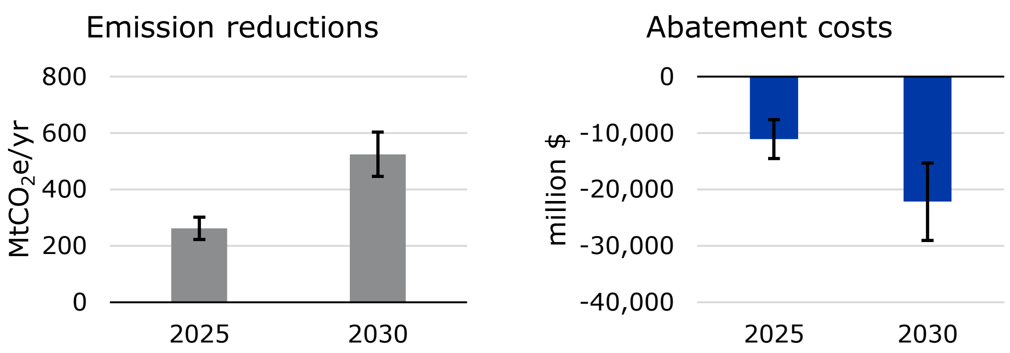
UPSCALING METHODOLOGY

Fuel efficiency and emission standards have proven successful in many countries, with varying conditions, all over the world. Many countries—both developed and developing—have fuel standards in place, which could be further strengthened. Therefore, the vehicle fuel efficiency strategy of the European Union is scaled up to the entire world, based on a regional approach (see Table 6 in Annex 1). The analysis is focussed on light-duty vehicles only. The upscaling potential is determined based on the assumption that all countries follow the European Union's 2005–2015 trajectory[82] in terms of fleet-average emission intensity (gCO_2e/vehicle-km) based on the standards set for 2015. This approach takes into account the different starting points of the various regions (i.e. regions that have higher fleet-average emission intensities will reduce emissions at a higher absolute rate). As a base case scenario, the baseline scenario from ICCT (2012)[83] is used. This baseline already includes vehicle fuel efficiency standards adopted up to 2012. Vehicle activity in the upscaling scenario (i.e. vehicle-km driven) per region in 2025 and 2030 are also taken from this baseline scenario. The abatement costs for upscaling this solution are based on global marginal abatement costs for 2030 for diesel and gasoline vehicles. The range of values for both technologies is applied[84]. See Annex 2 for more details on the assumptions used in the analysis.

UPSCALING RESULTS

If the fuel efficiency strategy of the EU is scaled up to the entire world, this could result in emissions savings of 262 $MtCO_2e$ per year in 2025 and 525 $MtCO_2e$ per year in 2030 globally. This is equivalent to 7% and 12% of the baseline emissions of light-duty vehicles in 2025 and 2030, respectively. Based on the range abatement costs of vehicle fuel efficiency for gasoline and diesel fuelled light duty vehicles[85] (-\$55/tCO_2e to -\$29/tCO_2e) the avoided costs of scaling up this solution are estimated at \$8–15 billion per year in 2025 and \$15–29 billion in 2030.

[80] European Commission (2012). Impact Assessment Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO2 emissions from new passenger cars. Available at: http://eur-lex.europa.eu/resource.html?uri=cellar:70f46993-3c49-4b61-ba2f-77319c424cbd.0001.02/DOC_1&format=PDF
[81] Neslen (Euractive) (2013). Report: Tough EU fuel economy rules could create 443,000 jobs. Available at: http://www.euractiv.com/energy-efficiency/report-tough-eu-fuel-economy-rul-news-518559
[82] ICCT (2012) ICCT Global Transportation Roadmap Model, Version 1-0, available at: http://www.theicct.org/global-transportation-roadmap-model
[83] ICCT (2012) ICCT Global Transportation Roadmap Model, Version 1-0, available at: http://www.theicct.org/global-transportation-roadmap-model
[84] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[85] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves



When interpreting these results, it has to be noted that the baseline already includes standards and policies adopted up to 2012, such as the example from Brazil mentioned before. Standards and policies are already delivering emission abatement in addition to the upscaling potential presented here. The adoption or more stringent emission standards, such as the proposed standards for 2025 in the EU, could result in even higher emission reductions. Based on extrapolation of the EUs proposed 2025 target to 2030, Fekete et al. (2015) find a global abatement potential of 1.9 $GtCO_2e$ in 2030[86].

KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- Apart from climate change mitigation, improvement of air quality and associated health benefits are important drivers for vehicle fuel efficiency policies. Applying the EU vehicle emission standards to developing countries worldwide could prevent 120 to 208 million premature air pollution related deaths annually by 2030 and save USD $600 billion to $2,400 billion in health costs[87].
- The technologies needed to comply with fuel efficiency standards are available and cost-effective.
- Consumers are generally more concerned about economic impact compared to environmental impacts of vehicle standards. However, informing consumers about the benefits of fuel efficient vehicles is important as consumers often doubt that fuel efficient vehicles will actually save them money on fuel costs[88].
- Car makers have been known to exploit loopholes in the EU (and other) laws to meet efficiency targets on paper but not in reality. A report[89] by Transport & Environment campaign group suggests that European car manufacturers employ a number of tactics to

[86] Fekete. H., Roelfsema, M., Höhne, N., den Elzen, M., Forsell, N. and Becerra, s. (2015). Impact of good practice policies on regional and global greenhouse gas emissions. NewClimate Institute, PBL and IIASA. Available at: https://newclimateinstitute.files.wordpress.com/2015/07/task2c_goodpracticeanalysis_july_2015.pdf

[87] Shindell, D., Faluvegi, G., Walsh, M., Anenberg, S., van Dingenen, R., Muller, N., Austin, J., Koch, D., Milly, G., (2011). Climate, health, agricultural and economic impacts of tighetr vehicle-emission standards. *Nature Climate Change*, 1, 59–66. Available at: http://www.nature.com/nclimate/journal/v1/n1/abs/nclimate1066.html.

[88] IEA (2012). Technology Roadmap. Fuel Economy of Road Vehicles. Available at: http://www.iea.org/publications/fueleconomy_2012_final_web.pdf

[89] Transport and Environment (T&E) (2013). Mind the Gap! Why official car fuel economy figures don't match up to reality. Available at: http://www.transportenvironment.org/sites/te/files/publications/Real%20World%20Fuel%20Consumption%20v15_final.pdf

improve a car's performance during testing, including taping over cracks to reduce air resistance, using special lubricants, and testing on unusually slick test tracks. This suggest that vehicle testing required to uphold EU standards may need improving, proper monitoring and verification should be part of the policy package.

- There is a considerable and increasing gap between real-world fuel economy and fuel economies found in driving cycles under laboratory test conditions, which are used in fuel efficiency standards. The difference between on-road and laboratory CO_2 emissions was found to be around 25% in 2011, up from around 10% in 2011[90]. Therefore, monitoring and testing of in-use vehicles is important.

2. Bus rapid transit (BRT), Colombia

Transport oriented development (TOD) is carried out in Colombia through a Nationally Appropriate Mitigation Action (NAMA) for which international, public and private funding has been accessed to facilitate the building of TOD neighbourhoods in cities across Colombia. The countries innovative bus rapid transit (BRT) systems have become a best practice example for low-cost and sustainable urban transport worldwide. The fundamental 'technology' of this NAMA is the so-called "TOD neighbourhood", which focuses commercial real estate development and affordable housing near transit stations and enables people to walk, commute, work, shop and play safely. High-quality pedestrian amenities, frequent public transit service and mixed-use development (retail, housing, commercial, services, public space) form the main elements for this innovative development approach. Through the multi-stakeholder engagement and involvement in development and financing a shift can also be observed in how and where investments, public and private are made. The TOD NAMA is designed to continue the work that the BRT systems began and to address local investment gaps, technical capacity needs, imperfect public-private collaboration, inadequate urban policy integration and limited value capture and finance mechanisms[91,92,93].

The analysis of this solution focusses on the TransMilenio bus rapid transit (BRT) system in Bogotá. A bus rapid transit (BRT) system is a bus-based transit system that delivers high-quality, fast, comfortable, and cost-effective transport. A BRT system is characterised by dedicated bus lanes, with busways and stations typically aligned to the centre of the road, off-board fare collection, and fast and frequent operations[94]. The BRT system in Bogotá, the largest and most populous city in Colombia, was the first BRT system in the country and is already replicated successfully in other cities

[90] GFEI (2014). Fuel Economy State of the World 2014. Available at: http://www.fiafoundation.org/media/46111/gfei-annual-report-2014-lr.pdf

[91] International Partnership on Mitigation and MRV. (n.d). Colombia Transit-Oriented Development NAMA. Available at: http://mitigationpartnership.net/colombia-transit-oriented-development-nama

[92] International Partnership on Mitigation and MRV. (n.d.) Designing a vertically-integrated, transit orientated development NAMA. Available at: http://mitigationpartnership.net/gpa/designing-vertically-integrated-transit-orientated-development-nama

[93] International Partnership on Mitigation and MRV (n.d). Colombia – Designing a vertically-integrated, transit orientated development NAMA. Available at: http://mitigationpartnership.net/sites/default/files/colombia_gpa_long_0.pdf

[94] Institute for Transportation & Development Policy (IDTP). (2015). What is BRT? Available at: https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt/

in Colombia[95]. The first phase of the TransMilenio system was opened in 2000 and currently the system consists of 11 corridors, totalling a 112 kilometres, and transports 2.2 million passengers per day[96]. Emissions from BRT transport are lower compared to transport by regular buses or private vehicles because of high occupancy rates, as well as efficient driving conditions through the use of dedicated lanes. The TransMilenio system in Bogotá is achieving an emission reduction of 0.6 Mt CO_2e annually[97]. The TransMilenio systems replaces mainly (>90%) transport by regular buses, and to a far lesser extent private vehicles and taxi's[98,99].

The BRT systems in Colombia effectively reduce transport GHG emissions. In other countries other policies are used to reduce emissions. For example, in cities such as Amsterdam and Copenhagen, urban planning and bike parking facilities are used to make people choose cycling as their mode of transport.

Environmental and social co-benefits

Apart from modest savings in GHG emissions, BRT systems have many co-benefits. By the use of isolated lines BRT systems reduce overall traffic growth as well as traffic congestion, resulting in lower travel times, increased mobility, improved living conditions and better air quality. The TransMilenio system in Bogotá reduced average travel times by 32% and increased property values along the main line by 15-20%[100]. BRT systems have a positive effect on human health due to improved air quality and increased safety (i.e. fewer traffic accidents). The development of the infrastructure needed for BRT systems results in job creation.

Upscaling methodology

BRTs systems have proved great solutions for mass transport in densely populated areas, and are being already scaled up in many cities around the world. We scale up this solution to cities with a population exceeding one million in middle income countries. Higher income countries are excluded from the analysis, because large cities in these countries generally have metro systems in place already. Lower income countries are excluded because of the high capital intensity of this solution. Cities that already have a BRT system in place are excluded from the analysis. Based on these criteria 271 cities in 36 different countries are selected for upscaling (see Table 6 in Annex 1).

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[95] Turner, M., Kooshian, D., Winkelman, S. (2012). Case Study: Colombia's Bus Rapid Transit (BRT) Development and Expansion. Center for Clean Air Policy (CCAP). Available at: http://www.ccap.org/docs/resources/1080/Colombia-case%20study-final.pdf

[96] BRT Centre of Excellence, EMBARQ, IEA and SIBRT (2015). Global BRT data. Available at: http://brtdata.org/.

[97] UNFCCC (n.d). Project: 0672 BRT Bogotá, Colombia: TransMilenio Phase II to IV - Crediting Period Renewal Request. Available at: http://cdm.unfccc.int/Projects/DB/DNV-CUK1159192623.07

[98] Hook, W., Kost, C., Navarro, U., Replogle, M., Baranda, B. (2010). Carbon Dioxide Reduction Benefits of Bus Rapid Transit Systems Learning from Bogotá, Colombia; Mexico City, Mexico; and Jakarta, Indonesia. Transportation Research Record: Journal of the Transportation Research Board, No. 2193, Transportation Research Board of the National Academies, Washington.

[99] Mejia, A. (2014) Elements of T-NAMA MRV. GIZ ASEAN Regional In-depth discussion event on MRV for Transport NAMAs. Ha Long City, Vietnam: 2 October 2014

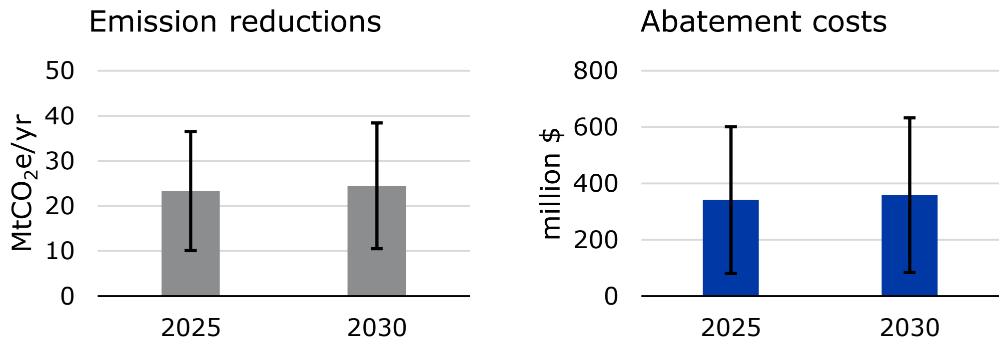
[100] Turner, M., Kooshian, D., Winkelman, S. (2012). Case Study: Colombia's Bus Rapid Transit (BRT) Development and Expansion. Center for Clean Air Policy (CCAP). Available at: http://www.ccap.org/docs/resources/1080/Colombia-case%20study-final.pdf

The TransMilenio BRT system in Bogotá transported 565 million passengers in 2013[101]. Assuming an average trip distance of 7.5–15 kilometres per passenger, we estimate the annual passenger-kilometres travelled by BRT to be around 550–1,100 kilometres per inhabitant. This solution is scaled up based on the assumption that other cities reach the same amount of passenger-kilometres travelled by BRT per inhabitant. The 2025 and 2030 populations of the cities is estimated by applying projected country-specific growth rates for urban population[102] to the latest historic value[103] available.

We assume that the passengers travelling by BRT would have otherwise travelled by regular bus, light-duty vehicle, or non-motorized transport. The emission mitigation factor of using BRT is the difference between the emissions per passenger-kilometre travelled by BRT and these alternative modes of transport. See Annex 2 for more details on the assumptions and data sources used in the analysis.

Upscaling results

If Bogotá's BRT system is scaled up to other cities exceeding one million inhabitants in middle income countries, this could result in emissions savings of 10–37 $MtCO_2e$ per year in 2025 and 11–38 $MtCO_2e$ per year in 2030 globally. Based on the abatement costs of Bogotá's BRT system[104] ($8/$tCO_2e$ to $16/$tCO_2e$) the abatement costs of scaling up this solution are estimated at $80–600 million per year in 2025 and $83–630 million in 2030.



Although the emission mitigation of upscaling this solution is limited compared to the other solutions considered, it has to be noted that BRT system is generally part of a broader transit oriented development (TOD) programme, including, for example, high density walkable districts, biking

[101] BRT Centre of Excellence, EMBARQ, IEA and SIBRT (2015). Global BRT data. Available at: http://brtdata.org/.
[102] United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, CD-ROM Edition.
[103] United Nations Statistics Division (2015). UNSD Demographic Statistics. City population by sex, city and city type. Available at: http://data.un.org/Data.aspx?d=POP&f=tableCode%3A240
[104] Kahn Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y. Muromachi, P. J. Newton, S. Plotkin, D. Sperling, R. Wit, P. J. Zhou, 2007: Transport and its infrastructure. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

facilities (e.g. bike rental systems, bikeway networks), fuel efficiency standards and disincentives to use private cars. The total emission mitigation impact of such TOD programmes can be significantly larger that the impact of the BRT system alone.

KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- BRT systems are significantly cheaper compared to other urban mass transportation systems[105].
- Hard infrastructure is needed for this solution and investment costs are typically high, with part of the costs being transferred to operators and passengers through increase in fares.
- Public resistance needs to be overcome when dealing with increased fares. However, once the system is in place user-satisfaction is generally high due to reduced travel time and high quality.
- In Colombia, there was strong opposition to BRT development from existing bus operators, especially bus owners fearing loss of income[106].
- Transit oriented development requires effective collaboration and coordination between national and local government, and the commitment of private project developers investing in the approach. Five governance elements are important to enable implementation:
    - multi-level governance with effective coordination of national, regional and city policies
    - city leadership and financial authority
    - transparency and accountability
    - policy integration at the local level.
    - Municipal governments can also use international and regional networks of cities to transfer knowledge and innovation more effectively[107]

[105] IEA (2012). Energy Technology Perspectives 2012. International Energy Agency (IEA).
[106] Turner, M., Kooshian, D., Winkelman, S. (2012). Case Study: Colombia's Bus Rapid Transit (BRT) Development and Expansion. Center for Clean Air Policy (CCAP). Available at: http://www.ccap.org/docs/resources/1080/Colombia-case%20study-final.pdf
[107] Floater, G., Rode, P., Friedel, B., and Robert, A. (2014): Steering Urban Growth: Governance, Policy and Finance. New Climate Economy Cities Paper 02. LSE Cities. London School of Economics and Political Science.

6. Low carbon solutions in the industry sector

1. Reducing methane from fossil fuel production, USA

Established in 1993, the Natural Gas STAR Program is a flexible, voluntary partnership that encourages oil and natural gas companies to adopt proven, cost-effective technologies and practices that improve operational efficiency and reduce methane emissions. Given that methane is the primary component of natural gas and is a potent greenhouse gas—25 times more powerful than carbon dioxide (CO_2) in trapping heat in the atmosphere over a 100-year period—reducing methane emissions can result in environmental, economic, and operational benefits. Natural Gas STAR partners have operations in all of the major industry sectors (production, gathering and processing, transmission, and distribution) that deliver natural gas to end users. Since the inception of the program around 150 cost-effective technologies and practices have been implemented to reduce the amount of methane reductions. Solutions include improved inspection and maintenance but also technologies such as low bleed pneumatic controllers and pumps and vapour recovery units. In 2006 the initiative went international to expand its membership worldwide and significantly increasing the opportunity for methane reductions. In 2013, the initiative achieved emission reductions of around 24 $MtCO_2e$ based on the reporting submitted by its members[108,109].

In the U.S. methane emissions from the oil and gas sector are reduced through voluntary partnerships. In other countries other policies are in place to reduce methane emissions from the oil and gas sector. In Russia, for example, a policy is in place that targets to reduce methane flaring to 5%. The policy is coupled to preferential market access and penalties for companies[110].

Environmental and social co-benefits

Measures that reduce natural gas emissions will also reduce the emissions of conventional pollutants—volatile organic compounds (VOCs) and hazardous air pollutants (HAPs)—in the gas. The net reduction costs are low relative to conventional control programs due to the economic value of recovered gas[111]. The reduction of air pollutants and volatile organic compounds decreases the health risks that are associated with these emissions.

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[108] US Environmental Protection Agency (n.y.). Natural Gas STAR Program. Available at http://www.epa.gov/gasstar/accomplishments/index.html

[109] US Environmental Protection Agency (2013). 2013 EPA Natural Gas STAR Program - Accomplishments. Available at http://epa.gov/outreach/gasstar/documents/ngstar_accomplishments_2013.pdf

[110] Fekete. H., Roelfsema, M., Höhne, N., den Elzen, M., Forsell, N. and Becerra, S. (2015). Impact of good practice policies on regional and global greenhouse gas emissions. NewClimate Institute, PBL and IIASA. Available at: https://newclimateinstitute.files.wordpress.com/2015/07/task2c_goodpracticeanalysis_july_2015.pdf

[111] ICF International (2014). Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries. Available at https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf

Methane leakage control projects have a number of other benefits including safety improvements, maximizing available energy resources, reducing economic waste, protecting human health, and reducing local environmental impacts. Upgrading production assets with modern and efficient equipment may also improve operational and economic performance, making assets more robust and less susceptible to upsets and downtime[112]. The implementation and development of abatement measures may result in increased employment.

Upscaling methodology

Specific measures to be taken and abatement potential differs strongly by country and region. However, taking measures to reduce methane from oil and gas production is beneficial from both an environmental and an economic perspective in all oil and gas producing countries. Therefore, we scale up this solution to all oil and gas producing regions. However, in our approach we take into account the different circumstances in all these countries and regions (see *Table 8* in Annex 1). The upscaling potential is determined based on the assumption that all countries achieve the same share of the mitigation potential as was achieved in the USA in 2010. We define potential in two ways—the total technical abatement potential and the cost-effective abatement potential (i.e. at negative abatement costs)—and the results reflect a range based on those two definitions of potential. The baseline and abatement potentials per country or region are based on marginal abatement cost (MAC) curves for the oil and gas sector from US EPA (2013). The baselines in this study are based on the national communications submitted to the UNFCCC. The Natural Gas STAR Program achieved 38.1 $MtCO_2e$ of emission reductions in 2010[113]. This is equivalent to 60% of the cost-effective potential and 27% of the technical potential in that year. Specific abatement costs per country or region from the same MAC-curve are applied to calculate the abatement costs of achieving the same share of the potential in other oil and gas producing countries. See Annex 2 for more details on the assumptions used in the analysis.

Upscaling results

If the US strategy for reducing methane from oil and gas production is scaled up to all oil and gas producing countries, this could result in emissions savings of 315–420 $MtCO_2e$ per year in 2025 and 330–447 $MtCO_2e$ per year in 2030 globally. Based on the specific abatement costs per region[114], ranging from -$50 to -$3, the avoided costs of scaling up this solution are estimated at $6–9 billion per year in 2025 and $6–10 billion in 2030.

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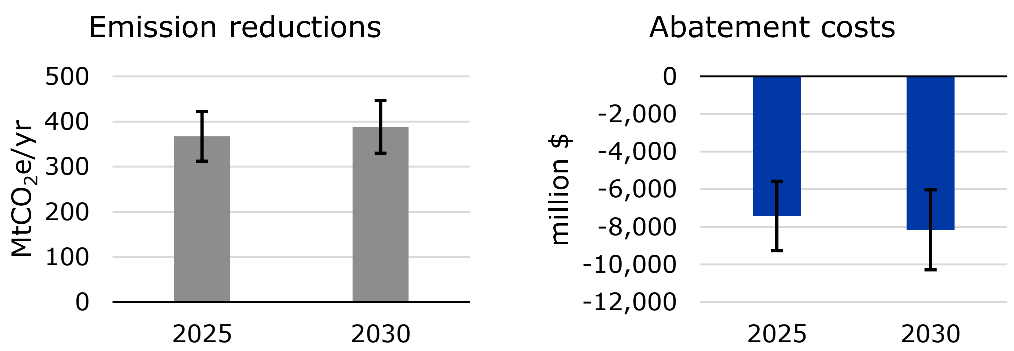
[112] Harvey, S. (2012). Leaking Profits - The U.S. Oil and Gas Industry Can Reduce Pollution, Conserve Resources, and Make Money by Preventing Methane Waste. Available at http://www.nrdc.org/energy/files/Leaking-Profits-Report.pdf

[113] US EPA (2010). EPA Natural Gas STAR Program Accomplishments. Available at: US EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Available at: http://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf

[114] US EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Available at: http://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf



All of these emission reductions can be achieved at negative abatement costs. Notably, the technical potential for reduction methane emissions from oil and gas production is higher. With aggressive reduction targets, Fekete et al. (2015) find a global abatement potential of up to 1.3 $GtCO_2e$ in 2030[115].

KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

The following key drivers and barriers have been identified for implementation of voluntary partnerships for reduction of methane emissions in the oil and gas sector:

- Barriers for implementing the solution are low as it often results in direct cost savings for the company. Additionally the US programme seems to have had little trouble expanding to other parts of the world as part of the Natural Gas STAR International.
- The main reason why the oil and gas sector does not voluntarily implement methane emissions reduction measures is that oil and gas companies often rank investments based on maximum yield. Even though methane control technologies have reasonable payback periods, this is not attractive enough compared to the high expected rates of return in the sector. The US programme tackles this problem by providing companies with the resources for technical assistance. Additionally, in some cases site-specific factors may make technologies unfeasible[116].
- The infrastructure needed for this solution is low as the technology to achieve the reduction in methane emissions already exists. The implementation lies mainly with the company. The right policy environment can support the implementation of the measures on a wider scale.

2. Industrial efficiency improvements, China

China's mandatory energy conservation target-setting policy for large energy users, the "Top-10,000 programme", was introduced in 2011, as an expansion of its successful predecessor, the "Top-1,000

[115] Fekete. H., Roelfsema, M., Höhne, N., den Elzen, M., Forsell, N. and Becerra, S. (2015). Impact of good practice policies on regional and global greenhouse gas emissions. NewClimate Institute, PBL and IIASA. Available at: https://newclimateinstitute.files.wordpress.com/2015/07/task2c_goodpracticeanalysis_july_2015.pdf

[116] Harvey, S. (2012). Leaking Profits - The U.S. Oil and Gas Industry Can Reduce Pollution, Conserve Resources, and Make Money by Preventing Methane Waste. Available at http://www.nrdc.org/energy/files/Leaking-Profits-Report.pdf

programme" which operated between 2006 and 2010. The Top-10,000 programme now covers two thirds of China's total energy consumption and aims to save 250 million t of coal equivalent (tce) by 2015. Under a contract signed with the government, participants in the Top-10,000 Programme are required to meet certain energy saving targets and implement energy management through activities including establishing energy measurement and management systems, submitting regular energy use audits and developing energy conservation plans. The greenhouse gas emission reductions resulting from the energy savings of 250 million tce range from 472 to 696 $MtCO_2e$, depending on the fuel mix of the saved energy[117].

In China, the top 10,000 is successful in increasing industrial energy efficiency. In other countries, policies are in place to do the same. For example, in India, the "Perform, Achieve and Trade" system improves energy efficiency in industry resulting in emission reductions of 26 Mt CO_2e by 2015

Environmental and social co-benefits

As a result of the coal savings achieved through the Top-10,000 programme, air quality is improved in China. In 2011, the level of emissions from coal plants is estimated to have contributed to quarter a million premature deaths in China[118]. Therefore, this improved air quality in turn results in a significant positive health impact. Furthermore, the energy efficiency measures in the programme create employment, as energy efficiency services are more labour-intensive than power generation.

Upscaling methodology

To upscale the Chinese policy, first the effects on industrial energy efficiency in China are assessed. For this the average growth rate of Chinese industrial energy demand from 2010 to 2012 is divided by the average growth of the industrial sector (industrial value added is used as a proxy for industrial growth, and a longer time series (i.e. since 2000) taken to account for price fluctuations) to calculate the energy demand reduction as a result of efficiency improvements. This is 4% reduction per year and it is assumed that this efficiency gain is driven by the Top-10,000 programme. This is considered a valid assumption as the best practices implemented by the companies in the top 10,000 programme are expected to be copied by other companies as well. Note that the 4% represents the average company and it is likely that the top 10,000 companies have even higher efficiency improvements. Subsequently, the efficiency improvement is calculated for the upscaling countries (i.e. other countries with an industrial energy consumption per value added above the world average of 2 kWh/US$ for which industrial emissions data is available). Next, the baseline industry energy consumption is calculated by extrapolating both the growth and the efficiency trend for each country. Then, the abatement scenario energy demand is calculated by combining the Chinese efficiency improvement trend and the country's industrial growth trend. Finally, the average emissions per industrial energy consumption is used to calculate abated emissions (assuming this to be constant until 2030).

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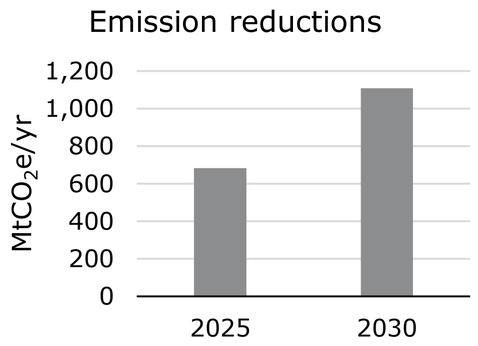
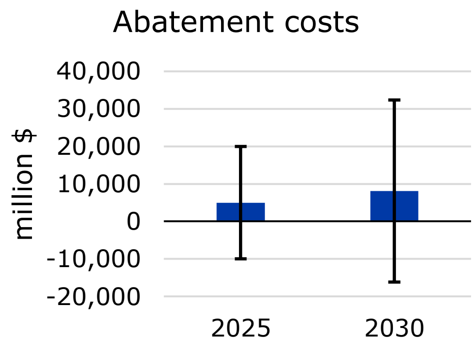
[117] The emission reductions are 472 and 696 $MtCO_2e$ for a 100% natural gas and a 100% coking coal fuel mix, respectively.

[118] Duggan, J. (2013). China's coal emissions responsible for 'quarter of a million premature deaths' in: *The Guardian* of 12-12-2013. Available at http://www.theguardian.com/environment/2013/dec/12/china-coal-emissions-smog-deaths

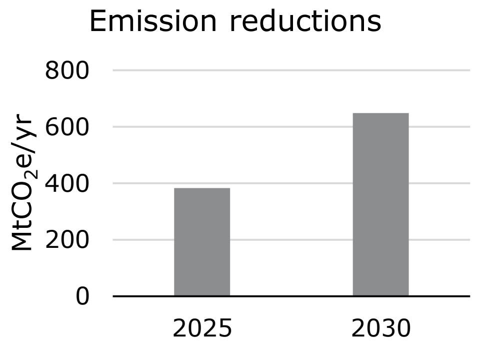
UPSCALING RESULTS

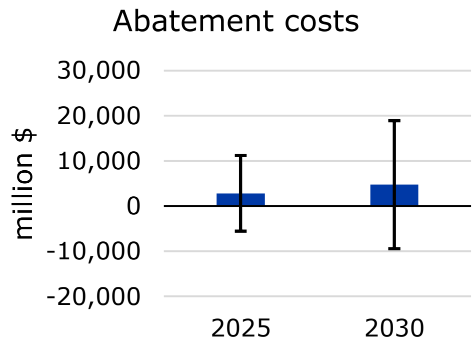
Upscaling China's strategy for improving industrial energy efficiency to countries that (i) have a high industrial energy consumption per industrial value added (above 2.8 kWh/USD) and (ii) of which recent (post 2005) industry emissions data is available results in 1,100 $MtCO_2e$/yr potential in 2030. The abatement costs for this solution range from -15 to 29 US$/$tCO_2e$. The total abatement costs for this solution range from -16 to 32 billion US$ in 2030.



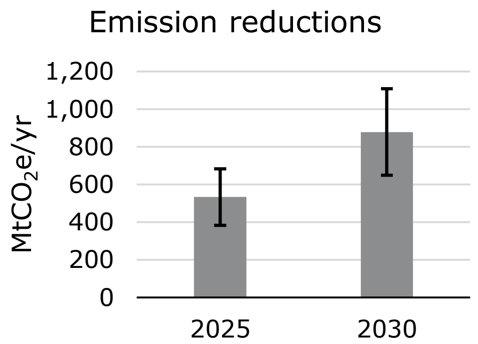


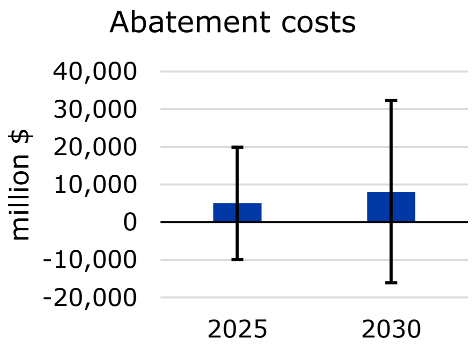
If instead of the 4% per year efficiency improvement a more conservative 3% per year is used the potential is ~650 $MtCO_2e$/yr in 2030. In that case, the costs range from -9 to 19 billion US$ for this emission reduction in 2030.





Because 4% demand reduction caused by energy efficiency improvements is higher than has been observed generally, an uncertainty range is created, including both the 3% and 4% reduction:





KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- Capacities to implement measures vary by region and enterprise. Therefore, when implementing this solution it is important that companies are supported in building these capacities. In China, the government and third party service companies have therefore organised capacity building events and some companies also set up their own training systems[119].
- Energy conservation and upgrading of operations requires financial resources at scale. In China, dedicated public finance support (central and provincial levels) and stimulated private investment help enable this.
- It is crucial to the credibility of the targets that guidelines and accounting methodology are clear, and that targets are third-party verified and energy savings audited. The target setting processes in China were not clear in the initial phase and created some resistance from enterprises. Targets under the Top-10,000 programme are disaggregated to local provinces and cities, with a more clear process.

3. Efficiency standards for electric motors, USA

The United States government implemented a policy that has increased the minimum motor efficiencies requirements at the federal level, covering (mainly industrial) electric motors both manufactured and imported for sale in the U.S. The Energy Policy Act of 1992 (EPAct) set minimum efficiency levels for all motors up to 200 horsepower (hp) purchased after October 1997. The U.S. Energy Independence and Security Act (EISA) of 2007 updated the EPAct standards starting in December 2010, including 201-500 hp motors. EISA assigns minimum, nominal, full-load efficiency ratings according to motor subtype and size. The U.S. Department of Energy (DOE) will update standards for electric motors once again and increase the minimum efficiency of new motors in mid-2016. The standards require motor manufactures and labellers to certify their motor minimum efficiency values before they are allowed to sell their products (pass/fail certified by US DOE).

Other countries, such as those in the European Union also have efficiency standards in place for electric motors.

The energy savings from the standards for electric motors range from 41 TWh[120] to 67 TWh[121] per year. This is equivalent to 28 to 47 $MtCO_2e$.

[119] International Partnership on Mitigation and MRV. China - Implementing a national energy efficiency Programme. Available at http://mitigationpartnership.net/sites/default/files/china_gpa_long.pdf
[120] U.S. Department of Energy (2009). Impacts on the Nation of the Energy Independence and Security Act of 2007. Available at https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/en_masse_tsd_march_2009.pdf
[121] U.S. Energy Information Administration (2014). Minimum efficiency standards for electric motors will soon increase. Available at http://www.eia.gov/todayinenergy/detail.cfm?id=18151

ENVIRONMENTAL AND SOCIAL CO-BENEFITS

The policies result in a decreased electricity consumption. As a result, the air quality is improved since power generation is mainly based on fossil fuels in the U.S. (coal and gas). This in turn decreases occurrence of respiratory diseases. The general effect of efficiency standards on employment is a shift of economic activity from a less labour-intensive sector (i.e. the utility sector) to more labour-intensive sectors (e.g. the retail and service sectors). Therefore, a positive effect on employment may be induced by efficiency standards

UPSCALING METHODOLOGY

The U.S. policy is scaled up by looking at the percentage reduction of industrial electricity consumption achieved in the U.S. and applying that same percentage to other countries.[122] Two different savings figures were found for the U.S.: 0.14 quadrillion Btu[123] and 0.23 quadrillion Btu[124]. This corresponds to 4 to 7% of industrial electricity consumption in the U.S. Next, the baseline industrial electricity demand is calculated by applying the growth from the *World Energy Outlook* to the 2012 industrial electricity demand per country[125]. Subsequently the U.S. reduction percentage is applied to the baseline consumption to calculate the electricity savings. Finally, these savings are multiplied by the countries' emission factor of fossil electricity generation. Energy efficiency standards are already implemented in several countries[126] so the potential is limited for these countries. We assume the actual potential for these countries to be between 0% and 50%.

UPSCALING RESULTS

Upscaling the U.S. electric motors efficiency standards to all countries results in 85 to 140 $MtCO_2e$/yr emission reductions in 2030. With the abatement costs ranging from -200 to -72 US$/$tCO_2e$, this results in total costs of implementing this solution of -28 to -6 billion US$ in 2030.

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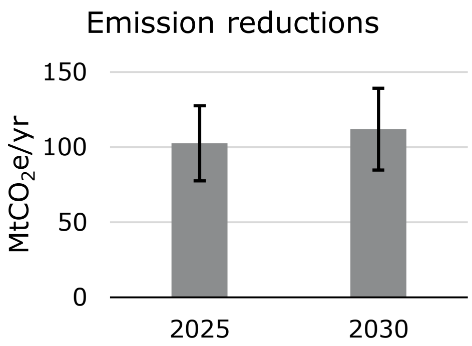
[122] The percentages are based on an impact assessment from the US DOE which studies the impact of energy efficiency standards of various products, including motors. The study shows the cumulative energy savings of motors in the USA. U.S. Department of Energy (2009). Impacts on the Nation of the Energy Independence and Security Act of 2007. Available at https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/en_masse_tsd_march_2009.pdf

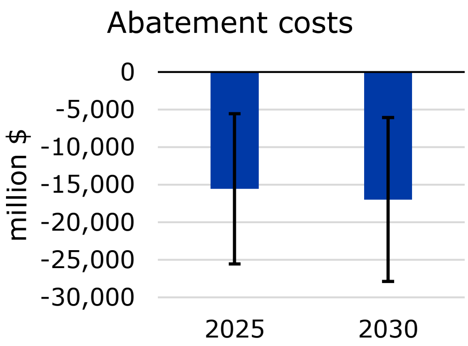
[123] U.S. Department of Energy (2009). Impacts on the Nation of the Energy Independence and Security Act of 2007. Available at https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/en_masse_tsd_march_2009.pdf

[124] U.S. Energy Information Administration (2014). Minimum efficiency standards for electric motors will soon increase. Available at http://www.eia.gov/todayinenergy/detail.cfm?id=18151

[125] IEA (2015). Energy Balances

[126] IEA (2014). Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems. Available at https://www.iea.org/publications/freepublications/publication/EE_for_ElectricSystems.pdf





KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

The following key drivers and barriers are identified for implementation of efficiency standards for electric motors:

- Generally, the barriers for implementing efficiency standards for electric motors are low.
- The UNEP energy efficiency appliances programme also includes motors. UNEP is working on scaling up energy efficiency standards and labels in motors in developing countries, with the support of the private sector[127].

[127] UNEP (2015). Efficient Appliances & Equipment. Available at http://www.unep.org/energy/eae/efficient-appliances-and-equipment.html

7. Low carbon solutions in the buildings sector

1. Building energy efficiency, Germany

The state-owned bank KfW (Kreditanstalt für Wiederaufbau) promotes energy efficiency in residential buildings through low interest loans or grants. Various programmes exist that target different building types, e.g. refurbishment of old buildings or construction of new buildings.
New buildings that exceed minimum energy performance standards are funded through the KfW programme "Energy-efficient Construction". They receive low-interest loans with staggered repayment bonuses depending on the efficiency standard. Existing buildings can obtain subsidies for energy efficiency investments via the KfW programme "Energy-efficient Refurbishment" and can choose among interest loans or grants. The introduction of the "KfW Efficiency House" system for energy classification of buildings allows for a higher promotion of buildings with higher efficiency standards. Also individual measures can obtain subsidies (e.g. for labour costs for architects or for consultations) from KfW programmes.

Between 2006 and 2014, 3.8 million homes implemented energy efficiency retrofits or were newly built in compliance with high energy efficiency standards in Germany. In 2013, the programme "Energy-efficient Construction" recorded 129,000 subsidy applications. Therewith, CO_2 savings of 0.094 Mt of CO_2e or energy savings of 336 GWh were achieved. The programme "Energy-efficient Refurbishment" recorded 276,000 subsidy cases in 2013, achieving savings of 0.65 Mt of CO_2e and 1,750 GWh of energy. In total, this is equivalent to 0.744 $MtCO_2e/a$.

Germany uses loans to stimulate buildings energy efficiency. Other countries also have policies in place to increase buildings energy efficiency. For example, Ireland shows the European best practice of labelling of buildings.

ENVIRONMENTAL AND SOCIAL CO-BENEFITS

The KfW programme stimulates investments in mostly local companies, thereby benefitting local craftsmen and building contractors. The program has resulted in the creation or retention of over 420,000 jobs in 2013[128]. Another social effect of the programme is that a house with better insulation requires less energy and thus reduce energy bills for its inhabitants. In this way the programme effectively helps to reduce energy poverty. Efficient buildings significantly benefit the electricity system, and can result in a more resilient grid[129]. Finally, energy efficient houses often have an

[128] Kuckshinrichs, Többen & Hansen (2015). Wirkungen der KfW-Programme „Energieeffizient Bauen", „Energieeffizient Sanieren" und „Energetische Stadtsanierung – Energieeffizient Sanieren (IKK/IKU)" auf öffentliche Haushalte im Förderjahr 2013. Available at https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-alle-Evaluationen/KfW-Studie-FJ-2013_07-Mai_1-(2).pdf
[129] Ecofys (2015). The role of energy efficient buildings in the EUs future power system. Available at http://www.ecofys.com/files/files/ecofys-2015-role-of-energy-efficient-buildings-in-power-systems.pdf

improved temperature and indoor air quality, resulting in health benefits, and a reduced risk of deaths from heatwaves or from cold in winter.

Upscaling methodology

The upscaling potential of the German KfW programme has been based on scaling it up to other high income countries with a similar climate (*Table 9* in annex). We assumed that these countries have a similar investment barrier for energy efficient construction and refurbishment, and a similar business case. We assumed that these countries can have the same annual reduction of CO_2 emissions intensity (CO_2 emissions per square meter residential building floor area) as the average in Germany between 2007 and 2011 (i.e. -1.3% per year). Applying this intensity reduction, the intensity per country for 2025 and 2030 is calculated, and multiplied by the projected floor area to calculate emissions in the abatement scenario.

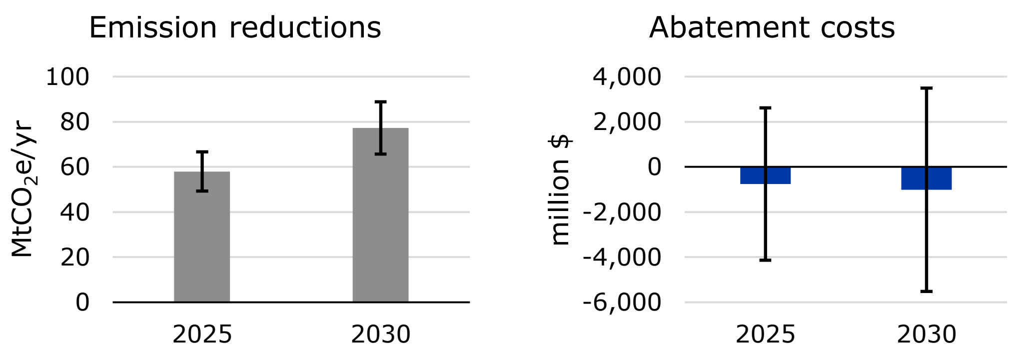
For all countries, the baseline development is assessed by first calculating the trend of total residential building floor area for the years 2006-2011 (using Oddyssee data[130] for European countries and IEA data[131] for global regions, downscaled to country level using population figures from World Bank[132]). Second, the emissions intensity reduction trend (the emissions per m^2) is calculated for each country for the years 2006-2011. The trends are used to project the intensity and floor area to 2025 and 2030. Finally, the future intensity is multiplied by the floor area to calculate the baseline emissions.

The abatement scenario emissions are subtracted from the baseline emissions to calculate the emission reduction potential.

Upscaling results

If the German KfW programme is scaled up to other high income countries with a similar climate, this yields an emission reduction of 77 $MtCO_2e$ per year in 2030. This emission reduction is equivalent to around 8% of the total annual CO_2 emissions of Germany or the annual emissions of a country like Finland[133]. Based on the abatement costs of energy efficient construction and refurbishing in Germany (US$ -56 to 35 /tCO_2e)[134] the costs of scaling up this solution is estimated to be between -$6 billion and $3 billion per year in 2030.

[130] Enerdata (2014). ODYSSEE Database.
[131] IEA (2015). Energy technology Perspectives 2015.
[132] Worldbank (2015) Population. Available at http://data.worldbank.org/indicator
[133] IEA (2014), 2012 numbers
[134] McKinsey (2007). Kosten und Potenziale der Vermeidung von Treibhausgasemissionen in Deutschland – Sektorperspective Gebäude



KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

Some key drivers and barriers can be noted for the implementation of a programme similar to the KfW programme:

- It is important to adequately inform home owners about policies in a way that is clear and comprehensible. In Germany, a large number of energy efficiency programmes exist in addition to the KfW programmes. This often led to confusion for the public as a large amount of information is available, which makes it difficult for interested individuals to select the right programme. Hence, individuals often decided against enrolling into a programme. To tackle this information barrier an information platform was built in Germany that helps the public obtain relevant and tailored information.
- For the acceptance of such a programme, it is important that in the beginning of the program (i.e. the application phase) participants are already well informed. This helps participants with administrative issues, such as complying with the high technical requirements to reach the energy efficiency standards. Energy efficiency consultations as well as consultations during the construction/renovation phase are now included in the KfW programmes, which helps with acceptance. An extensive survey of efficiency program participants throughout Germany revealed that participants were overwhelmingly positive about their experience and the results of the refurbishments. A large portion of participants would even consider undergoing refurbishments again in another dwelling if they moved.
- Although buildings efficiency is often a profitable investment, the required upfront investments are generally high. Therefore a large amount of financial means is needed to implement such a programme. This can be problematic for some countries that do not have a good access to capital.

2. Building energy efficiency, Mexico

The "green mortgage" programme in Mexico provides loans and subsidies for members of the National Workers' Housing Fund (Infonavit) interested in buying new "green" houses, which incorporate sustainable and energy efficient technologies, such as solar water heaters, compact fluorescents lamps, water saving faucets, and thermal insulation. Furthermore, loans and subsidies are offered for existing buildings. The promise is an increase in quality of life and decreased energy bills, through energy efficient technology that consumes less electricity, water and gas compared to standard solutions. The loans and subsidies have been in operation since 2010 and are part of the implementation tool of the "New Housing" Nationally Appropriate Mitigation Action (NAMA) in Mexico and directly aim to reduce emissions in Mexico's new building sector. It is possible that in the medium to long-term future the programme will merge with other building sector programme to form more holistic urban planning process including mandatory building codes.

The currently observed emission reductions are rather low with around 260 ktCO_2e observed in 2013[135]. However the measure has a large potential for upscaling which could significantly increase this number.

The loans and subsidies in Mexico effectively increases energy efficiency in buildings. In other countries, other policies do the same. For example in India, where the "Energy Conservation Building Code" describes energy efficiency standards for new buildings[136].

Environmental and social co-benefits

Since water saving faucets are also among the technologies for which financing is supplied, reduced water consumption is a co-benefit from the programme. Furthermore, health, comfort and welfare of the beneficiaries is expected as a result of the technologies. Insulation results in more comfort for those that cannot afford to have air conditioning. Health is improved by increasing the water quality with filters, which reduces the risk of gastro-intestinal diseases[137].
In addition there will be cost savings for the householder in energy bills as well as benefits to the country of reduced energy demand.

Upscaling methodology

The average emission reduction per household per year achieved in Mexico is divided by the average emissions per household in Mexico to get the reduction percentage per household. This percentage is then applied to the baseline emissions per household of the upscaling countries. The programme is scaled up to countries that have a similar climate to Mexico (excluding countries that are included in the German building energy efficiency upscaling). The number heating degree days in Mexico fall in the second quartile of countries, and the amount of cooling degree days fall in the first quartile. All countries that are in the second and first quartile of heating and cooling degree days respectively are selected[138]. The baseline emissions per household for these countries are calculated by first extrapolating the residential buildings emissions and the population per country using the 2008-2012 trends. Then, the household size projections are taken from the 2013 IEA report *Transition to*

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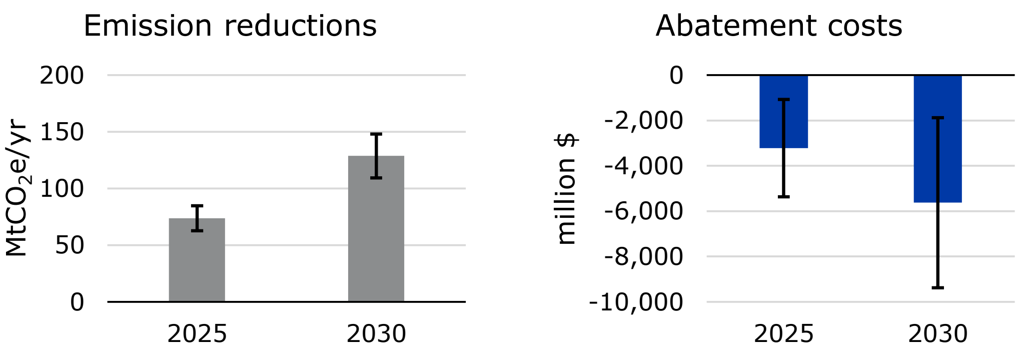
[135] World Finance (2014). Infonavit's mortgages pave way for Mexico's sustainable future. Available at http://www.worldfinance.com/banking/infonavits-mortgages-pave-way-for-mexicos-sustainable-future
[136] IEA (2015). IEA Codes: India – Energy Conservation Building Code 2007. Available at https://www.iea.org/beep/india/codes/energy-conservation-building-code-2007.html
[137] World Habitat Awards (2012). Green Mortgage – Mexico. Available at http://www.worldhabitatawards.org/winners-and-finalists/project-details.cfm?lang=00&theProjectID=9DA03455-15C5-F4C0-99170E7D631F50E9
[138] Baumert, K. & Selman, M. (2003). Data Note: Heating and Cooling Degree Days. World Resources Institute.

Sustainable Buildings[139]. Using this, the number of households is calculated from the projected population. The projected emissions are then divided by the amount of households to get the average emissions per household per country. The amount of households that is added to the program is assumed to be constant at the level in 2011 in Mexico (i.e. 0.312% of households per year)[140]. This means that in 2030 about 6% of the households are in the program. This percentage is multiplied by the number of households per country, the emissions per household and the percentage emissions reduction per household to calculate the amount of abated emissions.

For the abatement costs, the figures from the McKinsey abatement cost curve for Greece is used, as this country has a similar climate. This is multiplied by the abatement potential to calculate the total abatement costs.

UPSCALING RESULTS

Upscaling Mexico's building energy efficiency strategy to countries with a similar climate has an abatement potential of around 129 $MtCO_2e$/yr in 2030. The costs for this abatement ranges from -73 to -15 $/$tCO_2e$[141]. The total abatement costs range from -9 to -2 billion $.



KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

The following key drivers and barriers for the implementation of the solution have been identified:

- The solution effectively overcomes the financial barrier. Mexican families with low income often do not have enough money to invest in technologies that will reduce energy consumption even though they have a low payback period. By offering the loans and subsidies, families overcome this financial barrier. As a result, the policy is expected to be more effective in countries where this financial barrier is holding back energy efficiency investments. If other barriers exist, the solution might be less effective.
- Public acceptance of the programme is essential for its success. In an evaluation, 51% of the public were very satisfied, and 33% satisfied with the programme in Mexico. This justifies

[139] IEA (2013). Transition to Sustainable Buildings: Strategies and Opportunities to 2050. Available at http://www.iea.org/publications/freepublications/publication/Building2013_free.pdf
[140] Green mortgage program INFONAVIT – Mexico. Available at http://www3.cec.org/islandora-gb/en/islandora/object/greenbuilding%3A74/datastream/OBJ-EN/view
[141] McKinsey (2012). Greenhouse gas abatement potential in Greece. Available at http://www.mckinsey.com/locations/athens/Greenhouse_gas_abatement_potential_in_Greece/pdf/GHG_Abatement_Potential_in_Greece_Summary_Report.pdf

the scaling up of the programme within Mexico. If public acceptance in other countries is less positive, the implementation will likely be less effective so this aspect is an important part of the design of a programme.

3. Efficient cookstoves, China

China's improved cookstoves (ICS) distribution is considered to have been a success, with around 90% of households having access to cooking and heating stoves with at least some improved efficiency and emission features today.[142] The National Improved Stove Program (NISP) and its provincial counterparts were initiated in the early 1980s and are credited with introducing nearly 200 million improved stoves by the late-1990s, at a sustained rate of around 15 million per year.[143]

The direct cost of purchasing and installing the stoves was mostly borne by households and only subsidized marginally by the government. In addition, the governmental subsidization system was tailored according to different needs of provinces, allowing the system high flexibility and efficiency in expenditure. Instead of fully subsidizing improved stoves, the government spent most funding on R&D, training, product demonstration and public outreach. As a result, the majority of the programme's costs were contributed by households themselves, followed by local governments. Mainly, national funds were used for co-ordination, promotion and R&D activities. NISP's educational campaign eased public anxiety about using new products. The investment in R&D and training laid the foundation for NISP's successful implementation.[144]

Environmental and social co-benefits

Next to the climate effects, the deployment of ICS has several significant environmental benefits. The black carbon produced by biomass and coal use causes local pollution. Studies show that improved cookstoves reduce significantly both indoor and outdoor pollution from cooking. Household biomass and coal use is a significant contributor to poor air quality in urban areas in developing countries.[145] By reducing the need for solid biomass and charcoal, improved cookstoves also help prevent forest degradation and deforestation, especially in Africa and Asia.[146] This in turn also has a positive impact on preservation of biodiversity.

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[142] ESMAP-World Bank (2015). *The State of the Global Clean and Improved Cooking Sector*, p. 95-96. Available at https://openknowledge.worldbank.org/bitstream/handle/10986/21878/96499.pdf
[143] Smith, K., Keyun, D., (2010). *A Chinese National Improved Stove Program for the 21st Century to Promot Rural Social and Economic Development*. Available at http://cleancookstoves.org/resources/6.html
[144] Yai, E., (2009). *Stove Revolution: Cookstove Improvement Projects in China*. In Climate Alert,p. 15. Available at: http://climate.org/PDF/climatealertautumn2009.pdf
[145] ESMAP-World Bank (2015). *The State of the Global Clean and Improved Cooking Sector*, p. 22. Available at https://openknowledge.worldbank.org/bitstream/handle/10986/21878/96499.pdf
[146] Idem. p. 2

Furthermore, ICS deployment policies have strong social and economic development co-benefits. The most significant ones are health-related: cookstoves cause at least 4.3 million premature deaths annually and 110 million disability-adjusted life years (DALYs) primarily among women and children, resulting from household air pollution, including lower respiratory infections, chronic obstructive pulmonary disease, lung cancers, heart disease, etc.[147] Improved cookstoves also have a positive impact on education. Traditionally, gathering biomass or buying coal for cooking purposes is done by women and children. Reduced fuel consumption frees up time for other activities for them, improving conditions for women and facilitating school enrolment and attendance for children. In addition, by reducing fuel costs for households, reducing health hazards and increasing efficiency, improved cookstoves allow better energy access.

Upscaling methodology

The upscaling potential of the Chinese programme to deploy improved cook stove has been based on scaling it up to other regions with a large share of households using traditional cookstoves (*Table 9* in annex). The selection of regions for scale up was based on data from the World Bank – ESMAP report on the state of improved cookstoves in 2015. Four regions have a lower share of households with ICS than China: Southeast Asia, South Asia, Sub-Saharan Africa, and Latin America & Caribbean. It should be noted that figures for the region East Asia have been used as proxy for China. East Asia groups together China, Mongolia and North Korea, therefore it reflects very closely the situation in China (with more than 97% of the region's population).

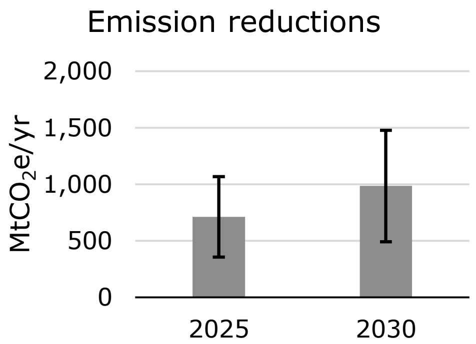
We used the UN 2030 population projections to determine the population of the selected regions in 2030.[148] We assumed that the number of people per household will remain constant until 2030 and determined the number of households per region on this basis. We then calculated the number of households with ICS if these regions reach Chinese levels of deployment (90% of households with ICS) by 2030. While this projection may seem to be ambitious for certain regions, such as Sub-Saharan Africa which currently has a deployment share of 26%, it is nonetheless consistent with the deployment numbers of the Chinese policy (15 million per year). For other regions, it is less ambitious as the gap relative to the Chinese share is smaller. The 2025 numbers have been calculated by linear interpolation. Our literature research didn't allow us to find reliable baseline scenarios for ICS deployment up to 2030. We therefore used baseline scenario projections for 2020 and interpolated them to 2030. We based ourselves, *inter alia*, on a previous report completed for UNEP and used a figure of an additional 2 million ICS per year up to 2030.[149] The difference between the number of cookstove in 2030 in the Baseline scenario and in the upscaling scenario gives the measure of the impact of an upscaling of Chinese policies: an additional 492 million of households would have ICS in 2030.

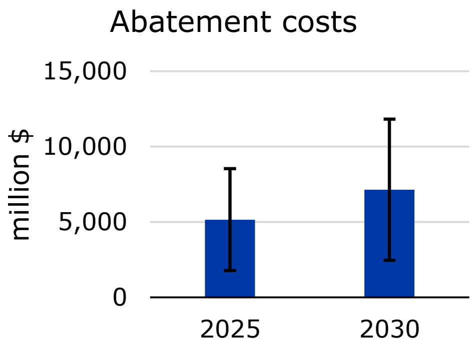
[147] Idem. p. 2
[148] UN statistics, available at http://esa.un.org/unpd/wpp/
[149] UNEP (2015). *Climate commitments of subnational actors and business: A quantitative assessment of their emission reduction impact*, p. 17. Available at: http://apps.unep.org/publications/pmtdocuments/-Climate_Commitments_of_Subnational_Actors_and_Business-2015CCSA_2015.pdf.pdf

Emission reductions linked to replacement of traditional cookstoves through ICS are difficult to assess with precision. They may be impacted by several parameters: fuel use (if biomass, whether renewable or not), device efficiency (of replaced and of improved cookstove), cooking practice. There are also diverging results on SLCP (Short-Lived Climate Pollutants) reduction through improved stoves, as well as on the accounting of their impact, given the fact that they are short lived and that their impact depends on co-emissions of other particles. These parameters can be measured and taken into account at project-level if appropriate monitoring is in place. However, they are very complex to account for at an aggregate, regional level, as is the case in this study. Various sources estimates reduction at 1-3 tCO_2e/stove/year[150], and 1-4 tCO_2e/stove/year[151]. Based on these sources, we have used a relatively conservative range of 1-3 tCO_2e/stove/year.

Upscaling results

Using this value of 1-3 tCO_2e/stove/year, our calculations yield a mitigation potential of between 500 to 1,500 $MtCO_2e$ per year in 2030 by upscaling China's strategy. Based on abatement costs of USD 5-8/tCO_2e[152], we determined total abatement costs of USD 2.5-11.8 billion for this emission reduction in 2030. It should be noted that these costs do not take into account the large health and environmental benefits linked to ICS distribution.





Key drivers and barriers for implementation

- Upfront investment needed to buy an efficient cookstove is the most important barrier, as efficient cook stoves cost more than homemade, traditional ones. Therefore subsidies and information programmes were necessary to ensure uptake, especially in poorer regions.
- Practicability is extremely important and should not be sacrificed over thermal efficiency. ICS must be designed with a view to local conditions and cooking habits and tastes. For instance, in the 1990s, deployment of improved cookstoves slowed down because they were not suitably designed: cookstove doors were too small, inconvenient to use and had cooking characteristics that were different from previous cookstoves. Therefore, cookstoves had to be

[150] Stockholm Environment Institute (2013). *Assessing the Climate Impacts of Cookstove Projects: Issue in Emissions Accounting*, p. 3. Available at: http://sei-us.org/Publications_PDF/SEI-WP-2013-01-Cookstoves-Carbon-Markets.pdf.
[151] Environment Protection Agency (2010). *Particle Pollution*, p. 10. Available at : http://www3.epa.gov/airtrends/2010/report/particlepollution.pdf
[152] Stockholm Environment Institute (2013). *Assessing the Climate Impacts of Cookstove Projects: Issue in Emissions Accounting*, p. 3. Available at: http://sei-us.org/Publications_PDF/SEI-WP-2013-01-Cookstoves-Carbon-Markets.pdf.

designed according to local needs, then tested and adapted to ensure uptake and efficient use.

- Deployment of efficient cookstoves was held back by the lack of awareness that improved cookstoves lead to energy costs savings and by the lack of selling networks. Local governments had to carry out information campaigns about savings associated with improved cookstoves and support companies establishing selling networks.
- Cookstoves tend to wear out relatively rapidly (life expectancy of a few years only), especially when not used properly. If they break down too quickly, people switch back to traditional cookstoves. To remove this barrier, information about correct use of efficient cookstoves had to be disseminated. After sale services still needs to be improved and programmes should better take into account regular replacement of worn out cookstoves.
- Another barrier is linked to the fuels used in improved cookstoves. Disruption of fuel supply causes people to switch back to traditional cookstoves. Availability of fuels is a primary consideration for fuel and stove selection. In parallel to the deployment of efficient cookstoves, supply chain must be set up to ensure that the required fuel (whether biomass, biofuel, etc.) is available at an affordable price. A top concern among producers is the lack of a biomass briquette supply chain, owing to high cost and a low technology level.[153]
- China's coal stove market is highly commercialized, having developed rapidly due to the large market potential; at the same time, product quality is patchy, performance varies considerably, and household demand can be widely dispersed.

4. Appliance efficiency, Japan

In 1998, Japan initiated the Top Runner Approach as a programme to improve energy efficiency of end-use products and to develop world class energy-efficient products. The selected target machinery, equipment, and other items need to be products that satisfy the following three requirements:

1. the product is used in large quantities in Japan,
2. the product consumes considerable amounts of energy while in use, and
3. the product requires particular efforts to improve its energy consumption performance.

Based on this concept, machinery, equipment, and other items have been continually added and, in 2015, 31 product categories are targeted with a focus on high energy-consuming products, covering substantial product ranges, including passenger vehicles, household appliances, white appliances, electronics and vending machines. Differentiated standards are set based on a range of parameters that affect energy efficiency within product groups. These parameters include function, size, weight, types of technologies, fuel used (e.g. passenger vehicles) and others. Compliance with the standard is evaluated by corporate average product sales. To comply with the standards, producers must make sure that the weighted average efficiency of the products they sell in a target year achieves the standards. Therefore not all of a manufacturer's products have to meet the target, but the average of

[153] Information on drivers and barriers is taken from Shen. G., at al., (2014). *Factors influencing the adoption and sustainable use of clean fuels and cookstoves in China – a Chinese literature review*. Available at http://cleancookstoves.org/resources/261.html

all products has to. This flexibility enables producers to provide a wide range of models to meet the market demand while guiding the overall market to higher energy efficiency.

Improvements in the fuel efficiency of automobiles and appliances under Top Runner standards have been assessed as leading to a reduction of 21 $MtCO_2e$ in 2010 and 29 $MtCO_2e$ from other appliances[154]. This leads to around 50 $MtCO_2e$/year of emission savings.

In addition to Japan, many other countries such as the US and the EU are also implementing solutions to improve energy efficiency, for example through labels on products and minimum energy performance standards (MEPS).[155]

Environmental and social co-benefits

Improving appliance efficiency brings about positive impacts on natural resources and society. For example, as Japan is heavily reliant on fossil fuels for electricity generation, lower electricity consumption achieved through the Top Runner Programme leads to better air quality. As a result, it should have a positive impact on health.

Next to that, although there is no clear evidence for it, the general effect of efficiency standards is to shift economic activity from a less labour-intensive sector (i.e., the utility sector) to more labour-intensive sectors (e.g. the retail and service sectors). Therefore, a positive effect on employment may be deduced from the efficiency standards.

In addition, energy efficiency can lead to greater security of energy supply as it reduces the demand for energy. Appliance efficiency can also have an impact on peak loads for electricity which can also help in balancing the grid more economically.

Upscaling methodology

To estimate the potential of scaling the appliance efficiency solution of Japan to other countries, first the effect of the measure in Japan has been quantified. The residential electricity consumption per capita in Japan[156,157] from 1980 to 1995, the year in which the top runner program was initiated, has been extrapolated linearly to the year 2012. The actual residential electricity consumption per capita in 2012 lies 16% below this extrapolated value, based on which an annual saving of the top runner program of 1% (over 17 year) of the residential electricity consumption per year is deduced.

This annual decrease in electricity consumption with regard to the business as usual case, has been extrapolated to the forecast buildings electricity use[158] in other countries in 2025 and 2030. However, many countries have already implemented policies for increasing appliance efficiency which have

[154] Taishi Sugiyama (2009), Learning from Japan's experience in energy conservation. Available at: http://criepi.denken.or.jp/en/serc/research_re/download/09006dp.pdf

[155] CLASP (2014), Improving Global Comparability of Appliance Energy Efficiency Standards and Labels. Available at http://www.clasponline.org/~/media/Files/SLDocuments/2014/2014-09_Improving-Global-Comparability/IGC_Policymaker-Summary.ashx

[156] IEA database 2014, 2012 numbers for residential electricity

[157] World bank 2015, world development indicators, population, available at http://databank.worldbank.org/data/reports.aspx?source=2&country=&series=SP.POP.TOTL&period=

[158] WEO new policies scenarios 2014

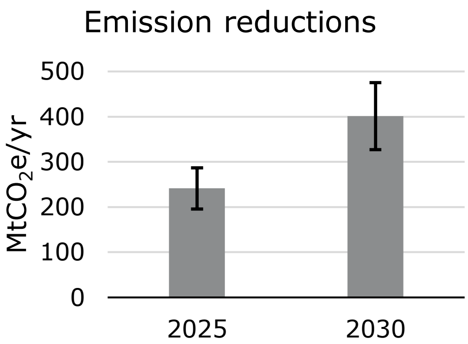
been included in their electricity use forecast. Therefore we correct the additional impact estimation of upscaling the top runner program of Japan, by the amount of measures that have already been taken in each country. In OECD countries, we assume that measures have been implemented that are equivalent to 60-80% of the top runner program, based on the reduction in residential electricity use per capita growth since 1995. For non-OECD countries, we assume that the measures that have already been implemented are equivalent to 0-20% of the top runner program, based on the number of minimum efficiency performance standards (MEPS) in a subset of these countries[159].

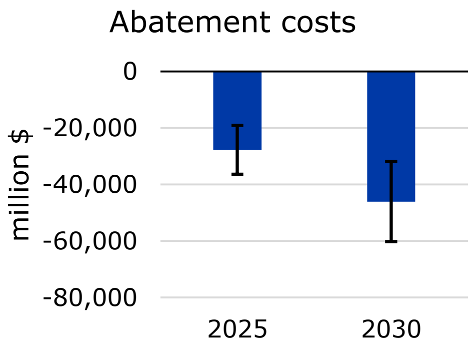
Based on the resulting electricity use reduction and the emission factors of electricity generation in each region[160], the emission reduction of upscaling the appliance efficiency measures in Japan to other countries has been estimated. For upscaling the potential, 2 options have been considered. In the first option, the solution has been scaled up to OECD countries, Russia, China and South Africa. In the second option, the solution has been scaled up to the whole world.

Please note that while cars are included in the Japanese top runner program, in upscaling this solution we only included the effects in household electricity use to avoid overlap with solutions in the transport sector.

UPSCALING RESULTS

Scaling up the top runner program of Japan to OECD countries, Russia, China and South Africa, would lead to emission reductions of 330-480MtCO_2e per year. Based on the abatement costs of residential electronics and appliances[161] (-$98-127/t$CO_2$e), the avoided costs of scaling up this solution can be estimated at $32,000-60,000M per year in 2030.





If the top runner program of Japan could be scaled up to all countries, this would lead to emission reductions of 650-880MtCO_2e per year. Based on the abatement costs of residential electronics and appliances[162] (-$98-127/t$CO_2$e), the avoided costs of scaling up this solution can be estimated at $64,000-112,000M per year in 2030.

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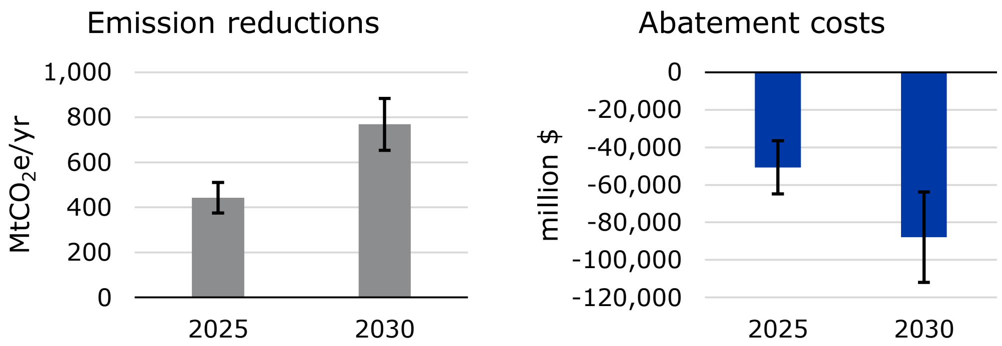
[159] Ecofys 2014, Impacts of the EU's Ecodesign and Energy/Tyre labelling legislation on third jurisdictions. Available at http://www.ecofys.com/files/files/ec-2014-impacts-ecodesign-energy-labelling-on-third-jurisdictions.pdf
[160] IEA database 2014, 2012 numbers
[161] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[162] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves



KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- Asymmetry of information can be a main barrier that the regulators of upscaling countries will face. In Japan, public authorities were reliant on industry data for setting the standards. To overcome this challenge, Japanese authorities engaged in sustained dialogue with industry associations, and set up committees including representatives from academia, industry, consumer groups, local governments and mass media. This ensures that all points of view are taken into account in standard-setting.
- Another challenge can be ensuring long term certainty for the industry to effectively invest in more energy efficient products. In Japan, this barrier was overcome by the government making it very clear that the programme would be a long term one by setting 5 year timeframes. The government also raised public awareness on the topic of energy efficiency, so as to boost responsible purchasing and give a market-driven incentive for energy efficient innovation.
- Barriers in the field of infrastructure needed are expected to be limited. In Japan the retail industry had to participate in the labelling process and the salesforce had to be trained on the importance of energy efficiency. Administrative workforce needs are limited: questionnaires are distributed to machinery, equipment, and other item manufacturers and importers soon after the target fiscal year, and information is obtained on the number of units shipped, energy consumption efficiency, and the like in the target fiscal year. Non-compliance with the standard is penalised: in case of non-compliance the Top Runner Programme uses a 'name and shame' approach, putting the brand image of companies at risk as opposed to their profit. No financial penalty is foreseen. Apart from this, no specific infrastructure was needed.
- In civil society acceptance, no major barriers are foreseen. In Japan, civil society has been involved in standard setting. There is a high public acceptance of the programme.
- This approach may not be replicable in countries where companies are smaller, and have less technological know how or where compliance culture is not as strong as in Japan. An important characteristic of the Japanese market that enables the programme's success is the market structure—which is dominated by a limited number of domestic producers. These all have high technological competency, and have experienced incentives to develop energy-efficient products to increase competitiveness against foreign producers. They also complied with the standards even without strict sanctions (which can be related to Japanese business culture and a cultural aversion to public 'shaming'). Nevertheless, setting MEPS and labels for

appliances at a country and regional level is feasible to scale up, as it has been proven by the UNEP programme on lighting and appliances.

8. Low carbon solutions in the agriculture and forestry sector

1. Low carbon agricultural programme, Brazil

Brazil's Low-Carbon Agriculture Programme, also referred to as the ABC-Plan (Programma Agricultura de Baixo Carbono) was started in 2010 to tackle the country's second largest source of GHG emissions: agriculture. The aim of the programme is to "promote the adoption of sustainable agricultural systems and practices that at the same time reduce GHG emissions, whilst improving the efficiency and resilience of rural communities and agricultural activities". The programme encourages six activities through offering farmers attractive lines of credits, these include:

i. No-till agriculture,
ii. Rehabilitation of degraded pastures,
iii. Integrated crop-livestock-forest systems,
iv. Planting of commercial forest,
v. Biological nitrogen fixation to reduce N-fertilizer use, and
vi. Animal waste treatment.

The program further promotes the protection and improved management of natural resources, namely through practices aimed at improving production efficiency. With the goal of achieving 134 to 160 $MtCO_2e$ in avoided emissions in 2020 the ABC Plan is considered the world's most ambitious mitigation plan on agriculture. The ABC-Programme fits into Brazil's National Policy on Climate Change (PNMC). The Plan further established a support component for training technicians and farmers, financing for research and development, and monitoring of activities and results.

Environmental and social co-benefits

Next to the climate effects, the low carbon agricultural programme ABC has several environmental benefits. Sustainable agriculture practices have positive effects on water ways and ground water sources. The programme also directly targets a more sustainable approach to agriculture, with the clear aim to increase soil uptake of nitrogen, rehabilitation of degraded pastureland and animal waste treatment. All these measures have a positive effect on the environment.

Furthermore, low carbon agriculture policies have strong social and economic development co-benefits. The ABC programme aims to improve and increase efficiency and resilience in rural communities, therefore strengthening the jobs that already exist and potentially increasing revenues. The subsidies provided through the ABC Program directly target rural development and making its communities more resilient by reducing poverty and strengthening the sources of income.

UPSCALING METHODOLOGY

The upscaling potential of the Brazilian programme to reduce GHG emissions from agriculture has been based on scaling it up to other developing regions in similar climate zones (*Table 10* in annex). The ABC programme was launched in 2010. However, its implementation has been lagging behind expectations in the first years.[163] The current position of implementation is hard to assess. It appears that an uptake of loans from the programme happened, starting in 2012, although the impact of these loans is less clear.[164] Research from Brazilian universities tend to assume that the objectives won't be reached in 2020, but rather 2025 or 2030.[165] As a result of this situation, there is no reliable assessment of the impact of the programme so far and we had to make an assumption on it to proceed with upscaling. Given the fact that the target is 134 to 160 MtCO_2e emission reductions in 2020 compared to a business as usual scenario, and that the programme had a slow start, we assumed that it has achieved at best a quarter of the target, or 37Mt CO_2e. In a more conservative scenario, the programme has achieved only half of that, or 18Mt CO_2e. These numbers have of course a very high uncertainty. This represents between 4 and 8% of total emissions linked to agriculture in Brazil.

Brazil's programme is tailored to fit its agricultural production and its challenges. The programme mainly focuses on restoration of degraded pasture, on agro-forestry and no-till agriculture, some of which are issues specific to Brazil. This may not be replicated to other countries, which however may have abatement potential of their own, arising from their own agricultural profile. In addition, as there is no assessment of the programme's impact so far, it is impossible to target specific production modes or agricultural practices. The best approximation available is therefore to apply the Brazilian share of reduction (4 to 8%) to other developing countries. Indeed, despite their diverse profiles, we assumed that all developing countries could reach such levels of reduction compared to the Business As Usual scenario in 2030. Therefore, we have used the FAO database[166] to retrieve the emissions linked to agriculture in Latin America (excluding Brazil), Africa and Asia. Emission reductions for 2025 have been calculated using a linear interpolation of emission reductions from 2015 to 2030.

UPSCALING RESULTS

Using the 2030 BAU estimates from the FAO database, we have calculated a mitigation potential of between 72 and 142 MtCO_2e per year in 2025, and of between 111 and 219 MtCO_2e per year in 2030 by upscaling Brazil's strategy. Based on abatement costs of USD 11/tCO_2e[167], we determined total abatement costs of between USD 1.2 billion and USD 2.4 billion abatement costs for this emission reduction in 2030.

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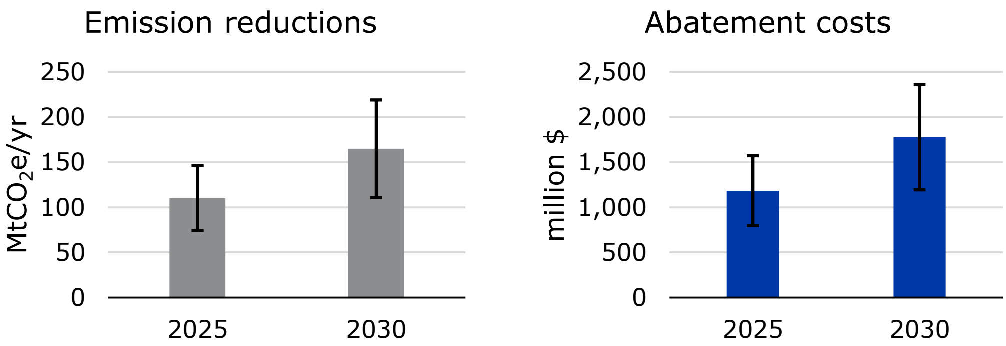
[163] Angelo, C. (2012). *Brazil's fund for low-carbon agriculture lies fallow*. Nature, 10. Available at http://www.nature.com/news/brazil-s-fund-for-low-carbon-agriculture-lies-fallow-1.11111
[164] Idem
[165] IDDRI (2015). *Beyond the Numbers: Understanding the Transformation Induced by INDCs*. p.38. Available at http://www.iddri.org/Publications/Collections/Analyses/MILES%20report.pdf
[166] Available at http://faostat3.fao.org/download/G1/GT/E
[167] McKinsey (2009). *Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve*. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves



BARRIERS FOR IMPLEMENTATION

- The main barriers faced were the slow uptake of the planned funds and limited financial flows in the first years of the programme, as other sources of funding and attractive loans were already available for farmers with less strict environmental requirements.
- Another issue is with assessing the performance in terms of emission reductions achieved. The infrastructure necessary to make the needed measurements is currently not in place. Better insight could be achieved if ABC farmers would provide regular soil analysis data, however this would demand a lot more oversight of practices, which is not popular in Brazil and would result in push back.[168]
- Soft infrastructure is also needed to put policy in place as well as to administer/manage the funding and check compliance. It should be noted that the policy making process in the Brazilian agriculture sector includes several ministries and government agencies and requires their collaboration to develop forward looking plans.[169]
- Civil society acceptance: Farmers have been slow to apply to the offered funding, with none of the initial budget made available in the first year being spent. Poor publicity is only part of the reason for slow up take, as other agricultural loans exist in the market that have less strict environmental requirements and slightly lower interest rates. Subsequently the rules for the ABC-Plan loans were loosened and interest rate was lowered from the initial 5.5% to 5% for the 2012/13 harvest.

2. Reducing deforestation, Brazil

Since 2004, the Brazilian government has been implementing a national plan, at both federal and state level, to reduce deforestation. The Action Plan for Prevention and Control of Deforestation in the

[168] Angelo, C. (2012). *Brazil's fund for low-carbon agriculture lies fallow*. Nature, 10. Available at http://www.nature.com/news/brazil-s-fund-for-low-carbon-agriculture-lies-fallow-1.11111

[169] Marques de Magalhães, M., Lunas Lima, D. (2014). *Low-Carbon Agriculture in Brazil: The Environmental and Trade Impact of Current Farm Policies.* Issue Paper No. 54. International Centre for Trade and Sustainable Development, Geneva, Switzerland. Available at https://seors.unfccc.int/seors/attachments/get_attachment?code=IHEHOQW57H8TOR0PPENLL9C2FLHPOVZJ

Amazon (PPCDAm) aimed at reducing illegal cutting of forests, is based on a three pillared strategy which includes: (1) territorial and land-use planning, (2) environmental control and monitoring, and (3) fostering sustainable production activities. Brazil did so through a set of policies: the enforcement of dedicated laws to punish illegal deforestation and clarify land owning rules, interventions in soy and beef supply chains to increase transparency on origin of goods, restrictions on access to credit and the expansion of protected areas.[170] As a result of these policies, the decline in deforestation between 2005 and 2012 has meant a reduction in emissions of around 3,575 $MtCO_2e$.[171] This has been achieved through a significant reduction of deforestation rate: from 27,700 km^2 per year in 2004, to 4,600 km^2, in 2012 (84% decrease), followed by a small increase in 2013, estimated at 5,900 km2.[172]

Environmental and social co-benefits

Next to the climate effects, reducing deforestation has an important positive impact on the water cycle. Trees are important to the water cycle as they absorb rain fall, thus regulating water flows. They also lessen the pollution in water by stopping polluted runoff. In the Amazon, more than half the water in the ecosystem is held within the plants, according to the National Geographic Society.[173] Stopping deforestation has positive consequence on the quality of land: tree roots anchor the soil and prevents it from washing or blowing away. Forest conservation improves quality of soil and prevents soil erosion. Finally, rainforest hosts some of the highest concentration of biodiversity in the world; hence, reducing deforestation enables the preservation of species diversity and strengthen the provision of ecosystem services.[174]

Furthermore, deforestation policy has a strong social and economic development component: it reinforces collective land tenure rights of indigenous people, and protects them better from illegal timber logging.[175] It also brought along financial benefits for traditional populations, through government purchase of family farm products and the creation of a cash allowance for families living in protected areas and below the extreme poverty line.[176]

Upscaling methodology

The upscaling potential of the Brazilian programme to reduce deforestation has been based on scaling it up to other middle income and low income countries in the tropical and subtropical belt with significant deforestation rates (*Table 7* in annex). The selection of countries for scale up was based on data from the annual Global Forest Resource Assessment Report from the FAO. Countries with deforestation rates per year that have been stable or increasing, and are above 0.2% of total forest

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[170] International Partnership on Mitigation and MRV (2014). *Implementing prevention and control policies for reducing deforestation*. Available at: http://mitigationpartnership.net/sites/default/files/brazil_gpa_long_0.pdf.

[171] Recent trends seem to show an increase of deforestation rate in 2013-2014. This was not taken into account in this study as we do not have the necessary hindsight on these data, but would undermine the success of the Brazilian policy.

[172] Instituto nacional de pesquisas espaciais (2014*). Cálculo da Taxa Anual de Desmatamento na Amazônia Legal*. Available at www.obt.inpe.br/prodes/prodes_1988_2013.htm.

[173] Live Science (2015). Deforestation: Facts, Causes & Effects. Available at: http://www.livescience.com/27692-deforestation.html

[174] International Partnership on Mitigation and MRV (2014). *Implementing prevention and control policies for reducing deforestation*. Available at: http://mitigationpartnership.net/sites/default/files/brazil_gpa_long_0.pdf.

[175] Union of Concerned Scientists (2011). Brazil's success in Reducing Deforestation. Available at: http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/Brazil-s-Success-in-Reducing-Deforestation.pdf

[176] International Partnership on Mitigation and MRV (2014). *Implementing prevention and control policies for reducing deforestation*. Available at: http://mitigationpartnership.net/sites/default/files/brazil_gpa_long_0.pdf.

area for the period 2010-2015, have been selected. This provides a group of 14 middle income countries and 10 low income countries. A small number of countries do not meet these cumulative criteria and were thus excluded, for example Mexico, which has seen a drop in its deforestation rate already in 2010-2015.

For middle income countries, it is estimated that they manage to decrease the deforestation rate by 80% in 2025, and that they maintain this rate until 2030. Low income countries only reach this reduction of 80% in 2030 (the 2025 level is calculated assuming a linear reduction from 2015 to 2030). It is extremely difficult to forecast the baseline deforestation rates of developing countries, as it is dependent on many political, economic, social and other parameters. We could not identify available sources of baseline that would be consistent for the studied countries. Therefore, the baseline deforestation rate for each country is assumed to be constant from 2015 to 2030, and equal to their 2010-2015 deforestation rate.

The difference between the decreased deforestation rate (decreased by 80%) and the baseline constant deforestation rate results in the forest area saved annually by upscaling the Brazilian policy to other middle and low income countries.

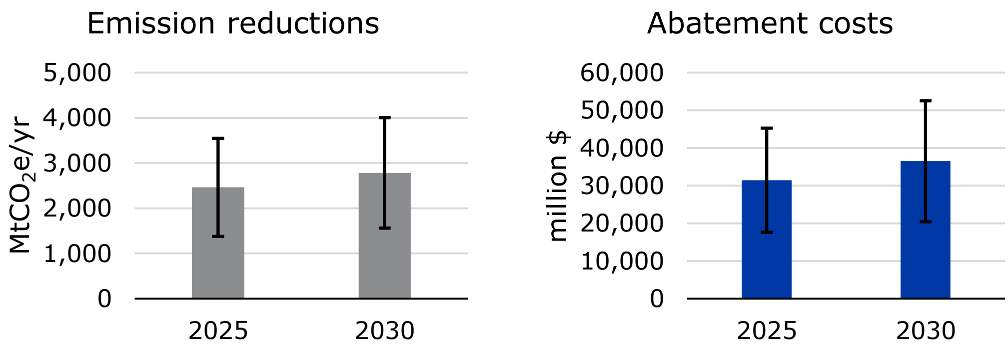
To calculate the emissions reduction, the saved forest area is multiplied by the emission factor of deforestation, taken from the Fourth Assessment Report of the IPCC: from 350 to 900 tCO_2e/ha.[177] This range represents the diversity of countries, as the emission factor depends on type of forest, soil, subsequent land use and other factors. As we cannot quantify precisely these factors, we cannot assess the distribution of the range and have therefore decided to use this full range, rather than narrowing it down.

UPSCALING RESULTS

If the Brazilian programme to reduce the deforestation rate is applied to other middle and low income countries from the tropical and subtropical belt, it can yield an emissions reduction of 1,400 to 3,500 $MtCO_2e$/year in 2025 and 1,600 to 4,000 $MtCO_2e$/year in 2030. These numbers are in line with results from other studies: the IPCC fourth assessment report estimates the potential for reduced deforestation in 2030 at 3,950 $MtCO_2e$/year in 2030[178], McKinsey has estimated it at 3,600 $MtCO_2e$/year in 2030[179] and a New Climate Economy report provides a figure of 3,300 to 9,000 $MtCO_2e$/year in 2030 for all measures linked to stopping deforestation, restoring degraded land and increasing agricultural productivity.[180]
Abatement costs are calculated using the McKinsey abatement cost curve, which provides specific cost figures for each region (Asia, Latin America and Africa) as the cost highly depends on subsequent land use of deforested areas (from slash and burn agriculture to pastureland to intensive

[177] IPCC (2007). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Chapter 9 – Forestry. Available at: https://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html
[178] IPCC (2007). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Chapter 9 – Forestry. Available at: https://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html
[179] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[180] New Climate Economy (2015). Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate. Available at http://2015.newclimateeconomy.report/wp-content/uploads/2014/08/NCE-2015_Seizing-the-Global-Opportunity_web.pdf

agriculture).[181] Abatement costs are around $13/tCO_2e$ for this solution, which results in abatement costs of $18,000 to $45,000 million per year in 2025 and of $20 to $53 billion per year in 2030.



Key drivers and barriers for implementation

- Establishing land registries to determine land ownership. Many public lands in the Amazon were illegally occupied, with legal barriers hindering legal settlement. Registries that recorded the titles of the properties were not computerised and the majority of data on properties were not geo-referenced, allowing land grabbing to continue.[182] The Brazilian government changed the law to make regularization more agile. To overcome this emerging barrier, the government has hired many employees exclusively for this activity. These new hires, as well as public servants, needed training to use new tools, especially the Rural Environmental Registry. Farmers also need training to insert their information in the registration system.

- One further barrier was the lack of dedicated resources. To increase the resources devoted to deforestation reduction policies, in 2008 the Brazilian government created the Amazon Fund, which raises funds and takes action to reduce deforestation.[183] For this reason, we have assumed that lower middle income countries require more time (15 years) to reach the Brazilian level.

- Showing determination from highest policy level. Political engagement of senior government actors is needed; based on a solid intervention strategy, and an ability to act on a variety of different deforestation causes. This demands high capacity for coordination and a clear

[181] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[182] International Partnership on Mitigation and MRV (2014). *Implementing prevention and control policies for reducing deforestation*. Available at: http://mitigationpartnership.net/sites/default/files/brazil_gpa_long_0.pdf.
[183] Idem

mandate. The fact that the Executive Office of the Brazilian Presidency coordinated the plan seems to have been an important success factor.[184]

- Involvement and empowerment of subnational governments is necessary from the outset: Early involvement may be more effective as later introduction has shown to result in conflicts.[185]

- Timely monitoring of trends in deforestation. At the beginning of the programme, it was difficult to quickly diagnose deforestation dynamics on the ground. The government created the DETER system, based on satellite data, to improve surveillance, primarily by reducing the time lag in observations of deforestation.[186]

3. Payments for Ecosystem Services, Costa Rica

Costa Rica has adopted a mix of economic and regulatory policies to protect and expand its forests. The Payment for Ecosystem Services (PES) programme was enacted in 1996. It has the twofold objective to increase the generation of ecosystem services while reducing poverty. To achieve this, PES gives monetary payments to land owners who maintain forest and agroforestry plantations, which provide environmental services. The PES programme has five modalities for the use of private land: 1) forest protection, 2) commercial reforestation, 3) agroforestry, 4) sustainable forest management, and 5) regeneration of degraded areas. Since the start of the programme, nearly one million hectares of forest in Costa Rica have been part of PES. Mainly, it aims at supporting afforestation and reforestation. Under the PES scheme, the land use sector moved from emissions of 2.4 MtCO2e in 1990 to a net sink of -3.5 MtCO2e in 2005. The forest cover in Cost Rica has now returned to over 50% of the country's land area, whereas it was of just 20% in the 1980s.

Environmental and social co-benefits

In addition to climate impact, the PES programme may be regarded as having positive environmental effects. The hydrological regime (infiltration, water quality and flows) is improved by the increased and improved forest cover. Afforestation prevents land degradation by preventing landslides as well as minimising soil erosion. Also, reforestation of deforested land creates diverse landscapes and therewith habitats for biodiversity protection, especially small mammals and birds.
Furthermore, the Costa Rican reforestation policy has a strong social and economic development component. The most important economic benefits are the steady cash payments throughout the duration of the contract and in the case of reforestation projects, the expectation of future payments in the form of timber. Payments to farmers (annual payments per hectare during the duration of the contract) are: protection ($ 64, $ 75 or $ 80); reforestation ($ 980 or $ 1,410); agroforestry ($ 1.3 or $ 1.9 per tree). Differentiated payment levels take into account the importance of the area

[184] Idem
[185] Union of Concerned Scientists (2014). *Deforestation Success Stories. Tropical Nations Where Forest Protection and Reforestation Policies Have Worked*. Available at: http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/deforestation-success-stories-2014.pdf
[186] International Partnership on Mitigation and MRV (2014). *Implementing prevention and control policies for reducing deforestation*. Available at: http://mitigationpartnership.net/sites/default/files/brazil_gpa_long_0.pdf.

(conservation gaps, zone of importance for water, degraded area, etc.) and use of native species. Many private reserves benefit from PES and use them to set up tourism activities. Being part of the PES also helps with protection from squatters, an important benefit for forest landowners who fear land invasions. Payments received under the PES allow the poor to invest into infrastructure development at community level, but also individual investments into health care and thus contribute to poverty reduction. In Costa Rica's Osa Peninsula, half of the environmental service sellers were able to move above the poverty line via PES cash. PES represented on average 16% of annual household income. Finally, of all PES contracts with individuals (rather than legal entities or associations), 28% are with women (1988 contracts). Of these, 1,094 (55%) are located in relatively vulnerable parts of the country. Although land is traditionally assigned to men in the Costa Rican society, as no legal land rights are needed to participate in the PES, women can also take part and benefit economically.

UPSCALING METHODOLOGY

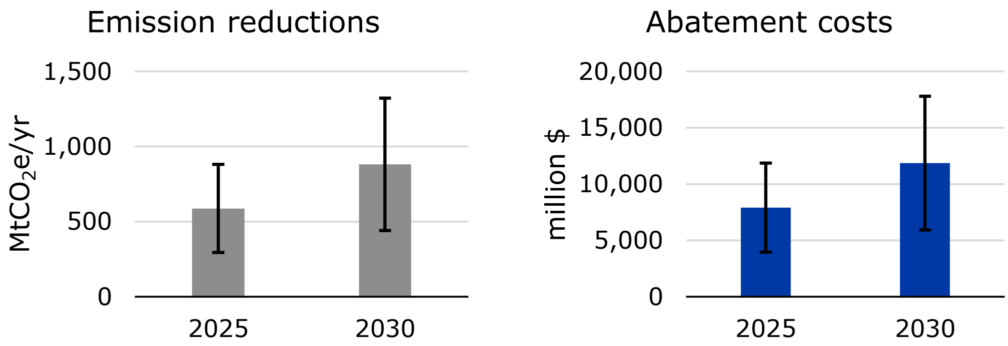
The upscaling potential of the Costa Rican programme to support afforestation has been based on scaling it up to countries with potential for afforestation as identified in the Fourth Assessment Report (AR4) of the IPCC[187] (*Table 7* in annex). To measure the impact of the PES programme in Costa Rica compared to its total potential for afforestation, we used FAO data on forest cover. The total potential was determined by the highest forest coverage recorded for Costa Rica: 70% in the 1950's. This share was down to 48% in 1996 when the programme started being implemented, and back up to 53% in 2013 (latest available FAO data). This increase of five percentage points corresponds to bridging 22% of the gap to the total potential of 70% determined earlier. While the forest coverage share had already started to grow prior to 1996, the role of the PES in maintaining this growth, and in preserving past afforestation gain, is underlined in several articles on the topic.[188] For instance, an article stresses that "[T]*he program has made a sizable mark on national land use, as of 2005 enrolling at least 10% of the country's forested area*."[189] It is clearly impossible to assess precisely the additionality of this programme (i.e. how much of the increase is directly due to the PES), however we assume it is in the most part due to the programme but also driven by other policies introduced in Costa Rica before the PES. To take this uncertainty into account nonetheless, we have applied a large uncertainty range to this solution. As we could not access the break-down of data on global afforestation potential, as published in the Global Restoration Initiative[190], we used the afforestation potential of mitigation measures of global forestry activities at costs equal or less than

[187] IPCC (2007). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Chapter 9 – Forestry. Available at: https://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html
[188] See Engel, S. at al. (2007). *Increasing the efficiency of conservation spending: the case of payments for environmental services in Costa Rica*. ETH Zuric. Available at http://www.pepe.ethz.ch/news/Engel_Wuenscher_Wunder_personal_version.pdf, and Ibarra, E., (2002). *The profitability of forest protection versus logging and the role of payments for environmental services (PES) in the Reserva Forestal Golfo Dulce, Costa Rica*. Available at http://www.cifor.org/library/2381/the-profitability-of-forest-protection-versus-logging-and-the-role-of-payments-for-environmental-services-pes-in-the-reserva-forestal-golfo-dulce-costa-rica/
[189] Johns, B., (2012). *PES and REDD+ : the case of Costa Rica*. American University. Available at: https://www.american.edu/sis/gep/upload/Johns_Bryan_SRP-The-Big-Kahuna.pdf
[190] Atlas of Forest Landscape Restoration Opportunities. Available at: http://www.wri.org/resources/maps/atlas-forest-and-landscape-restoration-opportunities

100 US$/t$CO_2$ of IPCC's AR4[191] as a proxy of total global potential for afforestation. It should be noted that these figures have a high uncertainty, as measurement of GHG that is stored in new or regenerated forests is extremely complex to establish, and is estimated by the IPCC between 1 and 35 tCO_2 per hectare in their calculation of the global afforestation potential. We applied the share of afforestation achieved by Costa Rica (22% as determined above), to the afforestation potential under 100 US$/t$CO_2$. This method avoids overlaps with the upscaling of the Brazilian solution on reducing the deforestation rate, as afforestation and stopping deforestation are two distinct categories in the IPCC report. Results for 2025 are calculated assuming a linear interpolation of 2030 results. The calculation of costs is based on the McKinsey abatement cost curve, with abatement costs of 13.5 US$/t$CO_2$ for afforestation measures.

UPSCALING RESULTS

If the Costa Rican programme for supporting afforestation is scaled up to all countries with afforestation potential, this could result in average emissions savings of 600 MtCO_2e per year in 2025 and 900 MtCO_2e per year in 2030 globally. These figures nonetheless have a high uncertainty. The abatement cost of scaling up this solution are estimated at $ 4,000-12,000 million per year in 2025 and $6,000–18,000 million in 2030.



KEY DRIVERS AND BARRIERS FOR IMPLEMENTATION

- Major difficulties were to assign tenure rights and overcome high administrative costs. Key to the success of the programme has been clear governance. Details for participation are announced annually in the official newspaper La Gaceta. The application documents are sent directly to local offices of FONAFIO (administrative authority of the scheme) or to an intermediary. As part of the contract, farmers must have a technical management plan, approved by a regent forestall who can also assist the farmer with the application form.[192]

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[191] IPCC (2007). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Chapter 9 – Forestry. Available at: https://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html

[192] Porras, I., (2013). *Payments for environmental services: lessons from the Costa Rican PES programme*, IIED. Available at: https://mpra.ub.uni-muenchen.de/47186/1/MPRA_paper_47186.pdf

- As tenure rights were not always clear and large parts of the forest are managed by indigenous communities, legal representatives were needed who negotiate PES contracts for the community. The money is then managed by an association that invests it back into community projects. Initially, people needed to be convinced that they obtain economic benefits and that PES does not simply mean that their land rights are taken away. Today, the scheme is widely accepted, but issues around land tenure remain.[193]

4. Cutting food waste, Denmark

Denmark's Environment Ministry has adopted a holistic Waste Strategy with the vision of a future without waste. Within this strategy the prevention of waste forms a key pillar and spans over all types of waste, from industry, business as well as households and includes chemical, technological and food waste. The strategy sets out to perform mapping of food waste to better understand where along the supply chain it occurs in Denmark to then specifically target the issues through new and innovative interventions through for example public-private partnerships or partnerships with industry. Some supporting initiatives include the following[194]

- Civil movements like "Stop Wasting Food" and Food sharing platforms support the government in creating awareness
- Composting of garden and organic waste is promoted
- All Danish supermarket chains have a food waste reduction strategy
- Over 300 restaurants in Denmark offer doggy bags as members of the REFOOD label against food waste
- The world's first international think-tank against food waste is established
- Improved packaging is established to reduce food waste

Since 2010 Denmark has managed to cut its food waste by 25%[195]. Based on the total food waste in Denmark of 586 kilo tonnes[196], this amounts to a food waste reduction of around 150 kilo tonnes per year. Note that this waste reduction is based on the FAO definition of food waste, covering the amount lost through waste at all stages between the level at which production is recorded and the household, e.g. storage and transportation, so the number would be higher if household food waste is also included. In this analysis household food waste is not included, because of lack of data. Using average emission factors[197] of each food waste category (gCO_2e/kg of food waste) and estimates of the share of different food groups typically wasted, as broken down by a FAO study[198], this amounts to roughly 0.14 MtCO_2e avoided per year.

[193] Idem.
[194] Copenhagen convention bureau, available at http://www.copenhagencvb.com/copenhagen/food-waste-denmark-down-25-cent
[195] The Copenhagen Post (2015). Food waste in Denmark down by 25 percent. Available at http://cphpost.dk/news/food-waste-in-denmark-down-by-25-percent.html
[196] FAO food balance sheets, available at http://faostat3.fao.org/download/FB/FBS/E Food waste defined as: Amount of the commodity in question lost through wastage (waste) during the year at all stages between the level at which production is recorded and the household, i.e. storage and transportation
[197] Brug mere spild mindre, available at http://www.brugmerespildmindre.dk/drivhusgasser&usg=ALkJrhjI3vNcthXLmtp5-lGsXbBMfBJX-A
[198] FAO (2013). Food wastage footprint, Impacts on natural resources. Available at http://www.fao.org/docrep/018/i3347e/i3347e.pdf

In other countries, food waste reducing measures are also being put in place. Recently, the USA introduced a food waste reduction target of 50% in 2030[199]. The European Commission is compiling an overview of good practices in food waste prevention and reduction, which covers the topics of[200]

- Research and innovation
- Awareness, information and education
- Policy, awards, self-imposed certification
- Food redistribution

Environmental and social co-benefits

Reducing food waste brings about positive impacts in natural resources and society, and it is therefore included in the sustainable development goals (SDGs) which aim at ending extreme poverty and tackling climate change. Cutting food waste avoids the economic losses associated with the food cost and waste treatment through landfills and incineration. A typical component to the "cutting food waste" movement in Denmark is the promotion to share food and offer surplus food to homeless shelters and other charities. Other food sharing initiatives have shown to relieve a share of economic pressure from low-income families if they are able to purchase food at lower prices or collect it for free. Furthermore, less food waste in the environment reduces the pressure on water, soil and air, which are usually the residues' sink after landfill and incineration treatments.

Upscaling methodology

The upscaling potential of the food waste reduction strategy of Denmark has been based on scaling it up to other high and upper middle income countries (*Table 3* in annex). We assumed that these countries can also reduce their food waste by 25% over a similar timespan as Denmark, i.e. before 2025.

The emission reduction associated with this waste reduction has been calculated based on different food waste categories reported on the FAO food balance sheets[201] (e.g. alcoholic beverages, animal fats, cereals, etc.). For each of these waste categories, the total waste in high income countries has been calculated based on these FAO food balance sheets and it has been assumed that a waste reduction of 25% can be reached before 2025 in each waste category. For each waste category, specific emission factors per wasted kg have been assumed based on specific known products within the category to calculate the emission reduction of this waste category (The specific assumptions are provided in *Table 29* in the annex). These emission factors include greenhouse gas emissions from the production of the products but not the emissions from waste disposal.

As a base case scenario, the historic waste production has been extrapolated linearly up to 2025 and 2030.

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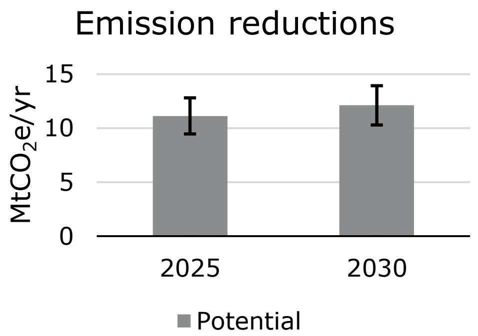
[199] USDA (2015), USDA and EPA Join with Private Sector, Charitable Organizations to Set Nation's First Food Waste Reduction Goals. Available at http://www.usda.gov/wps/portal/usda/usdahome?contentid=2015/09/0257.xml

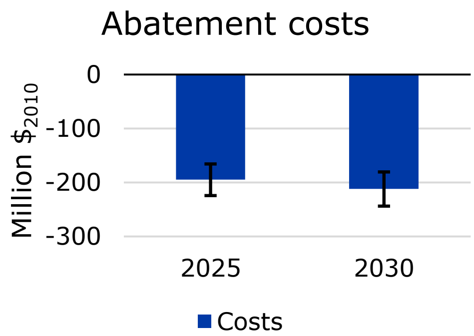
[200] The European Commission (2015), Good practises in food waste prevention and reduction. Available at http://ec.europa.eu/food/safety/food_waste/good_practices/index_en.htm

[201] FAO food balance sheets, available at http://faostat3.fao.org/download/FB/FBS/E

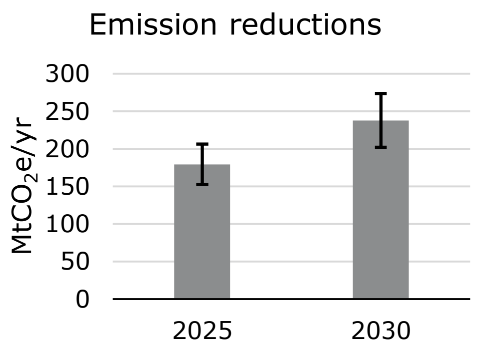
Upscaling results

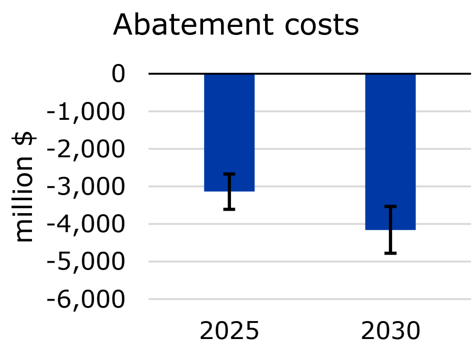
If the food waste reduction strategy of Denmark is scaled up to other high income countries, this yields an emission reduction of 12 $MtCO_2e$ per year in 2030. This emission reduction is equivalent to around one third of the total annual CO_2 emissions of Denmark or the yearly emissions of Luxembourg[202]. Based on the abatement costs of waste recycling[203] (-$17/$tCO_2e$) the avoided costs of scaling up this solution can be estimated at $210M per year in 2030.





Compared to high income countries, total food waste in upper middle income countries is relatively high (~factor 10), so the emission reductions by upscaling this solution increase significantly if the solution can be scaled up to both high and upper middle income countries. Scaling up this solution to high and upper middle income countries would yield an emission reduction of 240 $MtCO_2e$ per year in 2030. Based on the abatement costs of waste recycling[204] (-$17.5/$tCO_2e$) the avoided costs of scaling up this solution can be estimated at $4200M per year in 2030.





Key drivers and barriers for implementation

- Awareness raising and education is the core driver for scaling up this solution. Countries wanting to replicate this solution would need to roll out campaigns and educational programs to induce behavioural changes in consumers and supply chains (e.g. supermarkets,

[202] IEA (2014), 2012 numbers
[203] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[204] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves

restaurants). This could also be accompanied by incentives to trigger personal choices (at the individual level) or business operations changes (at the corporate level).

- Supporting policies would help change supply chain behaviour. Further barriers to sharing of food can exist especially if supermarkets and restaurants are bound by certain health regulation that do not allow them to donate food to organisations like homeless shelters. Creating more supportive regulation would incentivise the food sector to be willing to participate in cutting food waste programmes.
- Food preservation technologies could expand the replication of this solution in other climatic regions. Food sharing can be more difficult in hot and humid climates where food spoils more quickly than in a moderate climate like Denmark. Cutting food waste in hot climates should be bundled with programmes that foster the use of efficient cooling systems for food preservation.

9. Discussion

Countries in developed and developing regions are demonstrating that implementing low-carbon solutions is possible and cost-effective. Their actions are successfully reducing emissions and contributing to their economic growth and sustainable development. In the process of implementation they faced barriers, such as limited access to finance, social opposition or political resistance to new regulations, which they effectively overcame by introducing the right policies and incentives and the right financial packages. These examples are informative and could stimulate action in countries that are lagging behind on climate mitigation.

The results from our study should be considered conservative as we assess only a fraction of proven low-carbon solutions. By only scaling these examples up the world could cut emissions by 10 Gt CO_2e in 2025 and close to 14 Gt CO_2e in 2030[205]. This mitigation impact is equivalent to between 64% and 127% of the gap in 2030 between the aggregate effect of the pledges in the Intended Nationally Determined Contributions (INDC) submitted to 1st October 2015 and the level consistent with 2°C (UNFCCC, 2015). Lessons from scaling up these and other solutions would be even more essential if we aimed at limiting warming to 1.5ºC, as suggested by the poorest and most vulnerable countries. The potential for higher reductions would be bigger if more proven low-carbon solutions were considered. Since we scale up solutions only to the level of application achieved so far in the specific country case, we do not take into consideration the technological progress, we could argue that followers may act faster than first movers as there is some room for expanding scaling up even more.

For many of the cases, the costs of scaling up the solutions are less than the direct financial benefits they deliver. The aggregate abatement costs are on average $-18.2 billion in 2025 and $-38.5 billion in 2030. Scaling up all solutions would result in approximate costs of $-2/ton$CO_2e$ in 2025 and $-3/ton$CO_2e$ in 2030. These costs figures should be considered conservative as they do not include the co-benefits or the avoided climate change damages caused by business-as-usual options.

The level of uncertainty of the emission and cost estimations is about 20%, which is caused mainly by data limitations at the country level. In the cases where country-specific data was not available we used regional data. In most of the cases abatement cost data at the national level is not available; hence we opted for global cost data, or regional when available. This limitation leads to overestimated costs, specifically for the solar PV and wind power cases, where we did not find up-to-date abatement costs and had to use global cost figures from McKinsey MAC-curves.

For energy efficiency solutions, we do not correct for the rebound effect, taking into account that it is considered small, less than 10 - 20%; according to the IEA and ACEEE[206].

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[205] An average of 9 Gt CO_2e in 2025 and 12 Gt CO_2e in 2030, with an uncertainty of about 20%.

[206] IEA (2012). World Energy Outlook and ACEEE (2012). The rebound effect: large of small?

Furthermore, we did not analyse the overlap that might exist between solutions, such as in the Brazilian forest case and the Costa Rican payment for environmental services case. However, we tried to minimise the overlap whenever possible. In this example the Brazilian solution is limited to reducing the rate of deforestation; hence it covers areas that may be subject to deforestation. In the case of Costa Rica the solution covers afforestation and reforestation, but not deforestation, which is considered a different category in IPCC AR4.

Choosing the right baseline is also challenging. In the study we use baselines from existing scenarios (e.g. IEA current policy scenarios), but countries are taking action all the time so policies introduced after the scenarios, for example ones included in INDCs, will not be taken into account.

What is required to catalyse implementation?

Scaling up requires strong leadership and political will to place low carbon solutions on national agendas and addressing the barriers to enable implementation. The most prominent barriers are the policies that still favour fossil fuel-based economies and discourage investment in low-carbon practices. Two main factors are key to start overcoming these barriers: effective policy making and governance and finance incentives.

Effective policy making starts by identifying the mismatch between the low-carbon transition that is needed and the existing national policies and programmes. The mismatch would reveal ineffective policies that limit countries from enjoying the benefits of low-carbon solutions. Political leaders need to show bold political will to set ambitious and climate-smart policies; these include the removal of fossil fuel subsidies and other tax treatments that support carbon-intensive practices, proper regulation of the electricity market to ensure fair competition and investment, and incentives for sustainable land use in the cases of forestry, agriculture and urban transport. The example solutions in this report have been implemented through a mixture of policy types, tailored to the national circumstances. Examples of successful policies include subsidies for renewable energy, standards for energy and fuel efficiency and wider programmes bring together a number of policy approaches for example in the forestry sector.

Effective governance also requires reliable institutions to coordinate the policy making, the planning and implementation of low-carbon solutions. This coordination needs to be transparent and institutions should be accountable for their responsibilities.

Furthermore, the right financing packages are a prerequisite to incentivise investment in low-carbon solutions, especially for those that involve technologies and high capital costs. Policy makers need to leverage public funds and private sector finance; this could be fostered by designing public-private partnerships that result in win-win situations. A good example of this is the BRT in Colombia, where the city (public sector) is responsible for the system's infrastructure and the oversight of the BRT system, while the private sector is in charge of the system's operations and maintenance.[207]

[207] UNDP (2015). Examples of successful public-private partnerships. http://tcdc2.undp.org/GSSDAcademy/SIE/Docs/Vol15/10Colombia.pdf

Financing incentives also involve de-risking investments in low carbon technologies, especially in developing countries where risks tend to be high for various reasons (e.g. political instabilities, safety issues or economic decline). These are country-specific, but in general, policy makers could make country risk guarantees more explicit to investors. Insurance against country risks is provided to developing countries by international financial institutions, such as the Multilateral Investment Guarantee Agency (MIGA)[208].

[208] Waissbein, O., Glemarec, Y., Bayraktar, H., & Schmidt, T.S., (2013). Derisking Renewable Energy Investment. A Framework to Support Policymakers in Selecting Public Instruments to Promote Renewable Energy Investment in Developing Countries. New York, NY: United Nations Development Programme

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G. Cunha, L.A. Barroso, F.Porrua and B. Bezerra, Fostering Wind Power Through Auctions: the Brazilian Experience, International Association for Energy Economics, second quarter 2012, pg. 25-28https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCEQFjAAahUKEwj4v4eC87nHAhUEshQKHTKsAcg&url=https%3A%2F%2Fwww.iaee.org%2Fen%2Fpublications%2Fnewsletterdl.aspx%3Fid%3D167&ei=PPTWVfixJYTkUrLYhsAM&usg=AFQjCNEg0adNuTeaUxq6KdoghHFk22HFHQ

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11. Annex 1: Country groupings

Table 3. Energy efficiency solutions and country groupings

Solution	Description of selection	Selected regions		
• Appliance efficiency, Japan	OECD countries and Russia, China and South Africa	OECD countries Russia	China	South Africa
	All countries	OECD countries	Non OECD countries	

Table 4. Waste solutions and country groupings

Solution	Description of selection	Selected countries		
• Cutting food waste, Denmark	High income countries, based on world bank definition	Antigua and Barbuda	Estonia	New Zealand
		Australia	Finland	Norway
		Austria	France	Poland
		Bahamas	French Polynesia	Portugal
		Barbados	Germany	Russian Federation
		Belgium	Greece	Saint Kitts and Nevis
		Bermuda	Iceland	Slovakia
		Brunei Darussalam	Ireland	Slovenia
		Canada	Italy	Spain
		Chile	Latvia	Sweden
		China, Hong Kong SAR	Lithuania	Switzerland
		China, Macao SAR	Luxembourg	Trinidad and Tobago
		Croatia	Malta	United Kingdom
		Cyprus	Netherlands	United States of America
		Czech Republic	New Caledonia	Uruguay
	Upper middle income countries, based on world bank definition	Albania	Cuba	Panama
		Algeria	Dominica	Peru
		Angola	Dominican Republic	Romania
		Argentina	Ecuador	Saint Lucia
		Azerbaijan	Fiji	Saint Vincent and the Grenadines
		Belarus	Gabon	
		Belize	Grenada	Serbia
		Bosnia and Herzegovina	Hungary	South Africa
		Botswana	Iran (Islamic Republic of)	Suriname
		Brazil	Jamaica	The former Yugoslav Republic of Macedonia
		Bulgaria	Mauritius	
		China	Mexico	Tunisia

Solution	Description of selection	Selected countries		
		Colombia Costa Rica	Montenegro Namibia	Venezuela (Bolivarian Republic of)

Table 5. Renewable energy solutions and country groupings

Solution	Description of selection	Selected countries		
• Wind power, Denmark and Brazil	High income countries, based on world bank definition	Australia Austria Bahrain Belgium Canada Chile Croatia Cyprus Czech Republic Denmark Estonia Finland France Germany Greece Iceland	Ireland Israel Italy Japan Kuwait Latvia Lithuania Luxembourg Malta Netherlands Netherlands Antilles New Zealand Norway Oman Poland	Portugal Qatar Russia Saudi Arabia Slovakia Slovenia South Korea Spain Sweden Switzerland Trinidad and Tobago United Arab Emirates United Kingdom Uruguay USA
	Upper middle income countries (based on world bank definition)	Albania Algeria Angola Argentina Azerbaijan Belarus Belize Bosnia and Herzegovina Botswana Brazil Bulgaria China Colombia Costa Rica Cuba Dominica Dominican Republic	Gabon Grenada Hungary Iran Iraq Jamaica Jordan Kazakhstan Lebanon Libya Macedonia FYR Malaysia Maldives Marshall Islands Mauritius Mexico Montenegro	Panama Peru Romania Saint Lucia Saint Vincent and the Grenadines Serbia Seychelles South Africa Suriname Thailand Tonga Tunisia Turkey Turkmenistan Tuvalu Venezuela

Solution	Description of selection	Selected countries		
		Ecuador Fiji	Namibia Palau	
	Lower middle, low and unknown income countries	Afghanistan American Samoa Anguilla Armenia Aruba Bangladesh Benin Bermuda Bhutan Bolivia British Virgin Islands Brunei Burkina Faso Burundi Cambodia Cameroon Cape Verde Cayman Islands Central African Republic Chad Channel Islands Comoros Congo-Brazzaville Côte d'Ivoire Djibouti DR Congo East Timor Egypt El Salvador Eritrea Ethiopia Faroe Islands French Guiana French Polynesia Gambia Georgia Ghana Gibraltar	Guam Guatemala Guinea Guinea-Bissau Guyana Haiti Honduras Hong Kong India Indonesia Isle of Man Kenya Kiribati Kyrgyzstan Laos Lesotho Liberia Macau Madagascar Malawi Mali Martinique Mauritania Mayotte Micronesia Fed States Moldova Mongolia Montserrat Morocco Mozambique Myanmar Nauru Nepal Netherlands Antilles Nicaragua Niger Nigeria Niue	Northern Mariana Islands Pakistan Palestinian Territories Papua New Guinea Paraguay Philippines Pitcairn Islands Reunion Rwanda Saint Helena Saint Pierre and Miquelon Samoa Apia Sao Tome and Principe Senegal Sierra Leone Solomon Islands Somalia Sri Lanka Sudan Swaziland Syria Taiwan Tajikistan Tanzania Togo Tokelau Turks and Caicos Islands Uganda Ukraine Uzbekistan Vanuatu Vatican Vietnam Virgin Islands Wallis and Futuna Western Sahara Yemen Zambia

Solution	Description of selection	Selected countries		
		Guadeloupe	North Korea	Zimbabwe
• Solar PV, Bangladesh	Other countries with off-grid population	Afghanistan	Ghana	Nigeria
		American Samoa	Grenada	Northern Mariana Islands
		Angola	Guam	Palau
		Antigua and Barbuda	Guatemala	Panama
		Aruba	Guinea	Papua New Guinea
		Barbados	Guinea-Bissau	Puerto Rico
		Benin	Guyana	Rwanda
		Bhutan	Haiti	Sao Tome and Principe
		Botswana	Honduras	Senegal
		Brunei Darussalam	India	Sierra Leone
		Burkina Faso	Jamaica	Solomon Islands
		Burundi	Kenya	Somalia
		Cabo Verde	Kiribati	South Africa
		Cambodia	Korea, Dem. Rep.	South Sudan
		Cameroon	Lao PDR	Sri Lanka
		Cayman Islands	Lesotho	St. Kitts and Nevis
		Central African Republic	Liberia	St. Lucia
		Chad	Macao SAR, China	St. Vincent and the
		Colombia	Madagascar	Grenadines
		Comoros	Malawi	Sudan
		Congo, Dem. Rep.	Mali	Swaziland
		Congo, Rep.	Marshall Islands	Tanzania
		Curacao	Mauritania	Timor-Leste
		Djibouti	Micronesia, Fed. Sts.	Togo
		Dominica	Mongolia	Turks and Caicos Islands
		Equatorial Guinea	Mozambique	Tuvalu
		Eritrea	Myanmar	Uganda
		Ethiopia	Namibia	Vanuatu
		Fiji	Nepal	Virgin Islands (U.S.)
		French Polynesia	New Caledonia	Yemen, Rep.
		Gabon	Nicaragua	Zambia
		Gambia, The	Niger	Zimbabwe
• Solar PV Germany	Other high income countries, based on world bank definition (excluding countries with	Australia	Greece	Poland
		Austria	Greenland	Portugal
		Bahamas	Iceland	Puerto Rico
		Belgium	Ireland	Qatar
		Canada	Israel	Russia
		Chile	Italy	Saudi Arabia
		Croatia	Japan	Singapore

Solution	Description of selection	Selected countries		
	<10TWh solar potential)	Cyprus Czech Republic Denmark Equatorial Guinea Estonia Falkland Islands Finland France Germany	Kuwait Latvia Lithuania Netherlands New Caledonia USA New Zealand Norway Oman	Slovakia Slovenia South Korea Spain Sweden Switzerland United Arab Emirates United Kingdom Uruguay
	High and upper middle income countries, based on world bank definition (excluding countries with <10TWh solar potential) Note: High income countries not listed again; see row above	Albania Algeria Angola Argentina Azerbaijan Belarus Belize Bosnia and Herzegovina Botswana Brazil Bulgaria China Colombia Costa Rica	Cuba Dominican Republic Ecuador Gabon Hungary Iran Iraq Jamaica Jordan Kazakhstan Lebanon Libya Macedonia FYR Malaysia	Mexico Montenegro Namibia Panama Peru Romania Serbia South Africa Suriname Thailand Tunisia Turkey Turkmenistan Venezuela
	All countries (excluding countries with <10TWh solar potential) Note: High and upper middle income countries not listed again; see rows above	Afghanistan Armenia Bangladesh Benin Bhutan Bolivia Burkina Faso Burundi Cambodia Cameroon Central African Republic Chad Congo-Brazzaville Côte d'Ivoire Djibouti DR Congo Egypt	Guinea-Bissau Guyana Haiti Honduras India Indonesia Kenya Kyrgyzstan Laos Lesotho Liberia Madagascar Malawi Mali Mauritania Moldova Mongolia	Palestinian Territories Papua New Guinea Paraguay Philippines Rwanda Senegal Sierra Leone Solomon Islands Somalia Sri Lanka Sudan Swaziland Syria Taiwan Tajikistan Tanzania Togo

Solution	Description of selection	Selected countries		
		El Salvador Eritrea Ethiopia French Guiana Gambia Georgia Ghana Guatemala Guinea	Morocco Mozambique Myanmar Nepal Nicaragua Niger Nigeria North Korea Pakistan	Uganda Ukraine Uzbekistan Vanuatu Vietnam Western Sahara Yemen Zambia Zimbabwe
• Bioenergy for heating, Finland	Countries that have more than 3,000 HDDs per year and that have at least 80% of Finland's forested area per capita	Canada Mongolia Russia		

Table 6. Transport solutions and country groupings

Solution	Description of selection	Selected countries	
• Vehicle fuel efficiency, EU	All countries. Most countries have fuel efficiency standards in place. Taking into account the differences in the current situations almost all countries could benefit from enhancing fuel standards.	U.S. Canada Mexico Brazil Latin America-31 Russia Non-EU Europe China	Japan India South Korea Australia Asia-Pacific-40 Middle East Africa
• Bus rapid transit (BRT), Colombia	Cities with a population exceeding 1 million in medium income countries. Cities that already have a BRT system in place are excluded. The number of cities selected per country is shown in brackets.	Argentina (1) Armenia (1) Azerbaijan (1) Belarus (1) Bolivia (1) Brazil (1) Bulgaria (1) Cameroon (2) China (144) Cuba (1) Dominican Republic (1) Egypt (4) Georgia (1)	Jordan (1) Kazakhstan (1) Malaysia (1) Mexico (19) Mongolia (1) Paraguay (1) Philippines (4) Romania (1) Senegal (1) Serbia (1) Thailand (17) Turkey (8) Ukraine (5)

Solution	Description of selection	Selected countries	
		Ghana (2) Guatemala (1) Hungary (1) India (31) Indonesia (7) Iran (6)	Uzbekistan (1) Venezuela (1) Yemen (1) Zambia (1)

Table 7. Forestry solutions and country groupings

Solution	Description of selection	Selected countries and regions	
• Reducing the rate of deforestation, Brazil	Low and middle income countries from the tropical and subtropical belt with high deforestation rates and areas over the period 2010-2015 (selected based on FAO data)	Indonesia Myanmar Nigeria Tanzania Paraguay Zimbabwe DRC Argentina Bolivia Cameroon Mozambique Sudan Peru	Zambia Venezuela Botswana Cambodia Uganda Chad Honduras Mexico Mali Ecuador Somalia Namibia
• Payments for Ecosystem Services in Costa Rica	As solution is scalable in all regions with forest potential, all regions with afforestation potential have been considered	USA Europe OECD Pacific Central and South America Middle East Africa Other Asia	Non-Annex I East Asia (Cambodia, China, Korea (DPR), Laos, Mongolia, South Korea, Vietnam) Countries in Transition (Eastern Europe, former Soviet Union)

Table 8. Industry solutions and country groupings

Solution	Description of selection	Selected countries and regions	
• Reducing methane from fossil fuel production, USA	All countries. Taking into account the large differences in fossil fuel production across the world, all oil and gas producing countries could benefit from the wide range of measures implemented in this solution.	Australia Brazil Canada China India Indonesia	Africa Central & South America Middle East Europe Eurasia Asia

Solution	Description of selection	Selected countries and regions	
		Mexico Russia Turkey United States	
• Industrial energy efficiency improvement, China	Countries that have an industrial energy consumption per industrial value added of above 10 MJ/USD2010 of which recent (post 2005) industry emissions data is available.	Uzbekistan Republic of Moldova Ukraine Kyrgyzstan Mongolia Kazakhstan Russian Federation India	Iceland South Africa The former Yugoslav Republic of Macedonia Brazil Bulgaria Georgia
• Efficiency standards for electric motors, United States	All countries		

Table 9. Buildings solutions and country groupings

Solution	Description of selection	Selected countries	
• Buildings energy efficiency, Germany	European countries that have a higher residential buildings emissions intensity than Germany, and non-European countries with similar income and climate	Bulgaria Cyprus Denmark Greece Italy Latvia Lithuania Netherlands	Poland Romania Norway United States Russian Federation Canada Japan
• Buildings energy efficiency, Mexico	Same climate zone countries (same quartile of countries on both heating degree days and cold degree days). Lebanon excluded because of unreliable data.	Afghanistan Albania Algeria Argentina Australia Azerbaijan Chile People's Republic of China Ecuador Eritrea Islamic Republic of Iran Israel Italy	Lebanon Malta Mexico Morocco Namibia Nepal New Zealand Peru Portugal South Africa Spain Turkey Uruguay

Solution	Description of selection	Selected countries	
		Jordan	Zimbabwe
• Solar water heater deployment in China	Regions with similar or higher solar potential as China, similar level of income (at time of introducing policies) and low level of deployment of solar heating and cooling	Asia excluding China - 37 Middle East - 12	Non-OECD Americas – All Latin America countries except Chile and Mexico
• Cookstove deployment in China	Regions with significant share of population using traditional cookstoves	Southeast Asia South Asia	Sub-Saharan Africa Latin America and Caribbean

Table 10. Agriculture

Solution	Description of selection	Selected regions	
• Low carbon agriculture	Regions of developing countries (selected based on FAO data)	Latin America (excluding Brazil) Eastern Africa Middle Africa Southern Africa Western Africa	Central America Caribbean Southern Asia South-Eastern Asia Western Asia

12. Annex 2: Assumptions

Marginal abatement costs

The marginal abatement costs that are used for each solution to convert the abatement potential in abatement costs are displayed in the chart below. Note that for some solutions a range is used and for others a single cost figure is used.

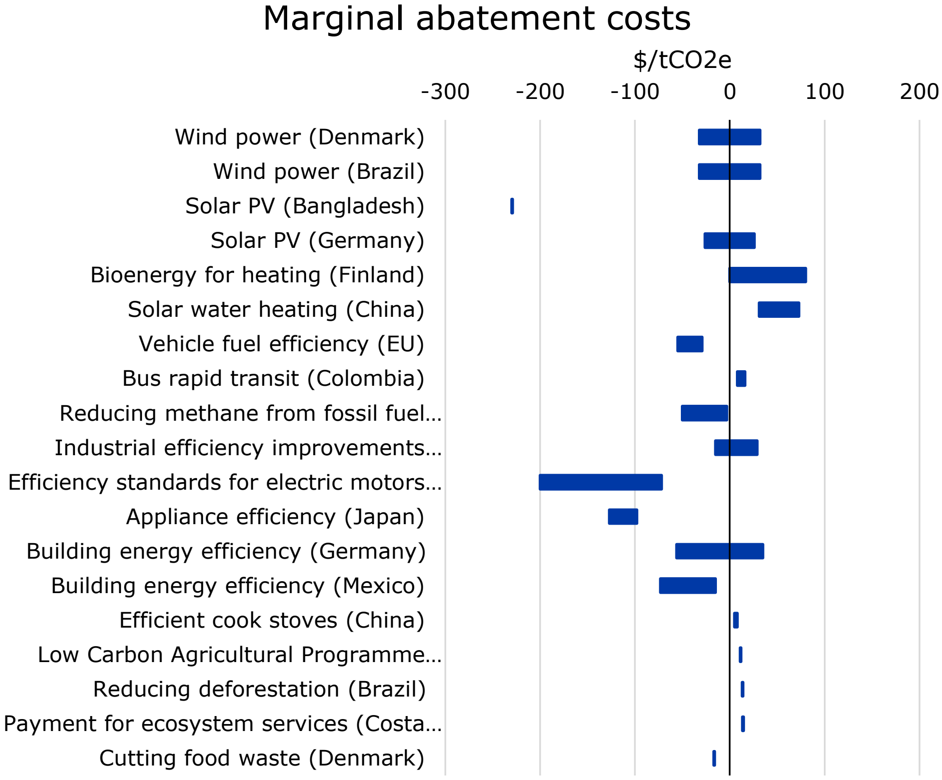

Figure 5. Marginal abatement costs used in the assessment

Table 11. Marginal Abatement costs of upscaled solutions

Marginal abatement costs ($/tCO₂e)		
Solution	**Minimum**	**Maximum**
Wind power (Denmark)	-32	32
Wind power (Brazil)	-32	32
Solar PV (Bangladesh)	-230	-229
Solar PV (Germany)	-26	26
Bioenergy for heating (Finland)	0	80
Solar water heating (China)	31	73

Marginal abatement costs ($/$tCO_2e$)		
Solution	**Minimum**	**Maximum**
Vehicle fuel efficiency (EU)	-55	-29
Bus rapid transit (Colombia)	8	16
Reducing methane from fossil fuel production (USA)	-50	-3
Industrial efficiency improvements (China)	-15	29
Efficiency standards for electric motors (USA)	-200	-72
Appliance efficiency (Japan)	-127	-98
Building energy efficiency (Germany)	-56	35
Building energy efficiency (Mexico)	-73	-15
Efficient cookstoves (China)	5	8
Low Carbon Agricultural Programme (Brazil)	11	12
Reducing deforestation (Brazil)	13	14
Payments for ecosystem services (Costa Rica)	13.5	14.5
Cutting food waste (Denmark)	-17	-16

Low carbon solutions in the renewable energy sector

Table 12

Wind power, Denmark and Brazil
Same share of realistic on shore wind power potential[209] as in Denmark or Brazil can be reached in other countries. This potential has been determined by an Ecofys project in 2015 and keeps in mind available amount of land (including limitations such as land-use competition and acceptance), resource quality and technology of wind turbines. Realistic on shore wind potentials are available as a range for each country and local capacity factors are not taken into account.
Other countries will reach this share in 2030, following a linear development path.
The share of offshore energy in the forecasted wind energy production in a base case scenario varies between 0-90%.
A country won't produce more wind power than 50% of its total forecasted electricity production.

Table 13

Solar PV, Bangladesh
The share of the total off-grid population that is supplied with a solar home system in Bangladesh can be reached in other countries with an off-grid population[210].
All solar home systems in these countries will be installed before 2025 (Bangladesh took 10 years)[211].
Business as usual scenario assumes no installation of solar home systems.
Solar home systems will be installed on houses which are the last to be connected to the grid.
Multiple assumptions on kerosene usage[212] • Average of 4 Lumen-hours per day of Kerosene lighting in off-grid households • Average Kerosene usage per hour of 7.5 mL/hr for a kerosene lamp • Average 5 people per household in off-grid households • Average of 3 kerosene lamps per off-grid household

209 Confidential Ecofys analysis (2014)
210 World bank, Access to electricity (% of population), available at: http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
211 Infrastructure Development Company Limited (2014), Solar Home System Program, available at: http://idcol.org/home/solar
212 Renewable Energy & Energy Efficiency Partnership (2009), 50 ways to end kerosene lightning, available at: http://global-off-grid-lighting-association.org/wp-content/uploads/2013/09/Fifty-Ways-to-End-Kerosene-Lighting-in-Developming-Countries-REEP.pdf

Table 14

Solar PV, Germany
Same share of realistic on solar PV potential[213] as in Germany can be reached in other countries (3 options; 1. High income countries only, 2. High and upper middle income countries only, 3. All countries)
Other countries will reach this share in 2030, following a linear development path.
A country won't produce more solar power than 50% of its total forecasted electricity production.

Table 15

Bioenergy for heating, Finland
The amount of available biomass in each country is not explicitly taken into account.
The share of bioenergy in total non-electricity energy consumption of buildings achieved in Finland (i.e. 53%[214]) is assumed to be feasible for all countries that have more than 3,000 HDDs[215] and that have an average amount of biomass residues per capita in the 2012-2014 period bigger than 10% of that of Finland (i.e. at least 0.1 cubic meter per capita[216]).
The solution is assumed to be cost-effective in certain cases (i.e. marginal abatement cost of 0).
The biomass is assumed to replace natural gas.

Table 16

Solar water heating, China
The consumption of energy from solar heating and cooling per person in China in 2012 is set as potential to be reached by other regions.
Baseline trend in selected regions is based on reference scenario in Greenpeace report 'Energy Revolution 2015'[217].
Solar thermal heating replaces fuel oil heating, with subsequent conversion rate to CO_2e (same assumption as in IEA SHC)[218].
Abatement costs based on worldwide and Chinese estimates[219].

Low carbon solutions in the transport sector

Table 17

Vehicle fuel efficiency, EU
The analysis covers light-duty vehicles only.
Reduction is determined compared to baseline projections[220], which already include vehicle fuel efficiency policies adopted up to 2012.

[213] Confidential Ecofys analysis (2014)
[214] IEA Balances (2014)
[215] Baumert, K. and Selman, M. (2003). Data Note: Heating and Cooling Degree Days. World Resources Institute.
[216] FAOSTAT (2015). Available at http://faostat3.fao.org/browse/F/*/E
[217] Greenpeace (2015). *Energy Revolution 2015*. Available at http://www.greenpeace.org/international/Global/international/publications/climate/2015/Energy-Revolution-2015-Full.pdf
[218] IEA SHC Programme (2015), Solar Heat Worldwide – Markets and Contribution to the Energy Supply 2013. Available at http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2015.pdf
[219] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
And McKinsey (2009). China's green revolution: Prioritizing technologies to achieve energy and environmental sustainability. Available at http://www.understandchinaenergy.org/chinas-green-revolution-prioritizing-technologies-to-achieve-energy-and-environmental-sustainability-2/
[220] ICCT (2012) ICCT Global Transportation Roadmap Model, Version 1-0. Available at: http://www.theicct.org/global-transportation-roadmap-model

Other countries follow the 2005–2015 EU's trajectory[221] in terms of fleet average emission intensity of light-duty vehicles (gCO_2e/km). The 2005–2010 trend is based on historic data, whereas the 2010–2015 trend is based on projections including the EU's 2015 mandatory standards.
Vehicle activity is assumed to be the same as in the baseline projections.
The analysis includes tank-to-wheel (TTW) CO_2, CH_4 and N_2O emissions.
Abatement costs are based on global marginal abatement costs for 2030 for diesel and gasoline vehicles of -$€_{2005}$20 and -$€_{2005}$38, respectively[222].

Table 18

Bus rapid transit (BRT), Colombia
The TransMilenio BRT system in Bogotá transported 565 million passengers in 2013[223].
The average trip distance is assumed to be 7.5–15 km per day.
It is assumed that the same amount of passenger-kilometres per inhabitant is reached in other cities.
Cities that already have BRT systems in place[224] are excluded from the analysis.
The population in 2025 and 2030 of the selected cities is estimated based on the population[225] in the latest historic year available and country-specific projections for urban population[226].
It is assumed the transport by BRT replaces the following transport modes[227,228]: 92% Bus 7% Light-duty vehicles (LDV) 1% Non-motorised transport or non-travel
Regional specific emission factors for LDV and bus transport are calculated from ICCT (2012)[229].
The emissions factor for BRT is taken to be 18–22 gCO_2/passenger-kilometre[230]
The analysis includes tank-to-wheel (TTW) CO_2 emissions.
The abatement costs of this solution in Bogotá are 8-16 $\$/tCO_2$[231]. Abatement costs are assumed to be similar in the cities the solution is scaled up to.

[221] ICCT (2012) ICCT Global Transportation Roadmap Model, Version 1-0, available at: http://www.theicct.org/global-transportation-roadmap-model
[222] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[223] BRT Centre of Excellence, EMBARQ, IEA and SIBRT (2015). Global BRT data. Available at: http://brtdata.org/.
[224] BRT Centre of Excellence, EMBARQ, IEA and SIBRT (2015). Global BRT data. Available at: http://brtdata.org/.
[225] United Nations Statistics Division (2015). UNSD Demographic Statistics. City population by sex, city and city type. Available at: http://data.un.org/Data.aspx?d=POP&f=tableCode%3A240
[226] United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, CD-ROM Edition.
[227] Hook, W., Kost, C., Navarro, U., Replogle, M., Baranda, B. (2010). Carbon Dioxide Reduction Benefits of Bus Rapid Transit Systems Learning from Bogotá, Colombia; Mexico City, Mexico; and Jakarta, Indonesia. Transportation Research Record: Journal of the Transportation Research Board, No. 2193, Transportation Research Board of the National Academies, Washington.
[228] Mejia, A. (2014) Elements of T-NAMA MRV. GIZ ASEAN Regional In-depth discussion event on MRV for Transport NAMAs. Ha Long City, Vietnam: 2 October 2014
[229] ICCT (2012) ICCT Global Transportation Roadmap Model, Version 1-0, available at: http://www.theicct.org/global-transportation-roadmap-model
[230] IEA (2012). Energy Technology Perspectives 2012. International Energy Agency (IEA).
[231] Kahn Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y. Muromachi, P. J. Newton, S. Plotkin, D. Sperling, R. Wit, P. J. Zhou, 2007: Transport and its infrastructure. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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Low carbon solutions in the industry sector

Table 19

Reducing methane from oil and gas production, USA
Other countries achieve the same share of the abatement potential[232] as reached in the USA in 2010[233].
Abatement potential is defined in two ways: 1) technical potential, 2) cost-effective potential.
Differences between countries and regions, both in abatement potential and abatement costs, are accounted for by applying country/region specific MAC-curves[234].
For 2025 the abatement potential was defined by linear interpolation between 2020 and 2030 potential.
Baseline emissions are taken from US EPA (2013)[235]. These baselines are based on national communications, which are not in all cases the most recent ones.

Table 20

Industrial efficiency improvements, China
All industrial efficiency improvements in China between 2008 and 2012 are assumed to be the result of the solution
The most recent emission factor (tCO2e/MJ)[236] is used per country to estimate emissions from energy consumption. This factor is assumed to be constant until 2030
The abatement cost of industrial efficiency measures[237] in China is assumed to be representative for other countries with low industrial energy efficiency.
Industrial value added [238] is used as a proxy for industry growth
All change in industrial energy demand not caused by growth of industrial output (measured in industrial value added) is attributed to energy efficiency improvements.

Table 21

Efficiency standards for electric motors, USA
The achieved electricity savings percentage of the U.S. (i.e. 4%[239] to 7%[240] per year) is assumed to be achievable for all industries in all countries.
The saved electricity is assumed to be the marginal electricity generated from fossil fuels in the respective country.

Table 22

Appliance efficiency in Japan
Other countries can reach the same reduction in buildings electricity use as Japan.
For OECD countries, it is assumed that 60-80% of the emission reductions of Japan is already achieved in a business as usual scenario, by policies currently being implemented.
For non-OECD countries, it is assumed that 0-20% of the emission reductions of Japan is already achieved in a business as usual scenario, by policies currently being implemented.

[232] US EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Available at: http://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf

[233] US EPA (2010). EPA Natural Gas STAR Program Accomplishments. Available at: US EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Available at: http://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf

[234] US EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Available at: http://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf

[235] US EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Available at: http://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf

[236] IEA (2014). CO2 from fuel combustion.

[237] McKinsey (2009). China's green revolution: Prioritizing technologies to achieve energy and environmental sustainability Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves

[238] Worldbank (2015). Industry value added. Available at http://data.worldbank.org/indicator

[239] US DOE (2009). Impacts on the Nation of the Energy Independence and Security Act of 2007. Available at https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/en_masse_tsd_march_2009.pdf

[240] EIA (2014). Minimum efficiency standards for electric motors will soon increase. Available at http://www.eia.gov/todayinenergy/detail.cfm?id=18151

Low carbon solutions in the buildings sector

Table 23

Building energy efficiency, Germany
All residential buildings emissions intensity reductions in Germany in the 2006-2011 period are assumed to be the result of the solution.
The trend of residential floor space[241] between 2006 and 2011 is extrapolated for each country.
For non-EU countries the floor space is calculated from 2012 average household sizes in regions[242], that are downscaled to countries on a per-capita basis[243]
The trend of GHG emissions[244] per m^2 residential floor space between 2006 and 2011 is extrapolated for each country to calculate the baseline.
The abatement costs[245] for Germany are assumed to be representative for the selected countries.

Table 24

Building energy efficiency, Mexico
An emissions reduction of 85% of average residential building emissions per household is assumed as a result of the solution[246].
The trend of population growth between 2008 and 2012 is extrapolated for each country.
The trend of residential buildings GHG emissions between 2008 and 2012[247] is extrapolated for each country to calculate the baseline.
The number of households with green mortgages is assumed to grow with 0.312% per year.

Table 25

Efficient cookstoves, China
The emission reduction per improved cookstove is 2 tCO_2e[248]
Selected countries reach Chinese rate of households with modern and improved stoves in 2030, in scale up scenario. 2025 values are obtained through linear interpolation.
Number of people per household remains constant from 2015 to 2030 in the selected regions
In BAU scenario, absolute number of additional modern and improved cookstove per year remains constant, at 2 million[249].
Cost of emissions reduction is between USD5 and USD8 (2010USD)[250].

Low carbon solutions in the agriculture and forestry sector

Table 26

Low carbon agricultural programme, Brazil
Only a quarter to an eighth of the 2020 target is achieved in 2015[251].
Selected countries, achieve the same level of emission reduction compared to BAU in 2030.

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[241] Enerdata (2014). ODYSSEE Database.
[242] IEA (2015). Energy technology Perspectives 2015.
[243] Worldbank (2015) Population. Available at http://data.worldbank.org/indicator
[244] IEA (2014). CO2 from fuel combustion.
[245] McKinsey (2007). Kosten und Potenziale der Vermeidung von Treibhausgasemissionen in Deutschland – Sektorperspective Gebäude
[246] Green mortgage program INFONAVIT – Mexico. Available at http://www3.cec.org/islandora-gb/en/islandora/object/greenbuilding%3A74/datastream/OBJ-EN/view
[247] IEA database (2015) Residential Buildings.
[248] Stockholm Environment Institute, Assessing the Climate Impacts of Cookstove Projects: Issues in Emissions Accounting, 2013, available at http://sei-us.org/Publications_PDF/SEI-WP-2013-01-Cookstoves-Carbon-Markets.pdf
[249] UNEP (2015). *Climate commitments of subnational actors and business: A quantitative assessment of their emission reduction impact*, p. 17. Available at: http://apps.unep.org/publications/pmtdocuments/-Climate_Commitments_of_Subnational_Actors_and_Business-2015CCSA_2015.pdf.pdf
[250] Stockholm Environment Institute, Assessing the Climate Impacts of Cookstove Projects: Issues in Emissions Accounting, 2013, available at http://sei-us.org/Publications_PDF/SEI-WP-2013-01-Cookstoves-Carbon-Markets.pdf
[251] Own assumption based on publications and interviews with experts

Northern Africa, Central Asia, and East Asia are considered being from different climate zones and are not selected.
Cost of emissions reduction is around USD10.5 (2010USD)[252].

Table 27

Reducing deforestation, Brazil
Middle income countries reach 80% rate decrease in 2025 (same as Brazil in 2013), maintain it up to 2030, low income countries reach 80% in 2030.
Carbon stock capacity of forest: 350-900 tCO_2e/ha[253].
Differences between countries and regions in abatement costs, are accounted for by applying country/region specific MAC-curves[254].
For 2025 the abatement potential was defined by linear interpolation between 2013 and 2030 potential.

Table 28

Payments for Ecosystem Services, Costa Rica
Total global afforestation potential is approximated with global potential at costs equal or less than 100 US$/tCO2.
Afforestation potential for Costa Rica is calculated by using the maximum recorded forest coverage in Costa Rica.
Increase in forest coverage between 1996 and 2013 in Costa Rica is attributed to impact of PES programme. It might also be linked to other, accompanying policies, however it is impossible to distinguish.
For 2025 the abatement potential was defined by linear interpolation between 2020 and 2030 potential.

Table 29

Cutting food waste, Denmark
In the business as usual scenario, historic food waste has been extrapolated linearly up to 2030.
Emission factors of food categories estimated based on specific products in category with available data. Estimates per food waste category listed in the following table.

Category	Emission factor ($g\ CO_2e/kg$)[255]	Estimated emission factor based on
Alcoholic Beverages	2710	Average of wine and beer
Animal fats	24000	Butter
Cereals – Excl. Beer	700	Bread
Eggs	1600	Egg
Fruits – Excl. Wine	250	Oranges
Meat	7667	Average of beef, pork and chicken
Milk – Excl. Butter	357	Milk
Offals	7667	Average of beef, pork and chicken
Oilcrops	1000	Rough estimate based on other categories
Pulses	1000	
Starchy Roots	220	Potatoes
Stimulants	1000	Rough estimate based on other categories, limited impact due to low volumes
Sugar & Sweeteners	1000	

[252] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[253] IPCC (2007), Fourth Assessment Report, Chapter 9: Forestry, available at https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch9.html
[254] McKinsey (2009). Pathways to a low-carbon economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves
[255] Brug mere spild mindre, available at http://www.brugmerespildmindre.dk/drivhusgasser&usg=ALkJrhjI3vNcthXLmtp5-lGsXbBMfBJX-A

	Sugar Crops	210	Cabbage
	Treenuts	1000	Rough estimate
	Vegetable Oils	1805	Rough estimate based on tomatoes and cabbage
	Vegetables	1805	Average tomatoes and cabbage
Countries can reach the 25% cut in food waste that Denmark realized, before 2025 (Denmark took 4 years) and waste volumes will level out afterwards.			

13. Annex 3: Results in tables and graphs

Potential ($MtCO_2e$)	**2025**			**2030**		
Solution	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**
Wind power (Denmark)	479	669	859	718	1,003	1,288
Wind power (Brazil)	9	10	12	13	15	18
Solar PV (Bangladesh)	3	4	5	3	3	3
Solar PV (Germany)	1,204	2,131	3,059	1,806	3,197	4,588
Bioenergy for heating (Finland)	159	187	215	164	193	222
Solar water heating (China)	114	134	154	116	136	157
Vehicle fuel efficiency (EU)	223	262	301	446	525	603
Bus rapid transit (Colombia)	10	23	37	11	24	38
Reducing methane from fossil fuel production (USA)	312	367	422	330	388	447
Industrial efficiency improvements (China)	383	533	684	648	879	1,109
Efficiency standards for electric motors (USA)	78	103	128	85	112	139
Appliance efficiency (Japan)	195	241	287	327	401	475
Building energy efficiency (Germany)	49	58	67	66	77	89
Building energy efficiency (Mexico)	63	74	85	109	129	148
Efficient cookstoves (China)	356	711	1,067	492	985	1,477
Low Carbon Agricultural Programme (Brazil)	74	110	146	111	165	219
Reducing deforestation (Brazil)	1,379	2,462	3,546	1,558	2,782	4,007
Payment for ecosystem services (Costa Rica)	294	588	882	441	882	1,323
Cutting food waste (Denmark)	153	179	206	202	238	274
Aggregated potential	**7,326**	**8,848**	**10,370**	**10,129**	**12,136**	**14,143**

Table 30. Abatement potential per solution in 2025 and 2030

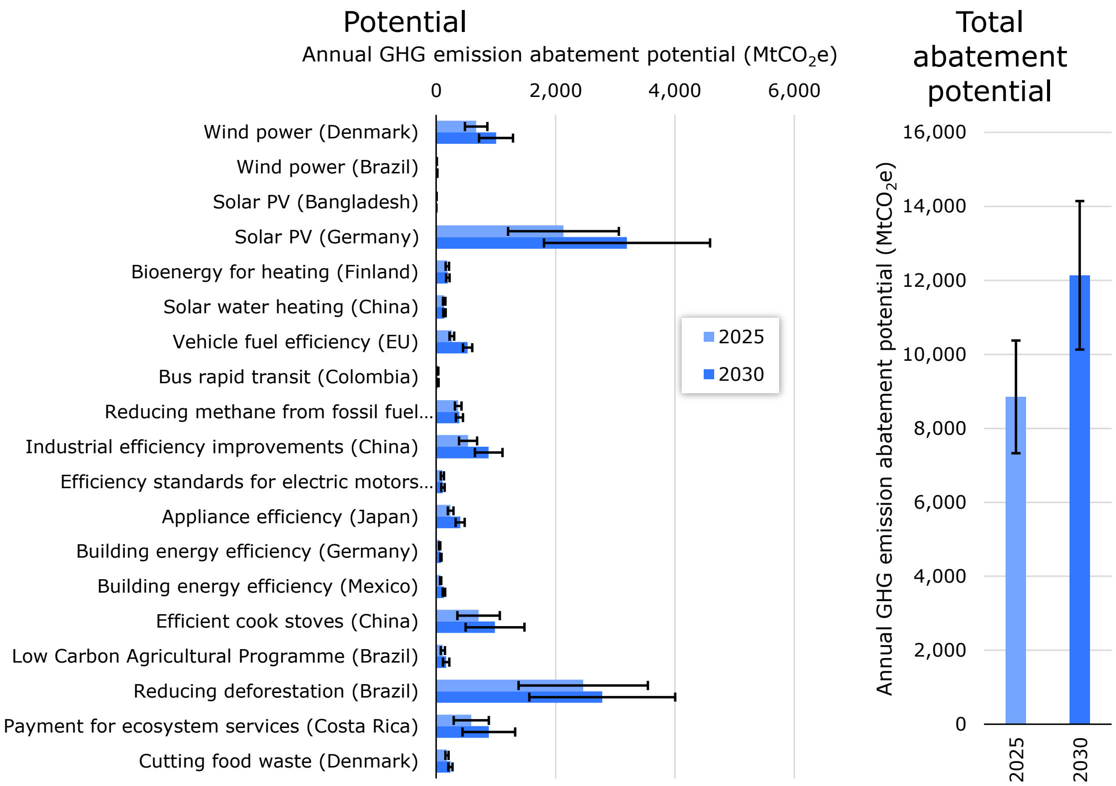


Figure 6. Abatement potentials for individual solutions and an aggregate of all solutions

Abatement costs (million $)	**2025**			**2030**		
Solution	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**
Wind power (Denmark)	-27,515	-	27,515	-41,273	-	41,273
Wind power (Brazil)	-381	-	381	-571	-	571
Solar PV (Bangladesh)	-790	-929	-1,068	-587	-691	-795
Solar PV (Germany)	-80,208	-	80,208	-120,313	-	120,313
Bioenergy for heating (Finland)	0	7,496	14,992	0	7,744	15,488
Solar water heating (China)	-9,750	-6,922	-4,095	-9,928	-7,049	-4,170
Vehicle fuel efficiency (EU)	-14,503	-11,068	-7,633	-29,047	-22,167	-15,288
Bus rapid transit (Colombia)	80	341	602	83	358	633
Reducing methane from fossil fuel production (USA)	-9,273	-7,424	-5,576	-10,285	-8,164	-6,042
Industrial efficiency improvements (China)	-9,964	4,982	19,929	-16,158	8,079	32,316
Efficiency standards for electric motors (USA)	-25,552	-15,553	-5,555	-27,894	-16,979	-6,064
Appliance efficiency (Japan)	-36,383	-27,730	-19,078	-60,240	-46,075	-31,910
Building energy efficiency (Germany)	-4,136	-760	2,616	-5,519	-1,014	3,492
Building energy efficiency (Mexico)	-5,372	-3,223	-1,074	-9,380	-5,628	-1,876
Efficient cookstoves (China)	1,778	5,157	8,535	2,462	7,140	11,818
Low Carbon Agricultural Programme (Brazil)	796	1,184	1,572	1,195	1,777	2,359
Reducing deforestation (Brazil)	17,618	31,461	45,304	20,442	36,504	52,566

Abatement costs (million $)	2025			2030		
Solution	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**
Payment for ecosystem services (Costa Rica)	3,954	7,909	11,863	5,932	11,863	17,795
Cutting food waste (Denmark)	-2,666	-3,137	-3,607	-3,536	-4,160	-4,784
Aggregated costs	**-107,117**	**-18,216**	**70,685**	**-170,962**	**-38,462**	**94,039**

Table 31 Abatement costs per solution in 2025 and 2030

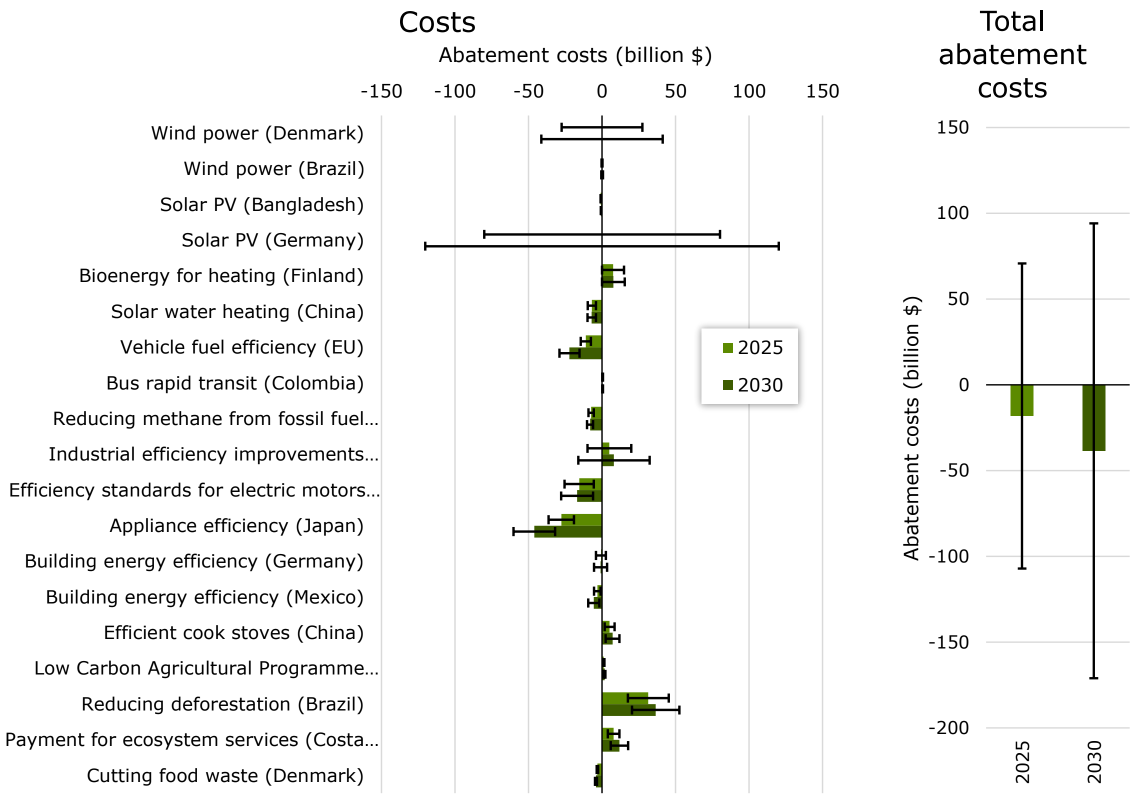
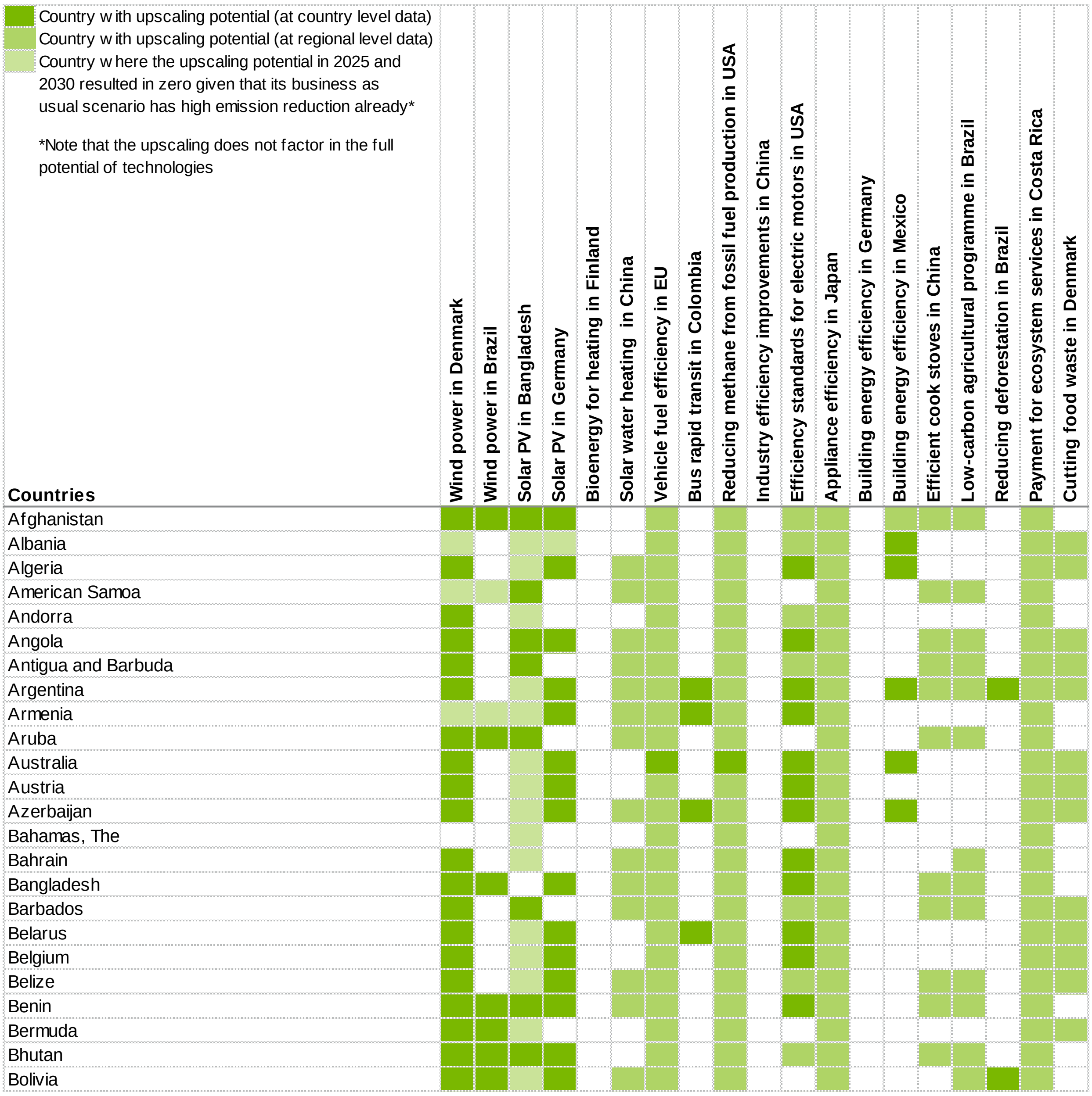


Figure 7 Aggregated and disaggregated abatement costs in 2025 and 2030

14. Annex 4: Overview of countries vs. solutions




Countries
Wind power in Denmark
Wind power in Brazil
Solar PV in Bangladesh
Solar PV in Germany
Bioenergy for heating in Finland
Solar water heating in China
Vehicle fuel efficiency in EU
Bus rapid transit in Colombia
Reducing methane from fossil fuel production in USA
Industry efficiency improvements in China
Efficiency standards for electric motors in USA
Appliance efficiency in Japan
Building energy efficiency in Germany
Building energy efficiency in Mexico
Efficient cook stoves in China
Low-carbon agricultural programme in Brazil
Reducing deforestation in Brazil
Payment for ecosystem services in Costa Rica
Cutting food waste in Denmark
Bosnia and Herzegovina
Botswana
Brazil
Brunei Darussalam
Bulgaria
Burkina Faso
Burundi
Cabo Verde
Cambodia
Cameroon
Canada
Cayman Islands
Central African Republic
Chad
Channel Islands
Chile
China
Colombia
Comoros
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Côte d'Ivoire
Croatia
Cuba
Curaçao
Cyprus
Czech Republic
Denmark
Djibouti
Dominica
Dominican Republic
Ecuador
Egypt, Arab Rep.
El Salvador
Equatorial Guinea
Eritrea
Estonia

Countries	Wind power in Denmark	Wind power in Brazil	Solar PV in Bangladesh	Solar PV in Germany	Bioenergy for heating in Finland	Solar water heating in China	Vehicle fuel efficiency in EU	Bus rapid transit in Colombia	Reducing methane from fossil fuel production in USA	Industry efficiency improvements in China	Efficiency standards for electric motors in USA	Appliance efficiency in Japan	Building energy efficiency in Germany	Building energy efficiency in Mexico	Efficient cook stoves in China	Low-carbon agricultural programme in Brazil	Reducing deforestation in Brazil	Payment for ecosystem services in Costa Rica	Cutting food waste in Denmark
Ethiopia																			
Faeroe Islands																			
Fiji																			
Finland																			
France																			
French Polynesia																			
Gabon																			
Gambia, The																			
Georgia																			
Germany																			
Ghana																			
Greece																			
Greenland																			
Grenada																			
Guam																			
Guatemala																			
Guinea																			
Guinea-Bissau																			
Guyana																			
Haiti																			
Honduras																			
Hong Kong SAR, China																			
Hungary																			
Iceland																			
India																			
Indonesia																			
Iran, Islamic Rep.																			
Iraq																			
Ireland																			
Isle of Man																			
Israel																			
Italy																			
Jamaica																			
Japan																			
Jordan																			
Kazakhstan																			
Kenya																			

Countries	Wind power in Denmark	Wind power in Brazil	Solar PV in Bangladesh	Solar PV in Germany	Bioenergy for heating in Finland	Solar water heating in China	Vehicle fuel efficiency in EU	Bus rapid transit in Colombia	Reducing methane from fossil fuel production in USA	Industry efficiency improvements in China	Efficiency standards for electric motors in USA	Appliance efficiency in Japan	Building energy efficiency in Germany	Building energy efficiency in Mexico	Efficient cook stoves in China	Low-carbon agricultural programme in Brazil	Reducing deforestation in Brazil	Payment for ecosystem services in Costa Rica	Cutting food waste in Denmark
Kiribati																			
Korea, Dem. Rep.																			
Korea, Rep.																			
Kosovo																			
Kuw ait																			
Kyrgyz Republic																			
Lao PDR																			
Latvia																			
Lebanon																			
Lesotho																			
Liberia																			
Libya																			
Liechtenstein																			
Lithuania																			
Luxembourg																			
Macao SAR, China																			
Macedonia, FYR																			
Madagascar																			
Malaw i																			
Malaysia																			
Maldives																			
Mali																			
Malta																			
Marshall Islands																			
Mauritania																			
Mauritius																			
Mexico																			
Micronesia, Fed. Sts.																			
Moldova																			
Monaco																			
Mongolia																			
Montenegro																			
Morocco																			
Mozambique																			
Myanmar																			
Namibia																			
Nepal																			

Countries	Wind power in Denmark	Wind power in Brazil	Solar PV in Bangladesh	Solar PV in Germany	Bioenergy for heating in Finland	Solar water heating in China	Vehicle fuel efficiency in EU	Bus rapid transit in Colombia	Reducing methane from fossil fuel production in USA	Industry efficiency improvements in China	Efficiency standards for electric motors in USA	Appliance efficiency in Japan	Building energy efficiency in Germany	Building energy efficiency in Mexico	Efficient cook stoves in China	Low-carbon agricultural programme in Brazil	Reducing deforestation in Brazil	Payment for ecosystem services in Costa Rica	Cutting food waste in Denmark
Netherlands																			
New Caledonia																			
New Zealand																			
Nicaragua																			
Niger																			
Nigeria																			
Northern Mariana Islands																			
Norw ay																			
Oman																			
Pakistan																			
Palau																			
Panama																			
Papua New Guinea																			
Paraguay																			
Peru																			
Philippines																			
Poland																			
Portugal																			
Puerto Rico																			
Qatar																			
Romania																			
Russian Federation																			
Rw anda																			
Samoa																			
San Marino																			
São Tomé and Principe																			
Saudi Arabia																			
Senegal																			
Serbia																			
Seychelles																			
Sierra Leone																			
Singapore																			
Sint Maarten (Dutch part)																			
Slovak Republic																			
Slovenia																			
Solomon Islands																			
Somalia																			

Countries	Wind power in Denmark	Wind power in Brazil	Solar PV in Bangladesh	Solar PV in Germany	Bioenergy for heating in Finland	Solar water heating in China	Vehicle fuel efficiency in EU	Bus rapid transit in Colombia	Reducing methane from fossil fuel production in USA	Industry efficiency improvements in China	Efficiency standards for electric motors in USA	Appliance efficiency in Japan	Building energy efficiency in Germany	Building energy efficiency in Mexico	Efficient cook stoves in China	Low-carbon agricultural programme in Brazil	Reducing deforestation in Brazil	Payment for ecosystem services in Costa Rica	Cutting food waste in Denmark
South Africa																			
South Sudan																			
Spain																			
Sri Lanka																			
St. Kitts and Nevis																			
St. Lucia																			
St. Vincent and the Grenadines																			
Sudan																			
Suriname																			
Swaziland																			
Sweden																			
Switzerland																			
Syrian Arab Republic																			
Tajikistan																			
Tanzania																			
Thailand																			
Timor-Leste																			
Togo																			
Tonga																			
Trinidad and Tobago																			
Tunisia																			
Turkey																			
Turkmenistan																			
Turks and Caicos Islands																			
Tuvalu																			
Uganda																			
Ukraine																			
United Arab Emirates																			
United Kingdom																			
United States																			
Uruguay																			
Uzbekistan																			
Vanuatu																			
Venezuela, RB																			
Vietnam																			
Virgin Islands (U.S.)																			
Zambia																			
Zimbabwe																			

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