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Sitra Studies
105

Green to Scale

Low-carbon success stories to inspire the world

Oras Tynkkynen (Ed.)

November 2015

Sitra Studies 105

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Low-carbon success stories to inspire the world

ISBN 978-951-563-945-5 (paperback)

ISBN 978-951-563-946-2 (PDF) www.sitra.fi

Enquiries about the publication: publications@sitra.fi

Photos: Alamy, Folio Bildbyrå, Getty Images, Shutterstock

Erweko, Helsinki 2015

Sitra Studies is a Publication Series which focuses on the conclusions and outcomes of Sitra's future-oriented work.

Printed matter
4041 0032

PEFC/02-31-120

SITRA STUDIES 105
Green to Scale
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November 2015

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Preface

LET US BE FRANK: the transformation to a zero-carbon world is not easy. We need to rapidly change infrastructure, investment flows and policies. We even need to change mindsets.

This report gives hope. Innovative analysis by Sitra and its international partners shows that it can be done.

The world's nations have already risen to the challenge. More countries than ever have committed to climate action that is more ambitious than ever.

Yet it is not enough to limit warming to tolerable levels. Countries need to do more and move faster.

This report will help governments meet their national climate commitments. More importantly, the report can help governments go beyond their current commitments.

Green to Scale has uncovered 17 climate solutions already in active use around the world. When scaled up, these proven solutions could cut global emissions significantly and deliver many other benefits, from improving people's health to enhancing energy security.

The solutions offer a menu of options for governments to consider. They can be applied by countries with different levels of development and across the economy – from energy to industry, from cities to transport, from food to land use.

It can indeed be done. We can limit global warming to a maximum of 2°C and seize the full potential of green, low-carbon growth.

We would like to sincerely thank all our partner institutions without which the project would not have been possible. With particular gratitude we want to acknowledge steering group members for providing their invaluable expertise, guidance and support.

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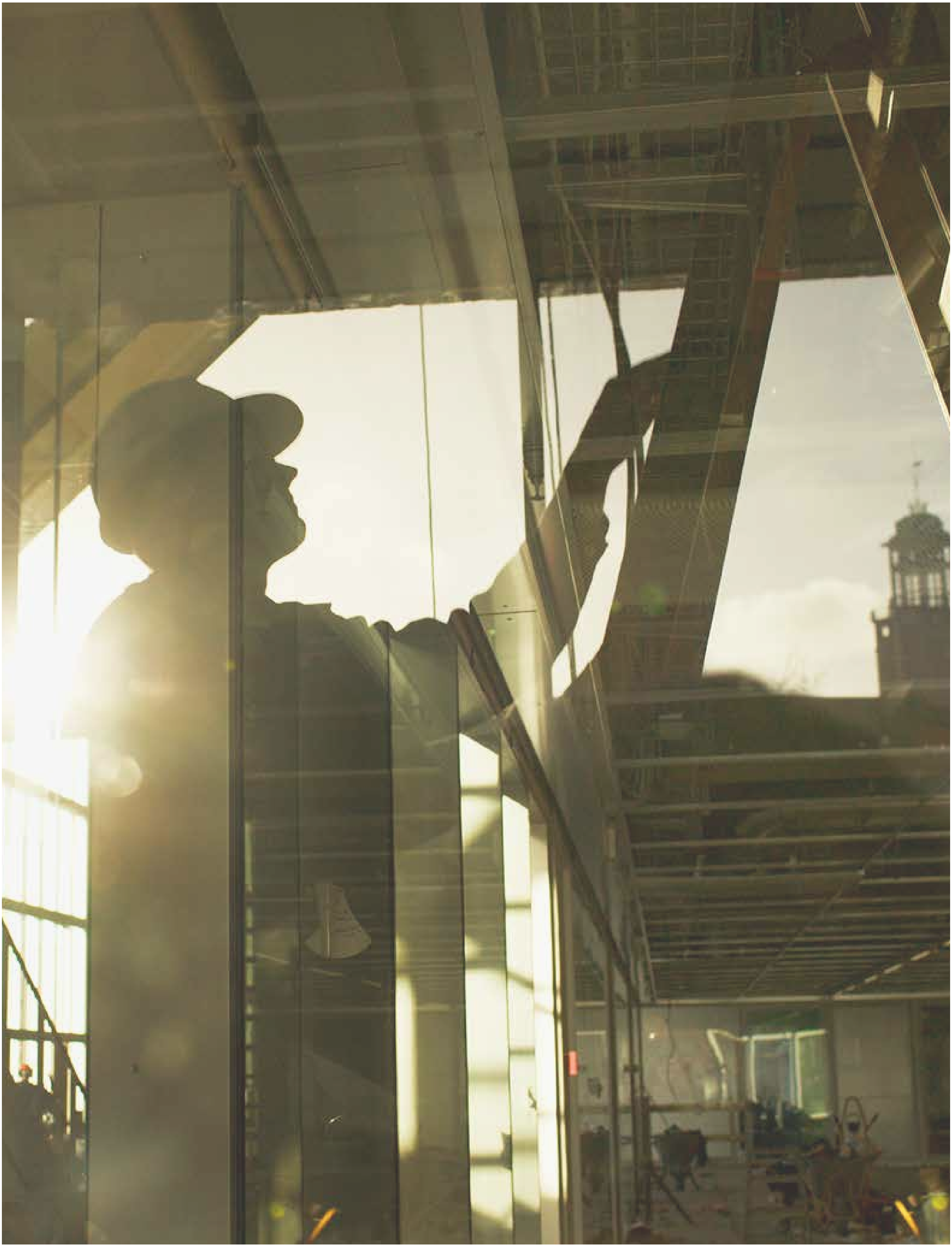


Executive Summary

Introduction

The message from the scientific community is clear: we need to act fast to avoid dangerous climate change. And yet many countries continue to hesitate. Emission targets fall short of what is needed to meet the internationally agreed target to limit global warming to less than 2°C.

This report takes a unique approach to addressing emissions, challenging the notion that climate action is overly difficult or expensive. We show that emissions-reducing solutions that have already proven to be successful can be scaled up internationally to deliver substantial and rapid emission reductions at the global level. Moreover, we show that many of these solutions are economically attractive.

The 17 proven solutions

The report addresses 17 climate solutions that have been proven on a significant scale in varying conditions. They cover all of the main economic sectors and can be applied in countries both in the global North and the South.

Together, the 17 solutions represent a comprehensive menu of low-carbon solutions for countries to choose from today. They can be categorised into five groups: renewable energy, transport, buildings and households, industry, and agriculture and forests.

Global scale-up: proven levels of adoption, no new technology or policy innovation necessary

The study proposes the international scale-up of these 17 climate solutions to a level of adoption in 2030 that has already been achieved by some individual countries today. The scale-up was designed on the basis of national circumstances, such as per capita and national incomes, economic structure or natural resources.

No new technology or policy innovation was considered. Countries only need to show the willingness to adapt these proven solutions to their circumstances.

Proven low-carbon solutions were found to have the potential to yield dramatic cuts in emissions. In total, the 17 solutions would cut annual greenhouse gases, measured

Table 1: Emission impact of scaled-up solutions

Annual impact ($MtCO_2e$) Solution (reference country)	2025	2030
Renewable energy		
Solar water heating (China)	134	136
Grid solar power (Germany)	2,131	3,197
Off-grid solar power (Bangladesh)	4	3
Wind power (Denmark)	669	1,003
Wind power (Brazil)	10	15
Bioenergy for heating (Finland)	187	193
Transport		
Vehicle fuel efficiency (EU)	262	525
Bus rapid transit (Colombia)	23	24
Buildings and households		
Building efficiency (Germany)	58	77
Building efficiency (Mexico)	74	129
Improved cook stoves (China)	711	985
Appliance efficiency (Japan)	241	401
Industry		
Industry energy efficiency (China)	533	879
Industrial electric motors (USA)	103	112
Reducing methane from oil and gas production (USA)	367	388
Agriculture and forests		
Low-carbon agriculture (Brazil)	110	165
Reducing deforestation (Brazil)	2,462	2,782
Afforestation and reforestation (Costa Rica)	588	882
Cutting food waste (Denmark)	179	238
Total impact	**8,848**	**12,136**

Table 2: Top five proven solutions for reducing emissions

Solution	Global emissions reduction by 2030 (Mt CO_2e)	Based on success in	Max. annual cost in 2030
Grid solar power	3,197	Germany	$120 bn
Reducing deforestation	2,782	Brazil	$53 bn
Wind power	1,018	Denmark and Brazil	$41 bn
Improved cook stoves	985	China	$12 bn
Afforestation and reforestation	882	Costa Rica	$18 bn

in carbon dioxide equivalent (CO_2e), by 9 billion tonnes (gigatonnes, Gt) by 2025 and by 12 Gt in 2030. These reductions are significant: 12 Gt is equivalent to nearly a quarter of annual global emissions today.

Economic rationale: low-carbon solutions can save money

The report finds that implementing the 17 solutions could actually save money over time. The annual median net costs of scaling up all the solutions are –$18 billion in 2025 and –$38 billion in 2030. The estimates include both capital investment and lifetime operating costs, but exclude societal benefits and avoided climate impacts.

While some low-carbon solutions may require large upfront investments, they deliver cost savings over their lifetime. For example, improving energy efficiency cuts energy use and investing in wind and solar power reduces fossil fuel use. Many low-carbon solutions have also become dramatically more economical over the past few years. The most well-known example is the cost of solar cells dropping by a staggering 80% in a matter of about five years.

Taking into account both costs and savings, the average net economic benefit for all the solutions is three dollars for every tonne of emissions reduced. This makes the selected package of solutions a good investment.

The full range of total economic impact is wide, from substantial savings to considerable costs. At the most pessimistic end of the range, scaling up all the solutions would have a net cost of $71 billion in 2025 and $94 billion in 2030. By comparison, $94 billion is equivalent to eight days of global fossil fuel subsidies, as estimated by the International Monetary Fund.

Table 3: Top five economically most attractive low-carbon solutions

Solution	Global emissions reduction by 2030 (Mt CO_2e)	Based on success in	Max. annual cost in 2030
Appliance efficiency	401	Japan	–$32 bn
Vehicle fuel efficiency	525	European Union	–$15 bn
Industrial electric motors	112	USA	–$6 bn
Reducing methane from oil and gas production	388	USA	–$6 bn
Solar water heating	136	China	–$4 bn

Climate solutions generate considerable co-benefits

Selected solutions are economically attractive even before taking into account all benefits. Reducing emissions by 12 Gt would help limit climate change significantly. This, in turn, would cut the costs of climate impacts such as droughts, forest fires, sea-level rise and food scarcity.

The solutions also deliver additional benefits in human health, employment, access to energy and ecosystem services. In this way they will contribute to countries achieving the Sustainable Development Goals (SDGs).

Barriers to scaling up proven climate solutions

These solutions may have been used successfully in one country, but that does not guarantee successful implementation elsewhere. Barriers include low awareness and weak institutions. Some solutions also require sizeable upfront investment, which may be challenging to finance. As with all action on climate change, high-carbon legacy policies such as fossil fuel subsidies also inhibit adoption of these solutions.

The cases from Bangladesh to Brazil and from the EU to the US show that breaking down these and other barriers is possible. Learning from the successes and challenges experienced by first movers can help the world implement proven solutions faster and easier. Government policy has a vital role to play.

Conclusion: we already have the tools available

The world already has the tools available to bring global emissions under control, over the next 15 years. Critically, there are solutions that have already been deployed at scale and at a reasonable cost. Ambitious climate action is not only possible; it is attractive.

This report will help governments meet their national climate commitments. More importantly, the report will hopefully help governments go beyond their current commitments. It can be done.

Implementing the 17 solutions could actually save money over time. The annual median net costs of scaling up all the solutions are –$18 billion in 2025 and –$38 billion in 2030.

We can reduce emissions sufficiently to limit global warming to a tolerable level. We know that it can be done, because it has already been done.

Introduction: Scaling Up Proven Solutions

MOMENTUM FOR climate action is growing. Governments, companies, religious leaders, investors and civil movements are coming together to call for swift decarbonisation. The message from the scientific community is clear: we need to act fast. Yet many countries hesitate. Emission targets fall short of what is needed to limit global warming to below the globally recognised risk limit of 2°C.

Often policymakers have reasonable questions and concerns. Do we have the necessary technology? How much will it cost? Are solutions feasible in my country? Or, simply, can it be done? This report tries to answer some of these questions. Critically, we analyse how far the world could cut emissions by scaling up existing low-carbon solutions, from parts of the world where they are already proven to comparable countries.

Trying to understand how far countries can cut their emissions is itself nothing new. What makes this analysis unique is its approach. We look at concrete examples of tried-and-tested solutions that have already been implemented on a significant scale in some countries – from Brazil to Mexico and China to Japan. Crucially, we focus on measures and innovations that have already been proven commercially.

When scaling up these solutions, we expect comparable countries to achieve only the same level in 2030 that others have already achieved today. No new technology. No radical policy innovations. No new levels in implementation. Instead, countries would need simply to do what others have already achieved.

This report suggests that we can reduce emissions sufficiently to limit global warming to a maximum of 2°C. We know that it can be done, because it has already been done.

While the starting point for the report is tackling climate change, other issues matter too. We therefore look at the costs of implementing low-carbon solutions. We illustrate what kind of co-benefits for health and employment, the economy and the environment such climate action can deliver.

The report presents a variety of proven, affordable low-carbon solutions that countries can choose from. These solutions are already being applied in varying conditions in both the global North and the South. They cover multiple sectors from energy to industry, from transport to forests. But in addition to what, it is important to know how. That is why we also share the stories from countries that have already achieved low-carbon successes. We look at both barriers to climate action and effective policies for removing them.

This is an important moment in history. If countries take decisive action, we can still tackle climate change and reap the benefits of green growth. But we are running out of time. This calls for an increase in the level of ambition. It also calls for a rapid implementation of current pledges. We need action on the ground – as manifested in the various examples in this report.

You are reading the editorial report which has been edited in structure, style and content to make the results more accessible. For background and details, please refer to the full Ecofys technical report available at www.greentoscale.net.

Global Results: Emissions, Costs and Benefits

Global emission impact

Scaling up proven, low-carbon solutions can reduce global greenhouse gas emissions dramatically. Our analysis shows that just 17 solutions could save about 9 billion tonnes (gigatonnes, Gt) of emissions in 2025, measured in the carbon dioxide equivalent (CO_2e). In 2030 the impact would be 12 Gt.

A reduction of 9 Gt is equal to the present emissions of the United States, Canada, Mexico and Central America combined. A saving of 12 Gt equals the emissions of China and Japan put together – or a quarter of global annual emissions. Reductions would be below baselines based on current policies.

To appreciate the size of the impact, it is useful to highlight two points. First, the report only analyses a sample of 17 possible solutions out of a universe of many more. If all proven solutions were included, the impact would be significantly bigger. Second, the solutions are only scaled up to a level in 2030 that leading countries have already achieved to date. Many countries do not need to stop there, however. For example, Denmark intends to continue building more wind power. Factoring in possible or even probable future advances would again increase the emission impact significantly.

There are various proven solutions in each of the main economic sectors. The biggest impacts in this analysis come from promoting renewable energy, saving and growing forests, and energy efficiency in industry, households and transport.

Particular solutions will appeal to different countries, according to their economic and natural resources and other national circumstances. Attractive solutions for high-income countries might be highly efficient household appliances and afforestation. For middle-income countries, the most promising solutions seem to be industrial and vehicle efficiency. Low-income countries would benefit particularly from reduced deforestation and improved cook stoves. Solar and wind power offer large potential across all income groups.

Impact by solution

The analysed climate solutions have different impacts, in terms of emission reductions. The most effective solutions can each achieve annual emission reductions of about one gigatonne or more by 2030.

Both solar and wind power have large emission reduction impacts. That is partly because they can be scaled up to most countries around the world. And it is partly because they address a major source of global carbon emissions today, which is burning fossil fuels to generate electricity.

Reducing deforestation and reforesting degraded land also have a big impact. That is because deforestation in tropical countries is a major source of emissions worldwide.

Figure 1: Emissions reductions impact by sector

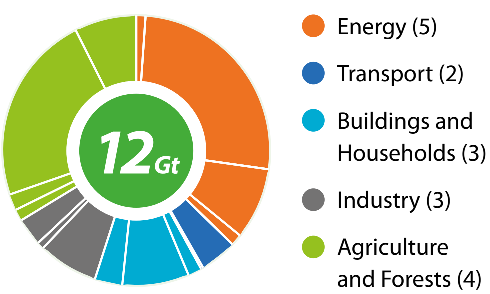
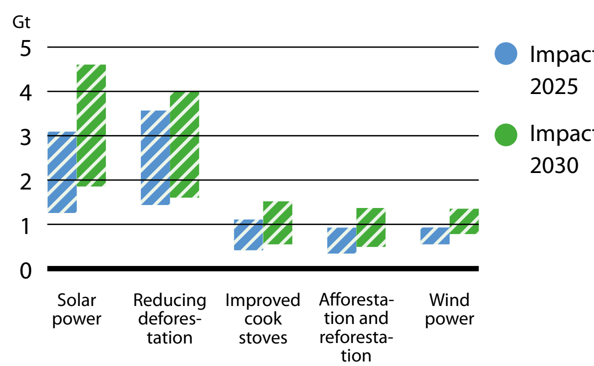


Figure 2: Top five solutions for reducing emissions



Climate solutions create considerable co-benefits

In addition to saving 12 Gt of emissions, scaling up the 17 low-carbon solutions would benefit our economy, improve our health, preserve our environment and create jobs

Renewable energy can create local jobs and cut energy imports. Solar power has created **115,000** jobs in Bangladesh alone

ENERGY EFFICIENCY IN INDUSTRIES CAN INCREASE COMPETITIVENESS AND IMPROVE ENERGY SECURITY

JOBS

CLIMATE-SMART AGRICULTURE CAN PRESERVE DEGRADED LANDS AND INVALUABLE WATER RESOURCES

Car fuel efficiency can cut fuel bills and improve air quality, decreasing healthcare costs

Building energy efficiency improvement projects employ over **400,000** in Germany alone

Cutting food waste can help low-income people through food-sharing and by decreasing prices

Sustainable transport in cities can cut traffic jams and reduce harmful pollution

Efficient cook stoves can reduce pollution, improving the health of especially women, who still do most of the cooking in developing countries

REDUCING FOREST LOSS CAN PRESERVE SPECIES DIVERSITY AND THE LIVELIHOODS OF INDIGENOUS PEOPLES

Low-carbon future is affordable

In 2030, 17 solutions would cost at most **17%** of how much we subsidise fossil fuels today

Direct fossil fuel subsidies in 2015 are **$548 billion** globally

Table 4: Emission reduction impact of scaled-up solutions

Impact ($MtCO_2e$) Solution (reference country)	2025 Minimum	2025 Median	2025 Maximum	2030 Minimum	2030 Median	2030 Maximum
Wind power (Denmark)	479	669	859	718	1,003	1,288
Wind power (Brazil)	9	10	12	13	15	18
Off-grid solar power (Bangladesh)	3	4	5	3	3	3
Grid solar power (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 oil and gas production (USA)	312	367	422	330	388	447
Industry energy efficiency (China)	383	533	684	648	879	1,109
Industrial electric motors (USA)	78	103	128	85	112	139
Appliance efficiency (Japan)	195	241	287	327	401	475
Building efficiency (Germany)	49	58	67	66	77	89
Building efficiency (Mexico)	63	74	85	109	129	148
Improved cook stoves (China)	356	711	1,067	492	985	1,477
Low-carbon agriculture (Brazil)	74	110	146	111	165	219
Reducing deforestation (Brazil)	1,379	2,462	3,546	1,558	2,782	4,007
Afforestation and reforestation (Costa Rica)	294	588	882	441	882	1,323
Cutting food waste (Denmark)	153	179	206	202	238	274
Total impact[1]	**7,326**	**8,848**	**10,370**	**10,129**	**12,136**	**14,143**

[1] Global minimum and maximum totals do not equal the sum of individual solutions (see the explanation in the methodology section).

Some solutions yield smaller emission savings. That may be because the solution, although promising, has not yet been implemented on a large scale, which limits the scope for scaling up in 2030. An example of such a solution is low-carbon agriculture in Brazil. In other cases, the approach used in this report may not take into account the full impact, such as with bus rapid transit instead of comprehensive transit-oriented development in Colombia, for reasons such as data availability.

Solutions with smaller global emission impacts may still be highly relevant, however. Some solutions may be particularly appropriate in certain countries, such as the use of bioenergy for heating in forested and cold countries. And others may vastly enhance human welfare, as in the case of off-grid solar power for communities which lack modern energy.

Costs and savings

The estimated median annual net costs of scaling up all the solutions are –$18 billion in 2025 and –$38 billion in 2030. In other words, reducing emissions with these solutions would not cost money, but would actually save money over time.

This is a remarkable result – perhaps even surprising for many. However, it is supported by a growing body of studies. Three factors can help in understanding the net savings.

First, many low-carbon solutions follow the same pattern: they require large upfront investments, but deliver cost savings over their lifetime. Improving energy efficiency cuts energy use and investing in wind and solar power reduces fossil fuel use.

Second, many low-carbon solutions have become dramatically more economical over the past few years, challenging the conventional wisdom that reducing emissions comes with a cost. The most well-known example is the cost of solar cells dropping by a staggering 80% in a matter of about five years.

Table 5: Costs of scaling up the solutions

Abatement costs (million $ per year) Solution (reference case)	2025 Minimum	2025 Median	2025 Maximum	2030 Minimum	2030 Median	2030 Maximum
Wind power (Denmark)	–27,515	-	27,515	–41,273	-	41,273
Wind power (Brazil)	–381	-	381	–571	-	571
Off-grid solar power (Bangladesh)	–790	–929	–1,068	–587	–691	–795
Grid solar power (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 oil and gas production (USA)	–9,273	–7,424	–5,576	–10,285	–8,164	–6,042
Industry energy efficiency (China)	–9,964	4,982	19,929	–16,158	8,079	32,316
Industrial 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 efficiency (Germany)	–4,136	–760	2,616	–5,519	–1,014	3,492
Building efficiency (Mexico)	–5,372	–3,223	–1,074	–9,380	–5,628	–1,876
Improved cook stoves (China)	1,778	5,157	8,535	2,462	7,140	11,818
Low-carbon agriculture (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
Afforestation and reforestation (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
Total costs	**–107,117**	**–18,216**	**70,685**	**–170,962**	**–38,462**	**94,039**

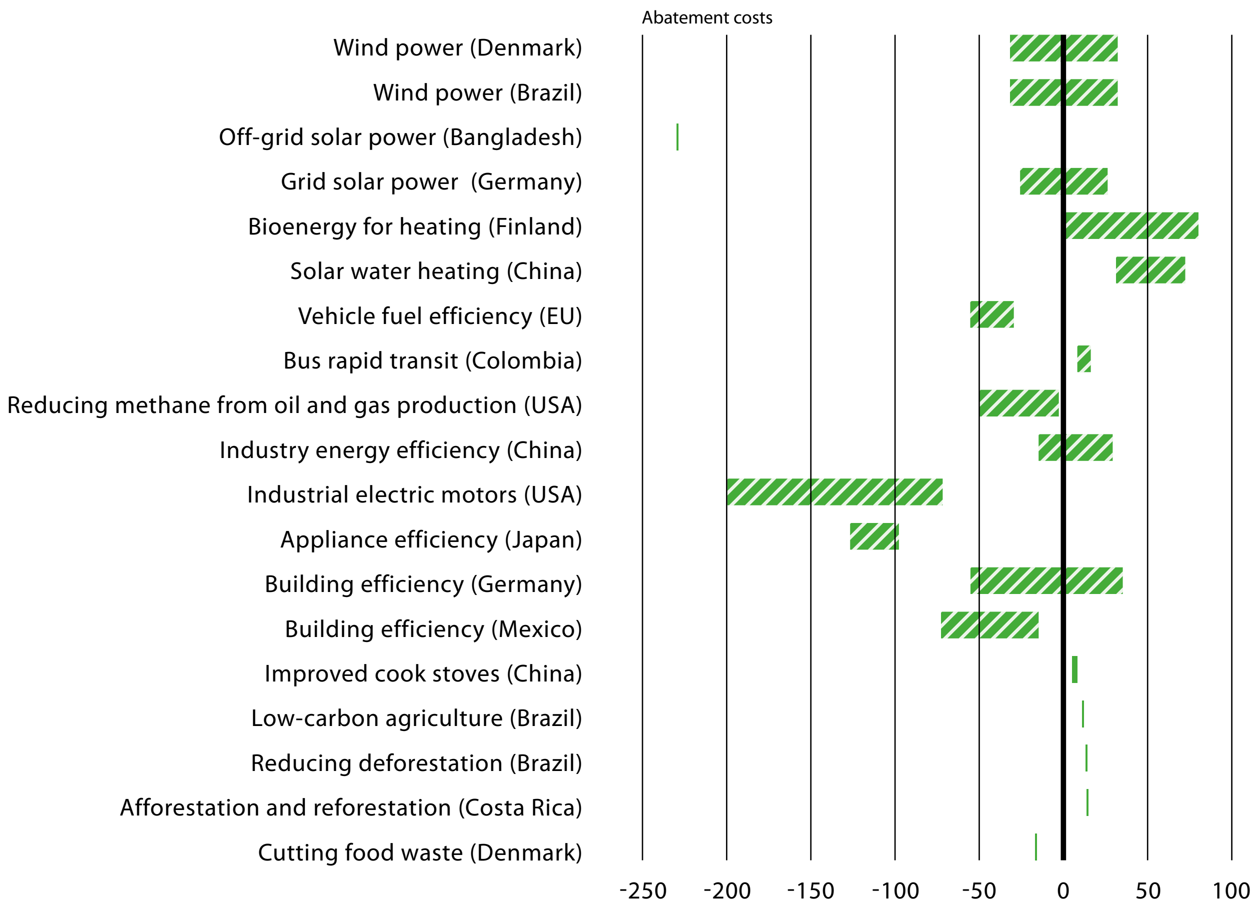
Third, solutions to this report have been selected partly because of their low costs. If additional solutions were included, the total costs might rise.

Taking into account both costs and savings, the average net economic benefit for all the solutions is three dollars for every tonne of emissions reduced. This makes the selected package of solutions a good societal investment. The costs per tonne of avoided emissions vary widely, however. The most expensive solutions have estimated abatement costs of up to 80 $/tCO_2e$. The cheapest solutions can provide considerable savings, of up to 230 $/tCO_2e$.

Likewise, the full range of total economic impact is wide, from substantial savings to considerable costs. At the most pessimistic end of the range, scaling up all the solutions would have an annual net cost of $71 billion in 2025 and $94 billion in 2030. By comparison, $94 billion is equivalent to eight days of global fossil fuel subsidies, as estimated by the International Monetary Fund, or less than the GDP of the Slovak Republic.

Turning to solutions that individually have negative or zero median costs, their total emission reduction impact would be 4.2 Gt in 2025 and 6.2 Gt in 2030. Total financial savings from implementing these measures alone would reach $77 billion in 2025 and $112 billion in 2030.

Figure 3: Marginal abatement costs per tonne of CO_2e



There are various affordable solutions with a potential to reduce emissions significantly while meeting social and economic goals.

Most solutions with negative costs are associated with energy efficiency. While some measures to improve efficiency may have high investment costs, they also reduce energy use and thus generate savings over time. Similarly, replacing kerosene for lighting with rooftop solar power, or reducing food waste, save money over time.

It is important to remember that cost calculations only take into account direct financial costs. They do not consider any additional co-benefits. An especially important co-benefit is avoided air pollution and the associated reduced health costs, as in the cases of improved cook stoves and bus rapid transit. Factoring in all co-benefits would make even more solutions economically attractive.

Neither do the figures take into account the benefit of avoided climate change. The solutions considered in this report can plug some of the gap between the current ambition to tackle climate change and the action needed to meet the internationally agreed target to limit global average warming to 2°C. Avoiding additional warming would be likely to bring enormous savings.

Co-benefits

All selected solutions have several co-benefits. Positive effects include improvements in health, employment, access to clean energy and the provision of ecosystem services.

Turning to specific solutions and associated co-benefits, improving energy efficiency and replacing fossil fuels in energy production and transport reduces air pollution and fuel imports. Measures to save or expand forests preserve biodiversity and supply ecosystem services, such as preventing soil erosion and landslides. Off-grid solar power, solar water heating and improved cook stoves all improve energy access. Energy-efficiency measures can contribute to reducing fuel poverty. Investment in renewable energy, upgrading building efficiency and public transport systems creates jobs, many of them local. Similarly, replacing imported fuels with domestic renewable energy sources or efficiency measures increases local employment.

Low-carbon solutions can also help meet the world's sustainable development goals (SDGs) to improve human welfare and protect the environment. Apart from the obvious contribution to avoided climate change, the solutions can help attain the goals of improved health and well-being, access to affordable and clean energy and building sustainable cities and communities.

In this report, most of the findings concerning co-benefits are presented qualitatively. Quantifying these benefits would be a valuable topic for further research.

Removing barriers

The analysis confirms that there are various affordable solutions with a potential to reduce emissions significantly while meeting social and economic goals. Why, then, are they not being deployed on a larger scale?

Implementation often faces several barriers. Four of them are common to many of the solutions.

First, people making policy and investment decisions may not be aware of the range of solutions available and their full benefits. Second, many countries have limited administrative capacity to plan, implement, monitor and enforce policies – especially in the global South. Third, some solutions require significant upfront investment costs and access to capital may be limited. Finally, all climate action is impeded by old, legacy policies which favour high-carbon infrastructure and lifestyles. For instance, annual fossil fuel subsidies still cost between $0.5 and 4.2 trillion depending on how these are calculated.

These and other barriers are real. Overcoming them, and thus realising the full potential of low-carbon solutions, requires determination, vision and leadership.

The cases described in this report show that breaking down the barriers is possible. Learning from the successes and challenges experienced by first movers can help the world implement proven solutions faster and easier.

Based on these experiences some general conclusions can be drawn. First, leadership and commitment at the highest possible level of decision-making can help tremendously. Second, incentives for action need to be aligned and disincentives removed. Third, using public money to leverage private investment with, for example, low-interest loans can provide a cost-effective alternative or complement to subsidies. Fourth, informing and engaging stakeholders and citizens is crucial for the acceptance of any climate policies. Finally, good governance and building capacity matter.

Table 6: Co-benefits provided by the solutions

	Improved air quality and health benefits	Economic benefits	Education, equality and safety	Increased energy security	Water, soil and forests
Wind power (Denmark)	■	■		■	
Wind power (Brazil)	■	■		■	
Off-grid solar power (Bangladesh)	■	■	■		
Grid solar power (Germany)	■	■			
Bioenergy for heating (Finland)		■			■
Solar water heating (China)	■	■	■		
Vehicle fuel efficiency (EU)	■	■		■	
Bus rapid transit (Colombia)	■	■			
Reducing methane from oil and gas production (USA)	■	■	■	■	
Industry energy efficiency (China)	■	■	■		
Industrial electric motors (USA)	■	■			
Appliance efficiency (Japan)	■	■			
Building efficiency (Germany)	■	■			
Building efficiency (Mexico)	■				■
Improved cook stoves (China)	■		■		■
Low-carbon agriculture (Brazil)		■			■
Reducing deforestation (Brazil)					■
Afforestation and reforestation (Costa Rica)		■			■
Cutting food waste (Denmark)	■	■			■

Discussion: What Do the Results Mean?

Why these solutions?

We selected 17 low-carbon solutions from an original list of 50 options. Selection criteria included proven emission impact, cost, co-benefits, potential for scalability and data availability. In addition, we ensured that the final set of solutions represented a range of economic sectors and countries.

There are many more proven solutions than could be covered in this project. Other promising options may include transport biofuels, electric vehicles and biking; offshore wind, biogas, heat pumps and geothermal energy; cutting F-gases and low-carbon cement production; reducing livestock methane; and cutting emissions from waste management. Some of the solutions analysed in this report could also be covered with a wider scope.

Are the estimates optimistic?

The level of uncertainty in the emission and cost estimates is about 20%. Ranges given for results try to capture some of the inherent uncertainties.

Some factors may lead to the results being somewhat optimistic. First, a portion of a reference case's emission impact may not be directly attributable to the solution in question. For example, some improvements in building energy efficiency may result independently of the analysed programmes.

Second, we have tried to minimise overlap between solutions. For instance, the Brazilian solution is limited to preserving existing forests while the Costa Rican case covers only establishing new forests or re-establishing forests already lost. However, some overlap is likely to remain between some solutions.

Finally, implementation at scale is not always easy in practice. Poorer countries especially often lack the capacity to roll out the solutions. Success requires determination and persistence. If solutions are not implemented in full, the emission impact and benefits will also remain proportionately smaller.

Are the estimates pessimistic?

Various factors indicate that the results may actually underestimate the true potential. First, only 17 solutions are analysed. If all proven solutions were included, the impact would be significantly larger.

Second, all solutions are applied only to the extent that some countries have implemented them already to date. Factoring in future advances would again increase the impact considerably. It can also be argued that those following can act faster since they can learn from the first movers.

Third, no new technologies or policies are assumed. However, the coming 15 years are likely to see a wealth of low-carbon innovations opening new possibilities for reducing emissions – just like we have seen in the past 15 years.

Finally, some solutions could perhaps have a larger scope or scalability. For instance, food waste could be addressed also on the production side and solar power results could include countries with a potential of less than 10 TWh a year.

On balance, the results are likely to be more conservative than overly optimistic. The total emission reduction potential in reality is probably even larger than indicated in this report.

How far can we go with proven solutions?

The emissions gap quantifies the difference between current and desired global emission pathways. The concept is useful in understanding how much more countries need to do collectively to limit global warming to below 2°C.

The baseline scenarios used in estimating the gap include the impact of existing or planned policies. Some of these policies already address solutions studied in this report. For example, many countries count on limiting emissions by building solar and wind power capacity which provide a significant share of the impact in our analysis.

The figures for the emissions gap and the total emission impact in our analysis are therefore not directly comparable. Some conclusions can still be drawn.

The commonly quoted United Nations Environment Programme (UNEP) report suggests that the emissions gap is 14 Gt (range 12-17 Gt) in 2030. A compilation of national climate commitments by the UN climate secretariat (UNFCCC) indicates that the 2030 gap could be 15 Gt (11-22 Gt) – assuming countries implement their emission pledges.

Our analysis shows that scaling up a selection of proven solutions would reduce emissions by 12 Gt (10-14 Gt) in 2030. Part of this potential can help in bridging the gap.

Not all countries include all the studied solutions in their climate pledges – let alone to the extent implemented by countries showing the way. The 12 gigatonne potential found in this analysis is up to three times the additional reductions that governments have pledged for the Paris Treaty. A significant proportion of the emission impact identified in this report is likely to be additional. Compared with the difference between a business-as-usual scenario with no climate policies and a pathway compatible with the 2°C target, the 17 selected solutions would cover more than a half.

Implementing these existing low-carbon solutions could therefore help significantly in bridging the emissions gap. If more proven solutions were included and if more ambitious achievements were considered in the future, this might be enough to close the gap. Scaling up the solutions would be even more essential if the world aimed at limiting warming to 1.5ºC, as suggested by the poorest and most vulnerable countries.

How robust are the cost figures?

To calculate the costs of scaling up the solutions we use data from marginal abatement cost curves developed by McKinsey, the US Environmental Protection Agency and other sources. In most cases cost data at the national level is not available so we had to opt for global or regional cost data.

Some of the original data may be outdated. For example, wind and solar power costs might be overestimated given that up-to-date abatement cost data for the world as a whole are not available in the literature. Both technologies have seen rapidly falling prices over the past years.

We can use wind power as an example. The McKinsey curve estimates global emission abatement costs beyond business as usual for projects implemented in the period up to 2030. For wind energy, abatement costs of around $22-32 per tonne of CO_2 have been estimated.

Since abatement costs are a forecast, likely future development has been taken into account. For example, for solar power a learning rate of 18% has been used. This results in power generation costs going down by four fifths between 2005 and 2030.

We analyse upscaling the renewable energy generation in leading countries to the whole world. The amount of renewable energy in 2030 in our analysis goes beyond the McKinsey forecast. 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.

If renewable energy costs just one cent per kWh more to produce than fossil energy, and given the avoided emissions are 500g of CO_2 per kWh, this would yield abatement costs of $20 per tonne of CO_2. However, if the renewable energy costs are just one cent per kWh less than fossil energy, abatement costs would go down to –$20 per tonne of CO_2. This shows how sensitive the mitigation costs are to the difference in generation costs between conventional and renewable power.

It is plausible that the rapid deployment in our analysis will cause wind power 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 tonne of CO_2) and –$22-32 per tonne of CO_2 as a minimum. Please note that this is highly driven by volume and it is caused by only a one cent per kWh difference in cost assumptions.

Implementing these proven low-carbon solutions could therefore help significantly in bridging the emissions gap.

How to build on the analysis?

This report analyses the global emission impact, costs, co-benefits, barriers and drivers for 17 proven low-carbon solutions by 2025 and 2030. There are various possible avenues for exploring the issue further. These include analysing:

- a bigger number of solutions;
- impacts at country or regional level;
- co-benefits quantitatively;
- success factors and policies in more depth.

We would very much welcome others building on our analysis and taking it further. We are also open to exploring possibilities for co-operation.

The total emission reduction potential in reality is probably even larger than indicated in this report.

Methodology

Solutions were scaled up to country groupings that have the necessary conditions in place for implementation – or can introduce them relatively easily.

Selecting solutions

We selected a sample of proven low-carbon solutions considered examples of best practice. We also aimed at having a broad coverage of different sectors and countries, from both the global North and the South.

We began with 50 potential solutions. They needed to meet three main conditions: to be proven to work on the ground; to have significant climate change mitigation potential; and to have high potential for scalability.

The analysis was based on a literature review, as well as in-house expert knowledge and input from project partners. This resulted in the selection of 30 solutions which were assessed according to five criteria: climate change mitigation; affordability; environmental co-benefits; socio-economic co-benefits; and ease of implementation. This qualitative assessment resulted in the identification of the most promising cases from the sample.

Country groupings

Solutions were scaled up to country groupings that have the necessary conditions in place for implementation – or can introduce them relatively easily. These conditions include income level, climate or natural resources. Solution-specific criteria for scalability were also taken into account.

For example, the Brazilian case of reducing deforestation was scaled up to other middle- and low-income countries in the tropical and subtropical belt with significant deforestation rates. The EU vehicle fuel-efficiency case was scaled up to all countries, since most major markets both in the North and the South already have fuel-efficiency standards.

Emissions

We assessed the emission reductions of scaling up the selected solutions in 2025 and 2030. The years were selected as they are key milestones in the international efforts to limit warming to a maximum of 2°C. The emission impact was estimated compared with a baseline based on current policies and trends.

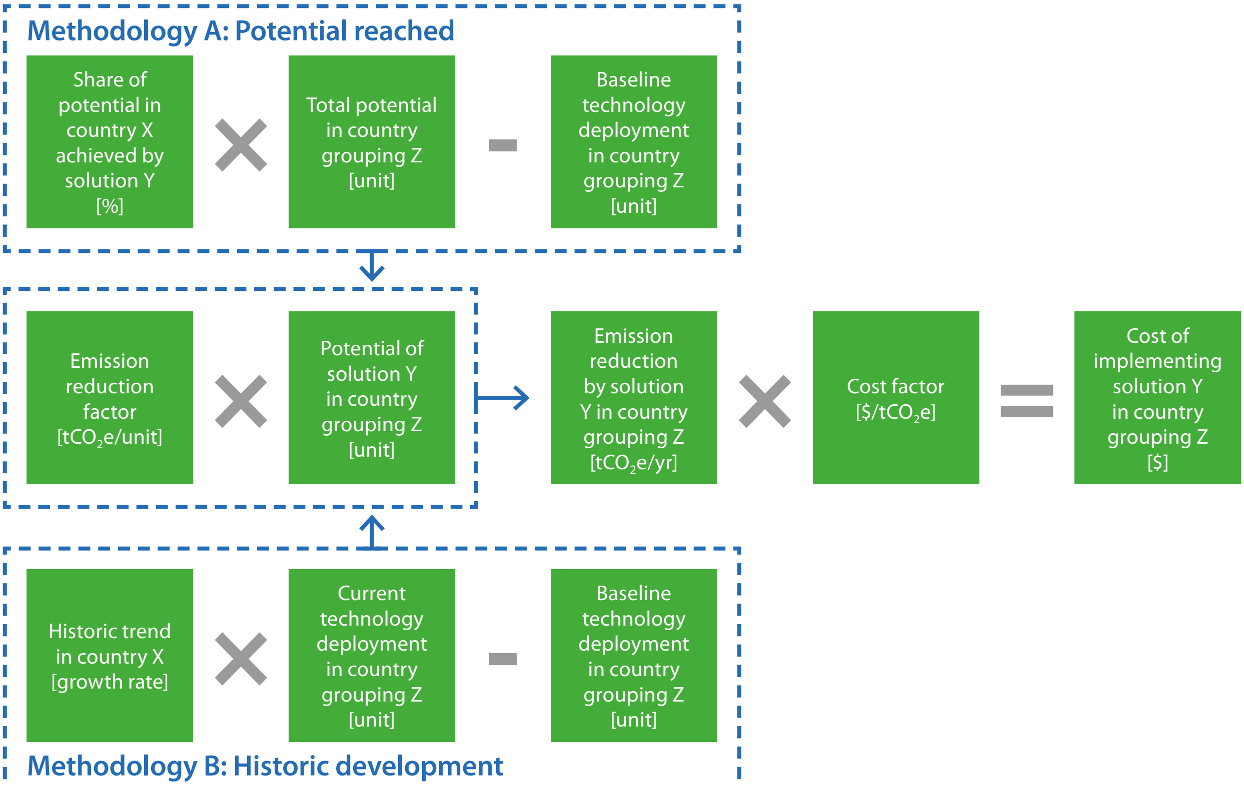
Results cover all direct greenhouse gases, presented in carbon dioxide equivalents (CO_2e). All emission figures are annual, unless otherwise stated. Totals in tables might differ slightly from the sums of parts due to rounding up.

The impacts of short-lived climate pollutants (SLCP) such as black carbon were not estimated, unless already included in underlying data. We covered direct emissions (scope 1) and those related to the use of electricity or heat (scope 2). Indirect emissions, such as emissions from material production or waste management, were not included.

For energy-efficiency solutions, we did not correct for the rebound effect. According to the International Energy Agency the impact would be relatively small, less than 20%.

It is highly unlikely that the impact of all the solutions will end up at the minimum or the maximum end of the

Figure 4: Schematic description of methodology



range, as the deviations are not correlated. For presenting the total emission impacts, we therefore used error propagation rules. In short, the square of the uncertainty in the sum is the sum of the square of the individual uncertainties. This makes the range in the totals much smaller than the sum of the individual ranges.

For the sake of simplicity, we used the exact median estimate of the emission savings in 2030 when presenting only one figure. However, the actual impact cannot be known with certainty so the full ranges provide a more reliable estimate.

All data used for comparing the emission impact with the emissions of different countries and the world total was taken from CAIT Climate Data Explorer. Figures are for 2012 and include land use.

Costs

To calculate the costs of upscaling the solutions, we used specific marginal abatement cost factors. Costs were estimated either per unit of implementation or per unit of emission reduction. The marginal abatement figures include investment costs. Costs were converted to 2010 US dollar rates.

Estimates were based on available literature and differentiated by country or region, where relevant. As there is limited data available on abatement costs per solution and country, we used the marginal abatement cost curves developed by McKinsey in 2009.

The McKinsey abatement costs include an estimated future learning rate. For solar and wind power in our analysis, the learning rate could be even higher since we scale up very successful country solutions globally, leading to a 2030 deployment beyond the McKinsey forecast. This could also result in lower abatement costs than those estimated by McKinsey.

Scaling up

For scaling up each solution, we selected the more suitable of two options: A) the share of potential achieved by the solution; or B) the historic development of the solution. The methodologies were further customised for each solution, if necessary.

The emission impact of each scaled-up solution was estimated using the following steps.

1. We selected an appropriate **unit of implementation**, such as gigawatts of wind power capacity or hectares of reforested land. For some solutions, the unit of implementation is a unit per capita.
2. We determined the **deployment level** in 2025 and 2030 if the solution were replicated with the same success rate as in the reference case.
    a. Methodology A: we determined the total potential in both the reference case and the country grouping. We then applied the share of the potential achieved in the reference case to the potential in the country grouping.
    b. Methodology B: we analysed the historic development achieved with the solution in the reference case and applied this rate to the country tier for upscaling.
3. We determined the **baseline deployment** rate in the country grouping. Where possible, we used established and authoritative scenarios, such as the International Energy Agency's current policy scenarios. If no existing scenario could be used, we assumed the historic trend would continue until 2030. The additional deployment from scaling up the solution is the difference between this baseline and the deployment based on methodology A or B.
4. Finally, to calculate emission reductions, we defined specific **emission-reduction factors** based on the literature per unit of implementation, for example $MtCO_2e$/GW for solar power. Where relevant, these factors were differentiated by country or region to reflect, for instance, the differences in power generation fuel mix or efficiency.

For example, in the case of energy efficiency in German buildings, the unit of implementation is emissions intensity, that is CO_2 emissions per square metre of residential building floor area. Historic development (methodology B) was used for scaling up: countries are expected to reach the same annual reduction in emissions intensity as the average in Germany between 2007 and 2011 (i.e. –1.3% per year).

The baseline development was calculated using the trend of total residential building floor area for the years 2006 to 2011. Second, the intensity trend was calculated for each country for the same years. These past trends were used to project the intensity and floor area to 2025 and 2030. Finally, the derived future intensity was multiplied by the floor area to calculate the baseline emissions.

For more information about methodology, please see the technical report available at greentoscale.net.

Project Background

THE GREEN TO SCALE PROJECT was launched by the Finnish think tank Sitra in early 2015. Sitra served as the secretariat for the project and provided core funding.

Renowned experts from the following institutions in 10 countries contributed to the analysis.

- Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering (CENERGIA/PPE/COPPE/UFRJ)
- El Centro Mexicano De Derecho Ambiental (CEMDA), Mexico
- European Climate Foundation (ECF)
- Ethiopian Development Research Institute (EDRI)
- Institute for Global Environmental Strategies (IGES), Japan
- Masdar Institute, the United Arab Emirates
- Renmin University of China
- Stockholm Environment Institute (SEI), Sweden
- World Resources Institute (WRI), the United States

In addition, UNEP DTU Partnership from Denmark and the International Finance Corporation (IFC) of the World Bank Group were represented in the project steering group.

Technical analysis for the report was commissioned from Ecofys, a leading international climate consultancy. Additional expertise has been provided by numerous institutions and experts who were kind enough to comment on the different concepts and drafts throughout the project.

The analysis has benefited tremendously from the guidance of the project partners and other institutions. However, their involvement should not be interpreted as official endorsement of the final results, underlying methodology or the way they are presented in this report.

The analysis has benefited tremendously from the guidance of the project partners and other institutions.

Solutions Catalogue

Green to Scale Low-carbon success stories

We already have the tools available to cut emissions – the know-how and experience of 36 countries that have successfully reduced emissions.

We have the solutions

Scaling up just 17 climate solutions could cut current global emissions by a quarter by 2030. This is equivalent to the total emissions of China and Japan combined.

Global partnership

Organisations from 10 countries have partnered with the Finnish Innovation Fund Sitra. The project Green to Scale has uncovered proven and attractive solutions to tackle the climate crisis.

Countries can do more

The results of the project can help countries to meet, improve and go beyond their national climate commitments – and at the same time lead to better health, more jobs and improved energy access.

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RENEWABLE ENERGY

Solar water heating in China
Grid solar power in Germany
Off-grid solar power in Bangladesh
Wind power in Denmark and Brazil
Bioenergy for heating in Finland

RENEWABLE ENERGY

Solar water heating

China has installed more solar water heaters than the rest of the world combined. Scaling up this solution would achieve carbon reductions exceeding the annual emissions of Belgium while cutting air pollution and creating local jobs.

Climate impact

In 2013, China had a massive solar collector capacity of 262 GWth, equivalent to 70% of global total. Solar water heating in China has reduced emissions by 76 Mt, compared with using default, mainly fossil fuel technologies.

Scaling up the Chinese programme to countries with similar solar conditions would reduce annual emissions by 136 Mt in 2030, compared with business-as-usual policies. The greatest potential is found in the rest of Asia (74 Mt) and in Africa (48 Mt).

Success factors

Solar collectors for water heating have been deployed in China on a remarkable scale. In 2013 alone, a total capacity of 45 GWth was installed, equivalent to 80% of global installations in that year.

Rapid deployment is driven by the low cost of solar thermal systems (STS). Another key driver has been a mandate to install solar water heating in urban areas in more than 11 provinces and 23 cities. From 2014, all new buildings have to install STS in areas where sunshine hours are higher than 2,200 annually.

An additional factor driving uptake is a subsidy scheme for rural inhabitants, equivalent to 13% of capital costs. China has a national goal to install 300 million m^2, or 328 GWth, of STS by 2020. Finally, the government provides financial support for “New Energy Cities” demonstration projects.

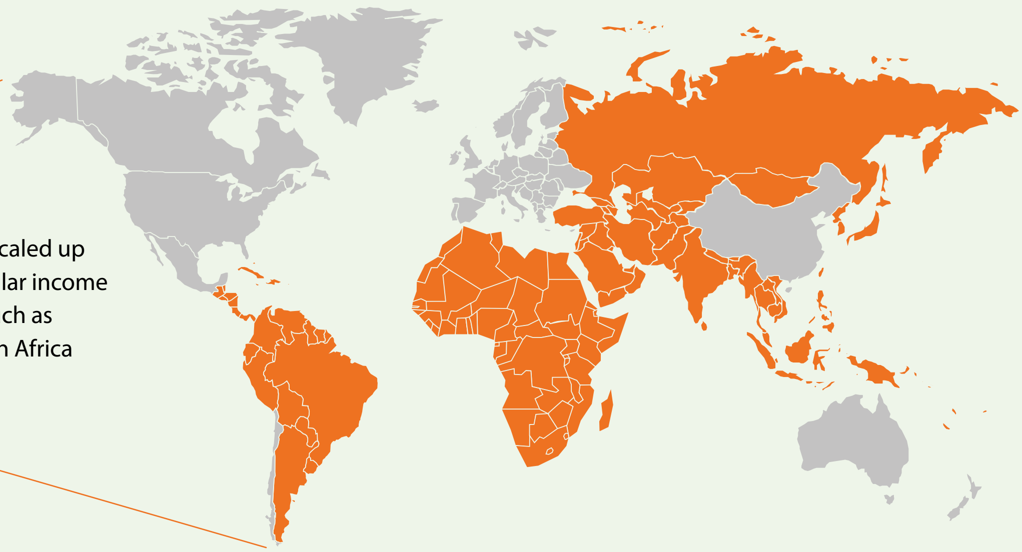
Costs

Solar water heating saves money over time as the “fuel” – sunlight – is available for free. The cost of reducing emissions using this solution over time is therefore negative, estimated at –31 to –73 $/t$CO_2$e. Scaling up the solution would result in total savings of $4-10 billion per year.

Co-benefits

By replacing fossil fuels, solar collectors improve air quality, especially in dense urban areas. This has a positive impact both on people’s health and the environment.

The installation of solar heaters is relatively labour-intensive, thus creating local jobs. The solar water heating industry employs around 600,000 people in China. Given its low cost and ease of installation, solar water heating



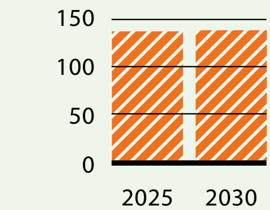
The solution can be scaled up to countries with similar income and solar potential such as Brazil, India and South Africa

may also contribute to improved energy access in remote and rural areas.

Barriers and drivers

- Solar heating deployment has been hampered by poor quality control. Establishing performance standards, and monitoring to ensure that these are implemented, may help increase adoption.
- Upfront costs of $200 are higher than for electric ($50) and gas heaters ($100). While low operational costs deliver a rapid return on investment, high capital costs can still be a barrier. The Chinese government has introduced subsidies to help poorer families cover these initial costs.
- No specific infrastructure is required and production lines are relatively easy to set up. However, support and education to enable better installation and after-sales service is needed.
- Public acceptance is high in China, where solar heating is considered a sign of modernity, similar to cell phones and air conditioning. In other countries residents may be reluctant to alter the external appearance of their homes.
- Solar heating can be deployed almost anywhere. However, investment costs are lower and output higher in countries with more solar radiation.

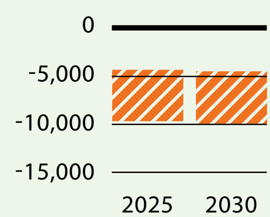
"The solar water heating industry employs around 600,000 people in China."



Emission reductions potential

136

$MtCO_2e$/year



Median abatement costs

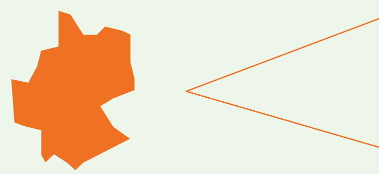
-7,049

Million $

RENEWABLE ENERGY

Grid solar power

Germany has increased its solar power generation capacity to the point that it supplies 6% of all electricity. The effect of scaling up solar globally would equal the United States becoming zero carbon while creating local jobs and improving energy independence.



Climate impact

In 2012 Germany produced 28 TWh of solar power, displacing electricity produced from natural gas and coal. This reduced emissions by about 18 Mt.

If the German success in solar power were replicated among other high-income countries, annual emissions would fall 720-1,330 Mt by 2030. If upper middle-income countries adopted solar in the same way, emissions would be reduced by 1,800-4,590 Mt. If the same uptake applied to all countries worldwide, the climate benefit would grow to a remarkable 2,490-6,170 Mt.

Success factors

The expansion of solar power in Germany has been driven by the Renewable Energy Act (EEG), which entered into force in 2000. The EEG guarantees the sale of electricity from renewables and its feed-in to the grid. It also offers producers a fixed rate of remuneration called a feed-in tariff (FIT).

This has driven up the share of renewable energy in Germany's electricity production to 25%, of which solar provides 6%. In 2013, 35 GW of solar power capacity had been installed in Germany.

It is left to German consumers to pay for the difference between the wholesale price of electricity and the remuneration rate for renewable energy. In 2014, the government reformed the EEG to curb the cost increase of further renewable energy expansion.

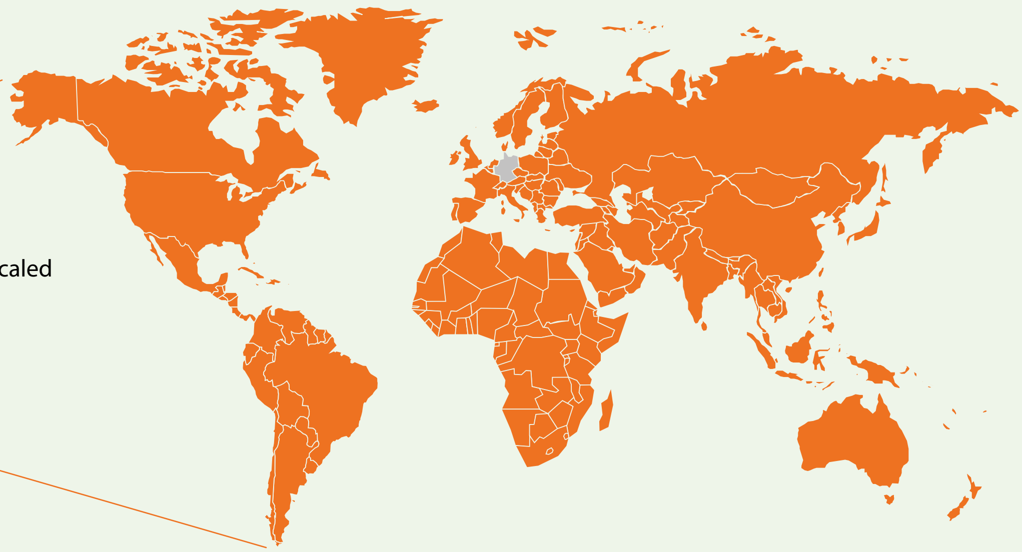
Other countries have used other schemes to promote solar power. These include auctions in Brazil, renewable portfolio standards and production tax credits in the US and mandatory requirements to install solar or green roofs in France.

Costs

The abatement cost is estimated at 26 $/tCO_2e$, assuming the price of solar power continues to decline in the future. However, when investing in solar power on a massive scale, unit costs may decline even further than anticipated. If solar power becomes even slightly cheaper than traditional power generation, the abatement cost may turn negative, at –26 $/tCO_2e$.

Using this wide cost range, the annual costs of scaling up solar power would reach an estimated –$35 billion to $35 billion for high-income countries by 2030, –$120 billion

The solution can be scaled up to all countries



to $120 billion for high and upper middle-income countries and –$160 billion to $160 billion for all countries.

Co-benefits

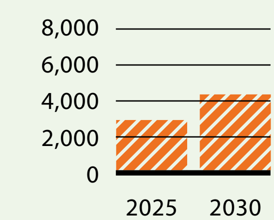
Solar power can cut energy costs for those consumers who can replace electricity bought from the grid. Increasing power generation with domestic, renewable sources reduces reliance on fuel imports, improving energy security.

Solar power can create and preserve jobs, in particular in installation and maintenance. In 2013, the solar industry employed 56,000 people in Germany. Solar power also has a positive impact on the local environment and health by displacing the burning of fossil fuels.

Barriers and drivers

- Solar panels have relatively high upfront investment costs. However, the costs have fallen dramatically in recent years. There are also cost-effective ways to encourage consumers to invest, such as low-interest loans or paying off debt through savings on utility bills.
- Large increases in solar generation capacity can require investments in new infrastructure, such as low-voltage networks. These costs can mean higher utility bills.
- Reaching very high shares of intermittent power generation using renewable energy may form a barrier. People need electricity at all times, so new energy storage infrastructure and increasing connectivity with other grids may be required.

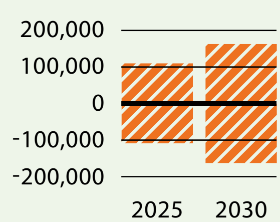
"When investing in solar power on a massive scale, unit costs may decline even further than anticipated."



Emission reductions potential

3,197

$MtCO_2e$/year



Median abatement costs

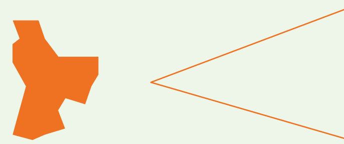
0

Million $

RENEWABLE ENERGY

Off-grid solar power

Bangladesh has provided affordable off-grid solar power to 13 million people. Scaling up this solution would achieve a climate benefit equivalent to cutting the annual emissions of Malta and provide access to modern energy for millions of people.



Climate impact

Solar home systems have been installed in 3.8 million houses in Bangladesh, serving 13 million people, or a quarter of the off-grid population. Since 2002, these systems have displaced an estimated cumulative 220 million litres of kerosene, reducing emissions by about 0.58 Mt.

Scaling up comparable levels of solar power for off-grid populations in similar countries would result only in modest emission savings, estimated at 3 Mt in 2030, reflecting the low energy use of such communities. However, it would provide affordable low-carbon power to around 200 million people with currently no grid access.

Success factors

Bangladesh established a national programme to support the use of solar home systems in areas where the electric grid was least accessible. The programme is managed by the state-owned Infrastructure Development Company (IDCOL). IDCOL certifies solar equipment and partner organisations (POs) which install and maintain solar systems. IDCOL also provides consumer credit, to reduce monthly payments to affordable levels for rural customers.

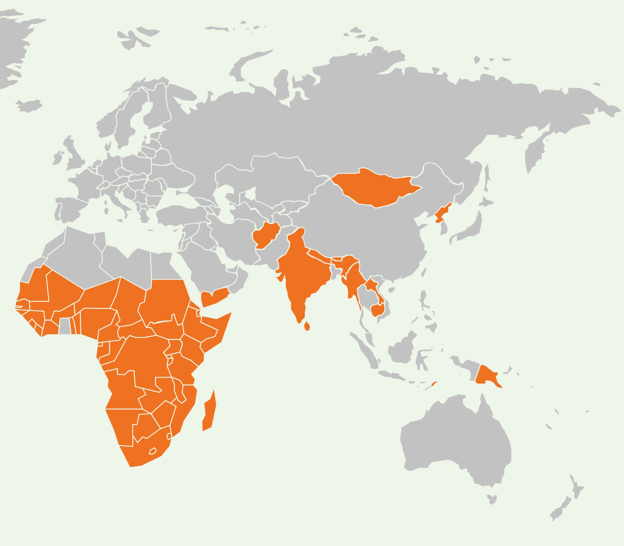
The POs offer a range of solar module products, from 10 watts to 135 watts, to suit a range of income levels. IDCOL receives funding from government and donor organisations to subsidise the price of solar systems and to refinance consumer credit.

Costs

Solar home systems save money over their lifetime, as they substitute for expensive fuel in kerosene lamps. As a result, they have a net negative emission abatement cost of approximately –230 $/t$CO_2$e. The estimated annual savings created by scaling up solar home systems could be $930 million in 2025 and $690 million in 2030.

Co-benefits

Besides reduced carbon emissions, off-grid solar power provides the critical benefit of modern energy access for people living in rural and deprived areas. With electricity, small businesses can stay open longer and children study better. Provision and maintenance of solar home systems also employs around 115,000 people in Bangladesh.



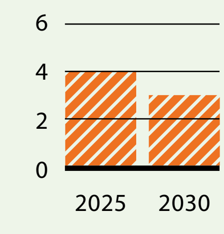
The solution can be scaled up to countries with large off-grid populations such as India, Nigeria and Colombia

Replacing kerosene lamps reduces indoor air pollution, and a lower incidence of respiratory diseases has been observed in Bangladesh. Women who work at home particularly benefit. Electricity access can also reduce the fire hazard of using kerosene lamps.

"Replacing kerosene lamps lowers the incidence of respiratory diseases."

Barriers and drivers

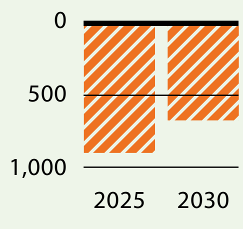
- The biggest barrier to an up-scaling of solar home systems is poor access to financing. In Bangladesh, funding from donors has reduced capital costs.
- Another barrier is insufficient awareness among rural households, addressed through public campaigns.
- Soft infrastructure to improve local know-how and address supply chains is also needed. IDCOL provides technical assistance and capacity building.



Emission reductions potential

3

$MtCO_2e$/year



Median abatement costs

-691

Million $

RENEWABLE ENERGY

Wind power

Wind power has helped many countries reduce emissions, including Denmark and Brazil. Scaling up the solution could yield carbon reductions greater than the combined, present emissions of Germany and France while boosting energy security.

Climate impact

Denmark already produces 39% of its power from wind, and Brazil has rapidly increased wind power generation to 5 terawatt hours (TWh) a year. This has resulted in annual emission savings of 8.6 Mt in Denmark and 1.1 Mt in Brazil, a country which already has a relatively low-carbon electric mix.

Denmark's relative level of wind power generation can be scaled up to high and upper middle-income countries and Brazil's level to lower-income countries. In total, this would reduce global annual emissions by 730-1,310 Mt in 2030.

Success factors

Denmark started using wind power in the 1980s. Today, the state supports onshore wind power through a feed-in tariff. This bonus is capped, based on the wholesale power price.

Denmark has set ambitious targets for low-carbon electricity, thus giving a clear signal to investors. The country aims to derive half of all its electricity from wind by 2020. By 2035, all power and heat should be from renewable sources.

Since 2005, Brazil has used auctions to commission a total of 72 GW of new power capacity, with three quarters coming from renewable energy sources. Contracts are designed to encourage diversification among renewables and attract additional technologies besides hydropower.

While Denmark has relied mostly on tariffs and Brazil on auctions, other countries have successfully used a range of other measures. For example in the US, renewable portfolio standards (RPS) and a federal production tax credit (PTC) have driven the wind power market, whereas Sweden has relied on green certificates.

Costs

Earlier McKinsey abatement cost estimates give reducing emissions with wind power a range of 22-32 $/t$CO_2$e. As scaling up wind power in this analysis results in very rapid deployment, it is plausible that costs would decline faster. To factor in the likely range, we use the McKinsey cost figures as a maximum and savings of –$22–32 per tonne of CO_2 as minimum.

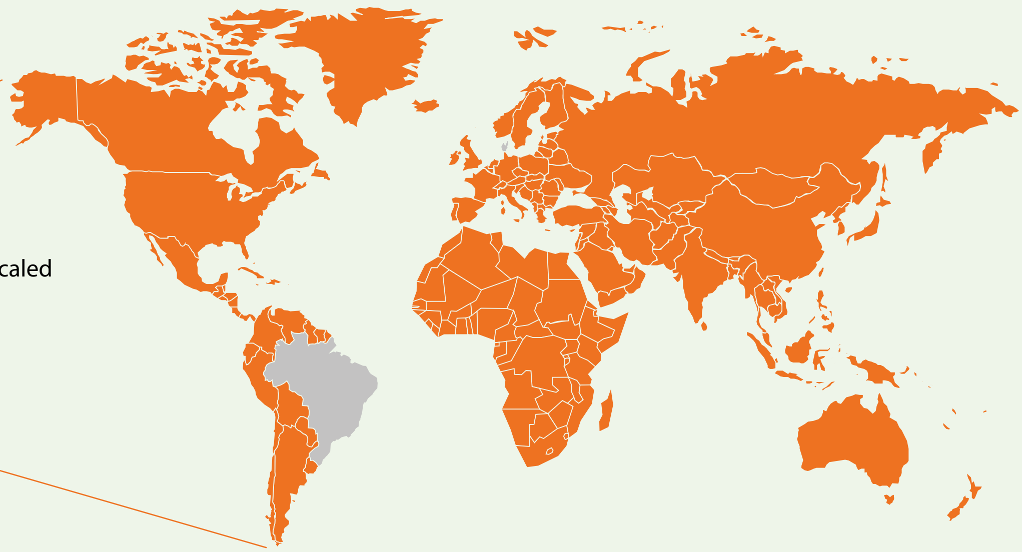
The range results in large differences in total costs. Scaling up wind power globally can therefore cost from $16 to $42 billion annually in 2030 or it can yield equally large annual savings, depending on the price difference between wind and conventional power.

Co-benefits

Denmark is transitioning to 100% renewable energy by 2050, where wind power will play a crucial part. This transition is expected to create at least 30,000 to 40,000 new jobs. In Brazil, it is estimated that the wind power industry will employ around 90,000 people in 2016.

Among other co-benefits, increasing the share of wind power can make a country less dependent on energy

The solution can be scaled up to all countries

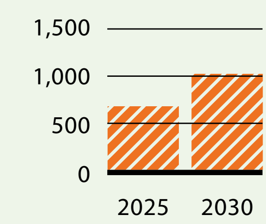


imports and less vulnerable to fuel price fluctuations. Wind power supports incomes for landowners. Replacing fossil fuels also reduces air pollution.

Barriers and drivers

- Public attitudes towards wind power are generally positive, but there can be local opposition, for example based on visual impacts and noise. The Danish Renewable Energy Act includes four provisions for promoting local acceptance:
  1. Funds to early project planning by local wind turbine owners;
  2. Mandatory auctioning of at least 20% of wind power project ownership to local people;
  3. Full compensation for loss of property value;
  4. Funds to enhance local scenic and recreational values, such as nature restoration projects.
- Transmission infrastructure must be built or strengthened to connect wind parks to the transmission and distribution network.
- Electricity system operation requires a well-functioning power market with accurate forecasts, adequate balancing capacity from other electricity sources and demand-side management to meet demand at all times.
- In the past, some incentive schemes have turned out fairly expensive. However, falling wind power prices make the technology increasingly competitive, with fewer – if any – subsidies needed.

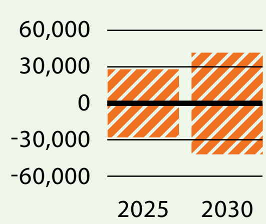
"Increasing the share of wind power can make a country less vulnerable to fuel price fluctuations."



Emission reductions potential

1,018

$MtCO_2e$/year



Median abatement costs

0

Million $

RENEWABLE ENERGY

Bioenergy for heating

In Finland a fifth of all energy is generated by burning biomass. Scaling up the solution would create jobs, improve countries' energy security and deliver carbon cuts equivalent to the present annual emissions of Bangladesh.

Climate impact

Bioenergy accounts for a fifth of all primary energy consumption in Finland. This reduces emissions by approximately 6.8 Mt annually.

The solution can be up scaled to countries with cold climates and large amounts of wood residue. This would reduce emissions by 193 Mt per year in 2030.

Success factors

For many years Finland has used large amounts of biomass to generate heat and power. Various domestic circumstances have contributed to this, including large forestry resources, a strong pulp and paper industry and extensive district heating networks.

Wood pellets are increasingly used instead of oil or electricity to heat individual buildings. Pellets and wood chips can also replace oil in the district heating networks, which supply half of the country's heating.

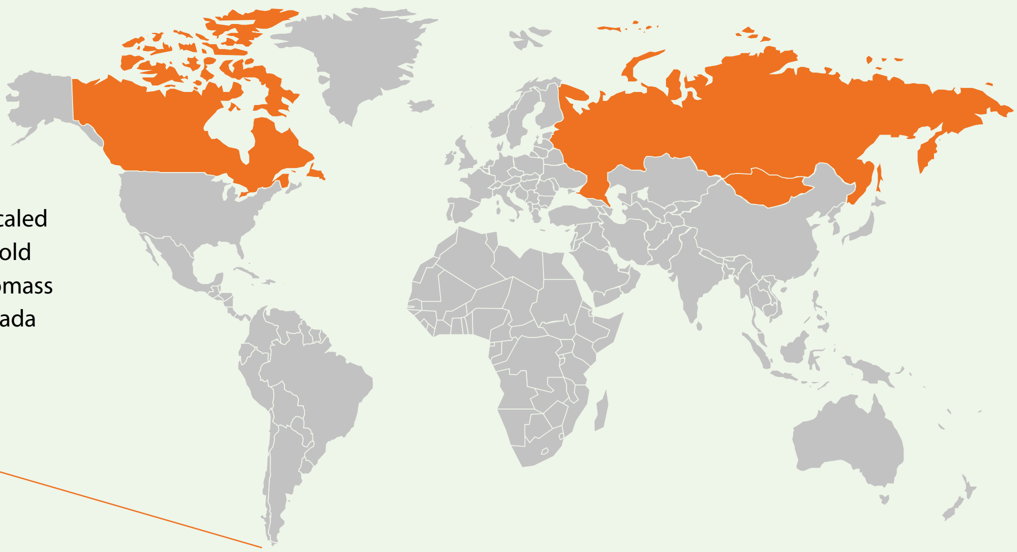
Finland has used a range of policy levers to promote biomass use, including investment in R&D, tax incentives and feed-in tariffs. Other countries have also successfully expanded the role of biomass. For example, Austria subsidises the upfront cost of biomass boilers and large plants.

Costs

Abatement cost estimates for biomass range significantly between zero and 80 $/t$CO_2$e, depending on local conditions. Scaling up the solution internationally would therefore cost from nothing to $15 billion per year in 2030.

Co-benefits

Bioenergy can have a positive impact on employment. By 2020, jobs in Finland's forest fuel supply chain and the supply of machinery are forecast to increase by five times. Reducing fuel imports also helps to improve energy security and the country's balance of payments.

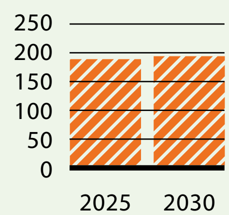


The solution can be scaled up to countries with cold climates and large biomass resources: Russia, Canada and Mongolia

Barriers and drivers

- Infrastructure is needed to use biomass for heating effectively. District heating systems are increasingly cost-effective in colder climates.
- Financial incentives may be required for biomass to compete with fossil fuels. However, if emissions are adequately priced through emissions trading or taxation, no public subsidies are necessary.
- Sustainable sources of biomass are a prerequisite. For some countries agricultural or consumer waste may provide alternative sources.

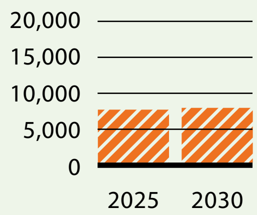
"Reducing fuel imports also helps to improve the country's balance of payments."



Emission reductions potential

193

$MtCO_2e$/year



Median abatement costs

7,744

Million $

USEO DEL ORO
TransMilenio
Viale
SUPERIOR
A004
TransMilenio
SHL-493

TRANSPORT

Vehicle fuel efficiency in the EU
Bus rapid transit in Colombia

TRANSPORT

Vehicle fuel efficiency

The European Union has cut the emissions of new cars by nearly one fifth. Scaling up this solution would produce carbon cuts equivalent to Saudi Arabia's annual emissions while cutting air pollution and improving energy security.

Climate impact

The EU has been successful in significantly increasing the fuel efficiency of new cars. The average CO_2 emissions of new cars fell by 17% from 2006 to 2012, from 160 g/km to 132 g/km.

If the EU's fuel-efficiency approach were scaled up to the entire world, this could result in emissions savings of 262 Mt annually in 2025. By 2030, the impact would double to 525 Mt.

The expected adoption of new EU standards for 2025 would result in an even larger impact. One estimate suggests that scaling up the EU's proposed targets could see savings of as much as 1.9 Gt in 2030.

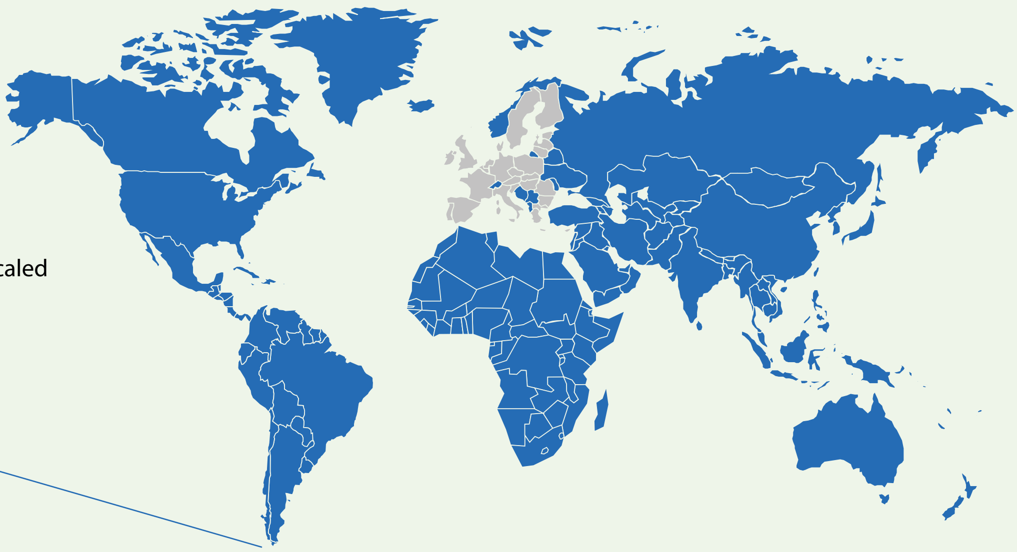
Success factors

The EU started programmes to reduce vehicle emissions in the mid-1990s. In the beginning this took the form of voluntary targets for manufacturers. The targets became mandatory in 2009, when a maximum of 130 gCO_2/km was set as the average for new vehicles in 2015. Passenger car standards of 95 g/km of CO_2 will be phased in for 95 per cent of vehicles by 2020, with 100 per cent compliance required by 2021.

The EU applies targets for both passenger cars and light commercial vehicles. The European Automobile Manufacturers Association (ACEA) and the European Commission monitor progress jointly. Manufacturers that do not comply are subject to penalties that rise progressively. In 2019, the penalties will increase to 95 euros per car for each g/km over the target.

Costs

More fuel-efficient vehicles tend to cost more to buy and less to run. Overall, increasing fuel efficiency is estimated to save money, with an abatement cost of –55 \$/tCO_2e to –29 \$/tCO_2e. The total savings of scaling up this solution are estimated to be \$8 to \$15 billion per year in 2025 and \$15 to \$29 billion in 2030.



The solution can be scaled up to all countries

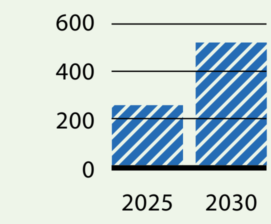
Co-benefits

Better fuel efficiency improves air quality, especially in urban areas. Fuel-efficiency standards benefit energy security because they reduce demand for imported fuels. Estimates for employment impacts vary: some studies suggest a negligible net impact, while others foresee significant numbers of new jobs.

"Vehicle testing and monitoring must be improved."

Barriers and drivers

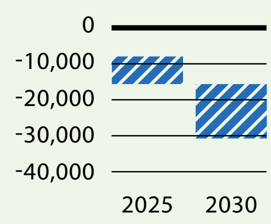
- The technologies needed to comply with fuel-efficiency standards are available and in many cases are cost-effective compared with driving less efficient cars. Most large vehicle markets already apply efficiency standards, helping ensure an adequate implementation infrastructure.
- Consumers are generally more concerned about prices than environmental impacts. Informing consumers about the benefits of fuel efficiency can increase support.
- There is a considerable gap between real-world fuel economy and results under laboratory test conditions. Car manufacturers employ a number of tactics to improve a car's performance during testing, as infamously highlighted by the Volkswagen scandal. Therefore vehicle testing and monitoring must be improved.



Emission reductions potential

525

$MtCO_2e$/year



Median abatement costs

-22,167

Million $

TRANSPORT

Bus rapid transit

The bus rapid transit system in the Colombian capital Bogotá carries more than half a billion passengers a year. If similar cities elsewhere had equivalent bus systems, emissions could be cut globally by as much as Norway produces, while also reducing congestion and air pollution.

Climate impact

The TransMilenio bus rapid transit (BRT) system in Bogotá transports 565 million passengers a year. BRT replaces trips by regular buses and, to a lesser extent, private cars and taxis, resulting in emission savings of 0.6 Mt a year.

BRT can be scaled up to other cities with more than one million inhabitants in middle-income countries. This would reduce emissions by 11 to 38 Mt in 2030.

BRT is part of broader transit-oriented development (TOD) that involves high-density walkable districts, biking facilities, fuel-efficiency standards and disincentives to use cars. The total emission impact of TOD programmes can be significantly larger than that of BRT alone, but providing reliable estimates is more challenging.

Success factors

BRT requires dedicated bus lanes. Stops and busways are typically positioned in the middle of roads and fares are collected off-board, ensuring fast and frequent operations.

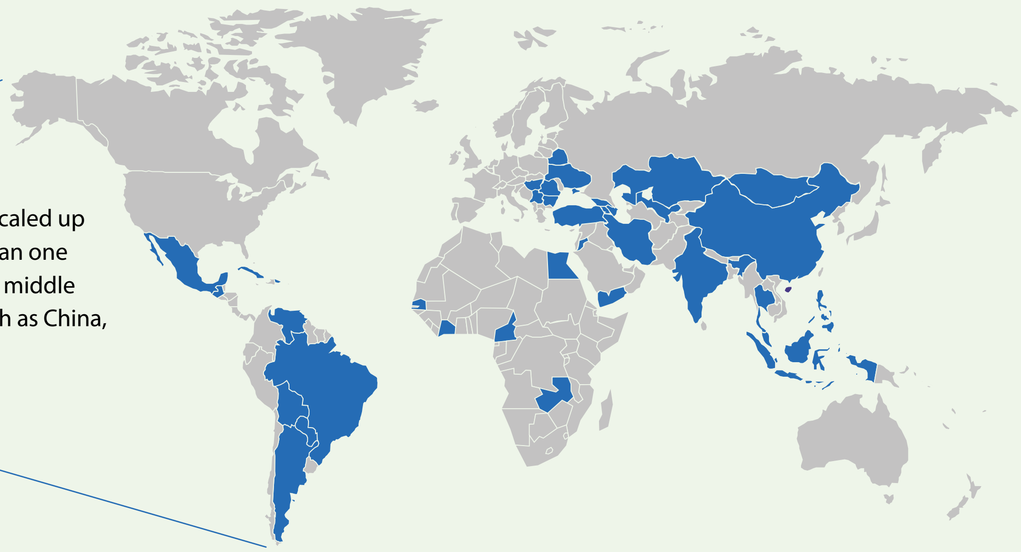
The first phase of the TransMilenio network opened in 2000. Today there are 11 corridors through the city, stretching to a combined 112 kilometres. Emissions from BRT are lower than from regular buses or private vehicles because of high occupancy rates and efficient driving conditions on dedicated lanes.

The BRT system in Bogotá was the first in Colombia and is being replicated in other cities. Public and private funds from home and abroad have been accessed to support the growth of cities using the transit-oriented development approach.

Various other policies have been used to reduce emissions from urban transport internationally. These include expanding local train, subway and tram services, congestion charging and creating pedestrian zones and bike lanes.

Costs

The abatement cost of BRT is estimated at 8-16 $/tCO_2e$. Scaling up this solution internationally would cost $80 million to $602 million by 2025 and $83 million to $633 million by 2030 per year.



The solution can be scaled up to cities with more than one million inhabitants in middle income countries such as China, India and Mexico

Co-benefits

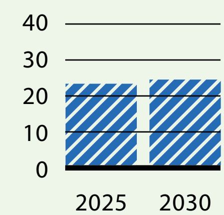
BRT reduces traffic congestion resulting in faster travel times and increased mobility. Improving public transport connections also boosts property values. The TransMilenio system in Bogotá reduced average travel times by 32% and increased property values along the main line by 15 to 20%.

Replacing regular buses and private cars reduces local air pollution and related health impacts. Investment in BRT infrastructure also creates jobs.

Barriers and drivers

- BRT systems are significantly cheaper to build than rail networks. However, upfront investment costs can still be a barrier for some cities. Financing can come from, for example, taxing properties that have increased in value by being close to BRT lines.
- Bus travellers may resist fare hikes and taxpayers may object to increases in taxes. However, once the system is in place, user satisfaction is generally high due to reduced travel time and high quality.
- Transit-oriented development requires effective collaboration and co-ordination between national and local government and private developers. This is significantly improved with strong municipal leadership and financial oversight, transparency and accountability, as well as policy integration at the local level.

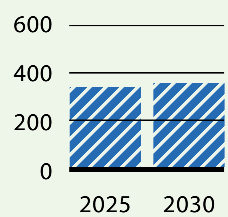
"Bogotá's TransMilenio system increased property values along the main line by 15 to 20%."



Emission reductions potential

24

$MtCO_2e$/year



Median abatement costs

358

Million $

BUILDINGS AND HOUSEHOLDS

Building efficiency in Germany and Mexico
Improved cook stoves in China
Appliance efficiency in Japan

BUILDINGS AND HOUSEHOLDS

Building efficiency

Germany and Mexico have already improved the energy efficiency of millions of buildings. A scale-up of their achievements internationally would reduce emissions by more than the Netherlands produces every year while cutting heating costs and improving energy security.

Climate impact

Between 2006 and 2014, nearly four million German homes were either given energy efficiency retrofits or were built to new more exacting efficiency standards, cutting emissions by 0.7 Mt. Meanwhile in Mexico, a green mortgage programme has delivered emissions savings of 0.3 Mt.

Scaling up the German model to other cold high-income countries would reduce emissions of 77 Mt by 2030. Scaling up the Mexican programme to countries with a similar climate would reduce annual emissions by a further 129 Mt.

Success factors

The German state-owned bank Kreditanstalt für Wiederaufbau (KfW) promotes energy efficiency in residential buildings through low-interest loans and grants. Various programmes target refurbishments of old buildings and construction of new buildings.

Mexico's green mortgage programme provides loans and subsidies for members of the National Workers' Housing Fund (Infonavit). Technologies eligible for support include solar water heaters, compact fluorescent lamps, water-saving taps and thermal insulation.

Other measures have been effective in improving energy efficiency in buildings in other countries. These include energy-efficiency standards in building codes, tax incentives and energy-efficiency labelling.

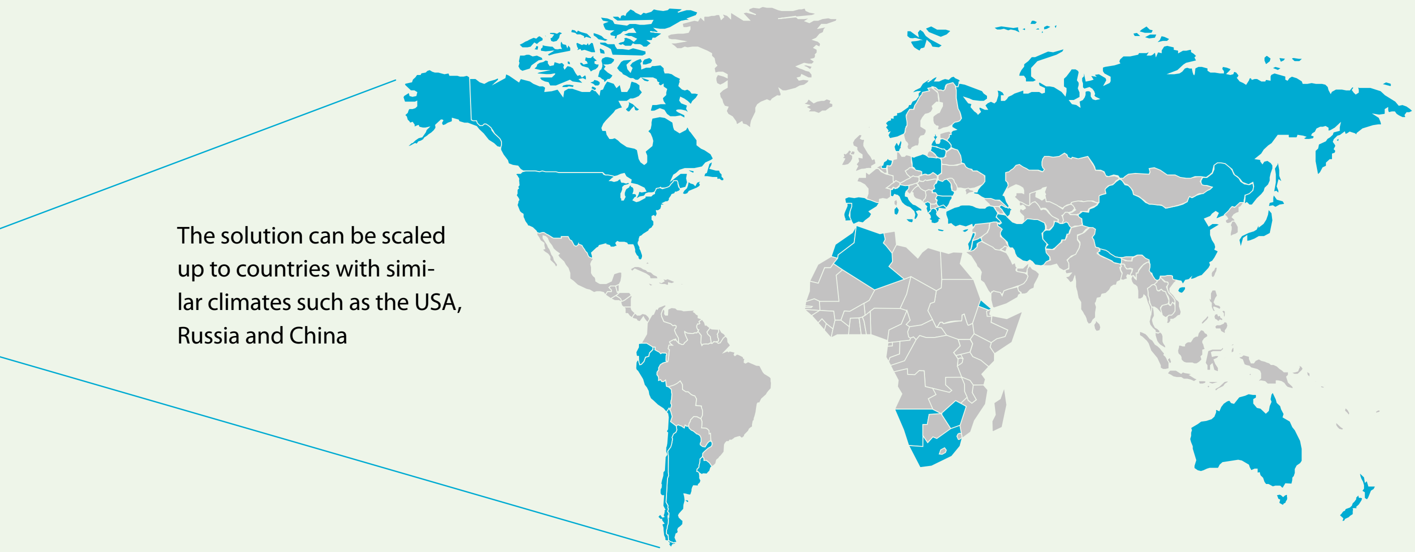
Costs

In the German case the estimated abatement costs of energy-efficiency measures vary from saving money at –56 \$/tCO_2e to costing 35 \$/tCO_2e. The total costs of scaling up the German approach range between –\$6 billion and \$3 billion per year in 2030.

In the Mexican case, improving building efficiency has shown negative abatement costs of –73 to –15 \$/tCO_2e. Scaling up the solution would therefore save money, from –\$9 billion to –\$2 billion.

Co-benefits

Improving energy efficiency in general reduces fuel imports and increases energy security. Energy efficiency



The solution can be scaled up to countries with similar climates such as the USA, Russia and China

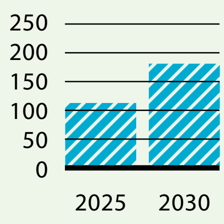
also reduces heating bills, which lifts people out of energy poverty. Energy-efficient homes often have better air quality, resulting in health benefits.

The German programme has resulted in the creation or retention of over 400,000 jobs in 2013. The beneficiaries are mostly local building contractors.

Barriers and drivers

- A large amount of funding is needed to implement programmes. This can be challenging for countries with limited public finances. Using public funding to catalyse private capital, and complementing financial incentives with other measures, can increase effectiveness.
- Building efficiency is often a profitable investment, but upfront costs are generally high. Financial incentives encourage more people to make the investments necessary.
- It is important to make sure homeowners are well informed about policies. In Germany, a platform was set up to help the public to get relevant, tailored information.

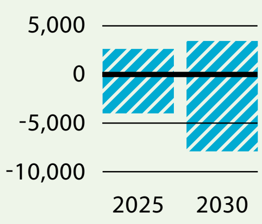
"Energy efficiency also reduces heating bills which lifts people out of energy poverty."



Emission reductions potential

206

$MtCO_2e$/year



Median abatement costs

-6,642

Million $

BUILDINGS AND HOUSEHOLDS

Improved cook stoves

China has provided improved cook stoves to almost all homes. Scaling up the solution would cut emissions by more than the current total emissions of the UK and France combined while improving people's health and empowering women in developing countries.

Climate impact

About nine out of ten Chinese households already have access to stoves with improved efficiency and cleaner burning. Each improved stove can be estimated to save emissions by 1 to 3 tonnes of CO_2e a year.

The Chinese programme could be scaled up to other countries where traditional cook stoves are still common. This would achieve annual emissions savings of 500 to 1,500 Mt by 2030.

Success factors

The National Improved Stove Program (NISP) and its provincial counterparts were initiated in the early 1980s. They have been credited with introducing nearly 200 million improved stoves by the late 1990s, at a rate of around 15 million per year.

Instead of subsidising the cost of the improved stoves, the government invested in R&D, training, product demonstration and public outreach to encourage take-up. The direct cost of purchasing and installing stoves was mostly borne by Chinese households.

Costs

Introducing improved cook stoves is estimated to have an abatement cost of 5 to 8 $/t$CO_2e$. Scaling up the solution would therefore cost $2.5 billion to $11.8 billion a year by 2030.

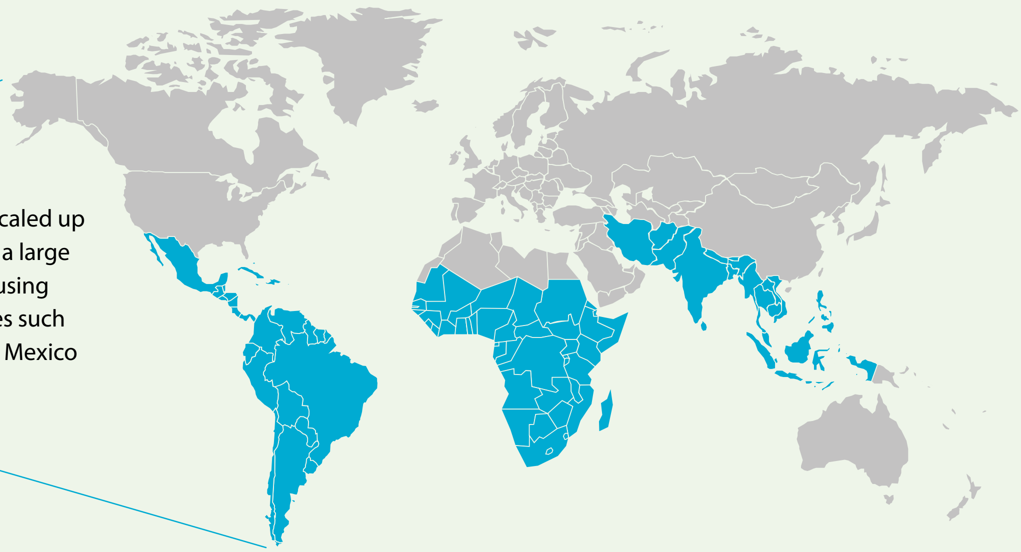
Co-benefits

Improved cook stoves (ICS) have substantial co-benefits that offer reason enough for deployment. Traditional stoves cause at least 4.3 million premature deaths annually and 110 million disability-adjusted life years – primarily among women and children. ICS significantly reduces both indoor and outdoor pollution from cooking with enormous health benefits. By cutting fuel costs and increasing efficiency, improved stoves provide better energy access.

Traditionally it is women and children who gather firewood or buy coal for cooking. Reduced fuel consumption frees up time for other activities, improving the lives of women and facilitating school attendance among children.

Further, by reducing the need for solid biomass and charcoal, improved cook stoves help prevent deforesta-

The solution can be scaled up to other regions with a large share of households using traditional cook stoves such as Ethiopia, India and Mexico

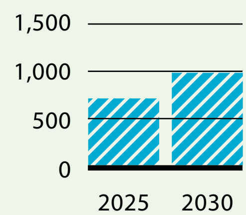


tion. This in turn has a positive impact on biodiversity, soil quality and water resource management.

"Traditional stoves cause at least 4.3 million premature deaths annually."

Barriers and drivers

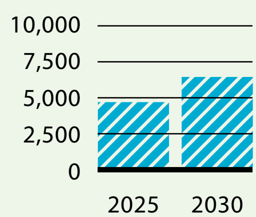
- High upfront investment costs often deter households from buying an efficient stove. This is the most important barrier and subsidies may be necessary to secure uptake, especially in poorer areas.
- ICS must be designed to suit local needs like cooking preferences. Stoves need therefore to be tested and adapted to ensure uptake and efficient use.
- Deployment has been held back by lack of awareness about savings. Information campaigns on the benefits of ICS and their correct use can address this barrier.
- Retailing networks need to reach remote and rural areas. Networks also need to provide after-sale services as well as fuel at affordable prices.
- In China product quality has been patchy and performance varies considerably. Quality control and standards are beneficial.



Emission reductions potential

985

$MtCO_2e$/year



Median abatement costs

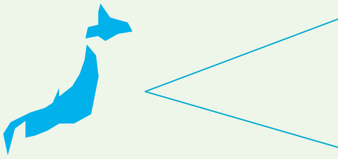
7,140

Million $

BUILDINGS AND HOUSEHOLDS

Appliance efficiency

Japan has improved the energy efficiency of appliances resulting in significant emission reductions. Scaling up energy-efficiency standards could reduce emissions by more than the present annual emissions of Canada while cutting energy bills for homes and businesses.



Climate impact

By 2010 Japan's Top Runner Approach energy-efficiency standards were delivering 21 Mt of emission reductions. Combined with other efficiency improvements in appliances introduced outside of the programme, they reduced annual emissions by around 50 Mt.

Scaling up the Top Runner Approach programme to other OECD countries, as well as Russia, China and South Africa, would deliver annual emission reductions of 330 to 480 Mt per year. If the programme were scaled up to all countries, the climate impact would increase to 650 to 880 Mt.

Success factors

In 1998, Japan launched the Top Runner Approach to improve energy efficiency in a total of 31 product categories. The focus is on high-energy-consuming products, including household appliances, electronics and vending machines.

Manufacturers were required to ensure that the weighted average efficiency of their products achieved certain standards. This flexibility lets producers provide a wide range of models to meet consumer demand while guiding the overall market to higher energy efficiency. A "name and shame" approach was taken to non-compliers, putting the brand of defaulting companies at risk.

Many other countries, including the US, China and Mexico, have also set minimum energy-efficiency standards. Other measures to encourage energy efficiency include product labelling and tax incentives.

Costs

Improving appliance efficiency saves money, delivering abatement costs of between –98 and –127 $/tCO$_2$e. Achieving similar improvements in energy efficiency across OECD countries, Russia, China and South Africa would save $32 to $60 billion per year by 2030. If the solution were applied to all countries, avoided costs rise to $64 to $112 billion.

Co-benefits

Improving energy efficiency cuts utility bills for homes and businesses. Efficiency measures reduce fuel imports and the need for large investments in power generation and transmission infrastructure.

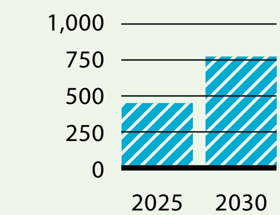
The solution can be scaled up to all countries

Energy efficiency also reduces the impacts and risks of generating power, such as air pollution from fossil fuels. Efficiency may also shift economic activity to more labour-intensive sectors of the economy having a positive effect on employment, although the link is not as clearly established.

"A 'name and shame' approach puts the brand of defaulting companies at risk."

Barriers and drivers

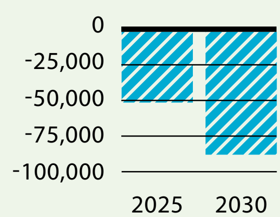
- Monitoring and enforcing standards requires good governance and administrative capacity. The experience of various countries suggests that efficiency standards can be applied in a variety of contexts.
- Asymmetry of information can be a barrier if regulators have to rely on industry data when setting standards. In Japan, authorities engaged in dialogue with industry associations and set up expert committees to hear different views.
- Another challenge can be ensuring long-term certainty for businesses. In Japan the government sets five-year time frames for implementing the new standards.



Emission reductions potential

401

$MtCO_2e$/year



Median abatement costs

-46,075

Million $

INDUSTRY

Industry energy efficiency in China
Industrial electric motors in the US
Reducing methane from
oil and gas production in the US

INDUSTRY

Industry energy efficiency

Significant energy savings have been delivered in China by improving the energy efficiency of industry. Scaling up the solution could reduce emissions by as much as Canada produces while cutting energy bills for industry and reducing local air pollution.

Climate impact

China's Top-10,000 programme covers two thirds of its industrial energy consumption. As a result, the energy efficiency of industry has improved on average by 3 to 4% annually.

The Chinese approach could be scaled up to other countries with high industrial energy consumption. This would deliver annual emission reductions of 650 to 1,100 Mt by 2030.

Success factors

China introduced Top-10,000 in 2011 as an expansion of its successful predecessor, Top-1,000. Each set mandatory energy conservation targets for the country's biggest energy users.

Under contracts signed with the government, participants in the programme are required to meet targets for energy savings. This involves various activities including conducting regular audits, setting up energy measurement and management systems and delivering energy conservation plans.

Other countries have used different tools to increase energy efficiency in industry. India's Perform, Achieve and Trade programme allows businesses to trade energy savings in a similar way to trading carbon credits, for example.

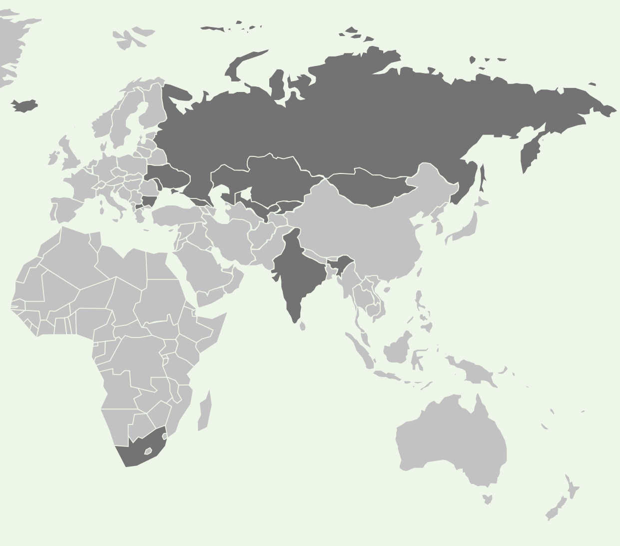
Costs

The estimated abatement costs of improving energy efficiency in industry have a broad range, from savings of 15 $\$/tCO_2e$ to costing 29 $\$/tCO_2e$. The total costs of scaling up this solution range from –$16 to $32 billion a year by 2030.

Co-benefits

Successful efficiency improvements reduce operational costs and improve competitiveness. They also reduce the need for fuel imports and improve energy security. As energy-efficiency measures are more labour-intensive than energy production, they can also create jobs.

Improving energy efficiency reduces air pollution and related health impacts. In China emissions from coal plants contribute to an estimated quarter of a million premature deaths in 2011.

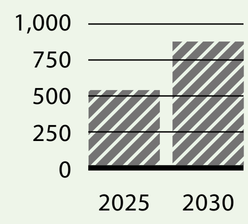


The solution can be scaled up to countries with high energy consumption in industries such as Russia, South Africa and Brazil

Barriers and drivers

- Capacity to implement measures varies by region and company. In China, the government and third-party service companies have provided capacity building and some companies have set up their own training systems.
- Energy conservation and upgrading of operations requires financial resources. In China, dedicated public funding and stimulated private investment have helped to enable this.
- Guidelines for industry and accounting methodology need to be clear. Targets should be independently verified and energy savings audited.

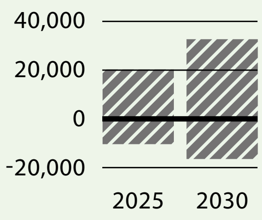
"In China emissions from coal plants contributed to an estimated 250,000 premature deaths in 2011."



Emission reductions potential

879

$MtCO_2e$/year



Median abatement costs

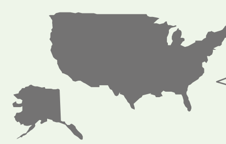
8,079

Million $

INDUSTRY

Industrial electric motors

The United States has applied energy-efficiency standards for electric motors used in industry. Scaling up this approach could deliver a climate benefit equivalent to the present annual emissions of Argentina while cutting fuel bills and improving competitiveness.



Climate impact

The US programme has cut annual energy use by an estimated 41 to 67 TWh. This results in an emission reduction of 28 to 47 Mt.

Electric motors are widely used in industries in all countries so the approach could be scaled up globally. This would reduce annual emissions by 85 to 139 Mt in 2030.

Success factors

The United States government applies minimum efficiency standards at the federal level. The rules cover mainly industrial electric motors both manufactured and imported for sale in the US.

The US Energy Independence and Security Act (EISA) assigns efficiency ratings according to motor type and size. The standards require manufacturers to certify their motor minimum efficiency values before they are allowed to sell their products.

Efficiency standards for electric motors are also used by other countries and promoted, for example, through the UNEP energy efficiency appliances programme. Other measures encouraging the uptake of energy-efficient motors include voluntary partnerships with industry, energy taxes and access to low-interest finance.

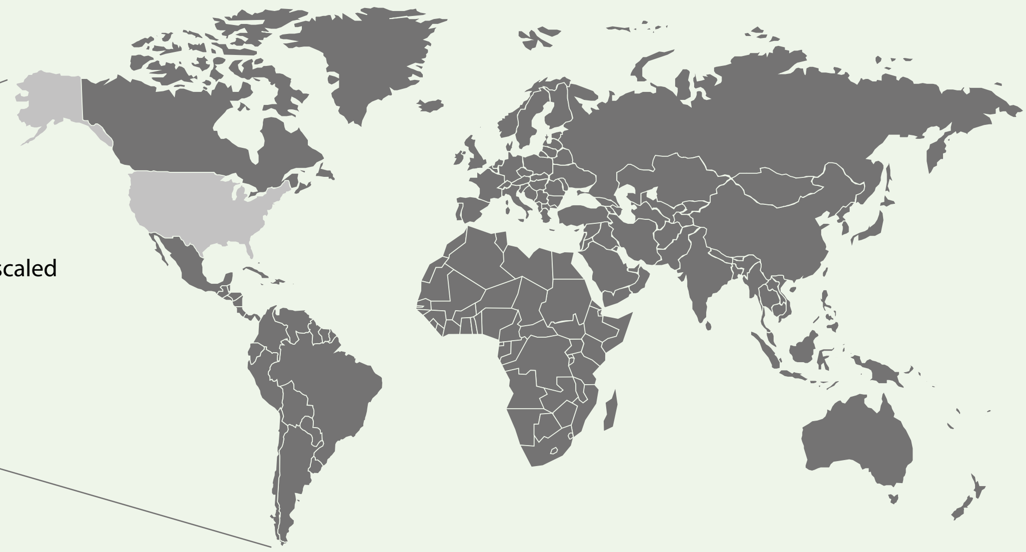
Costs

Improving the energy efficiency of electric motors cuts power consumption which saves money, delivering an estimated abatement cost of –200 to –72 \$/tCO_2e. Total savings from scaling up the solution globally would be \$6 to \$28 billion a year by 2030.

Co-benefits

Improving energy efficiency in industry reduces energy bills and improves competitiveness. It also reduces the need for imported fuel, improving energy security. As efficiency measures are more labour-intensive than power generation, improving efficiency can also create jobs.

Reducing energy demand also cuts air pollution from traditional power generation using fossil fuels. This in turn decreases harmful health impacts.

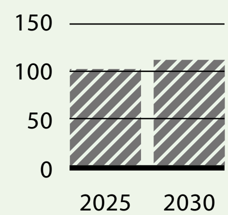


The solution can be scaled up to all countries

Barriers and drivers

- The barriers for implementing efficiency standards for electric motors are relatively low. The technology is established and widely available.
- Regulation can meet with scepticism from businesses. Involving different stakeholders in drafting rules, keeping them informed and highlighting benefits can address concerns.
- Good governance and administrative capacity is required to monitor and enforce standards. Conversely bad governance may mean slower adoption, especially in poorer countries.

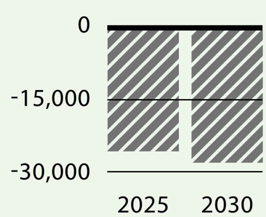
"The barriers for implementing efficiency standards for electric motors are relatively low."



Emission reductions potential

112

$MtCO_2e$/year



Median abatement costs

-16,979

Million $

INDUSTRY

Reducing methane from oil and gas production

The United States has already realised 60% of the cost-effective methane reduction potential from its oil and gas production. Scaling up this solution would yield carbon cuts equivalent to the annual emissions of Turkey while saving money and improving energy security.

Climate impact

A US programme to reduce methane from oil and gas production has achieved an emission reduction of 38 Mt in 2010, compared with business-as-usual levels. That is equivalent to 60% of the cost-effective carbon abatement potential and 27% of the technical potential.

If the US achievement in reducing methane were scaled up to all oil- and gas-producing countries, this could result in annual emissions savings of 315-420 Mt in 2025. By 2030, the reduction would be 330-447 Mt.

The technical potential for cutting emissions is considerably higher. With aggressive reduction targets, the global abatement potential could be as much as 1.3 Gt in 2030.

Success factors

Established in 1993, the US Natural Gas STAR Program is a flexible, voluntary partnership. It encourages oil and natural gas companies to adopt proven cost-effective technologies and practices which improve operational efficiency and reduce methane emissions. Measures include improved inspection and maintenance, but also technologies such as low bleed pumps and vapour recovery units.

Natural Gas STAR partners include operators in all major industry sectors that deliver natural gas to end users. Since its inception, the programme has implemented around 150 cost-effective technologies and practices to cut methane emissions. In 2006, the initiative expanded its membership worldwide, significantly increasing opportunities for emission reductions.

Costs

Reducing methane emissions from oil and gas production actually saves money, due to the economic value of the recovered gas. The savings in different regions range from –50 \$/tCO_2e to –3 \$/tCO_2e. Scaling up the solution would generate savings worth \$6 to \$9 billion per year in 2025 and \$6 to \$10 billion in 2030.

Co-benefits

Limiting fugitive methane emissions maximises available energy resources and reduces economic waste. Upgrading production assets to adopt suitable technologies and practices may improve operational and economic performance, making these more robust and less susceptible to downtime. The implementation and development of

The solution can be scaled up to all oil and gas-producing countries such as Russia, Brazil and Indonesia

The solution has been scaled up using regional data. The map indicates all the regions with scale-up potential, but the solution may not be applicable to all countries within the region. For more information, please refer to the technical report.

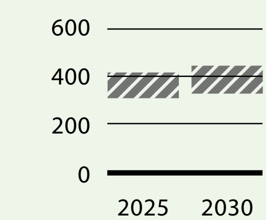
abatement measures may also result in increased employment and improved worker safety.

Cutting methane emissions reduces also the emissions of conventional pollutants, such as volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Cuts in air pollution in turn reduce health risks.

"The development of abatement measures may also result in improved worker safety."

Barriers and drivers

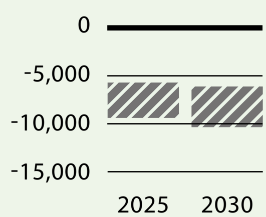
- Barriers for implementing the solution are low, as it often generates direct cost savings. Additionally, the US programme seems to have had little trouble expanding to other parts of the world.
- Oil and gas companies have not implemented cost-saving methane reduction measures more broadly because traditionally they expect even higher rates of return for invested money. The US programme tackles this problem by providing companies with resources for technical assistance.
- The technology to cut emissions already exists. However, in some cases site-specific factors may make technologies infeasible.
- Implementation lies mainly with companies. The right policy environment is required to drive adoption on a wider scale.



Emission reductions potential

388

$MtCO_2e$/year



Median abatement costs

-8,164

Million $

AGRICULTURE AND FORESTS

Low-carbon agriculture in Brazil
Cutting food waste in Denmark
Reducing deforestation in Brazil
Afforestation and reforestation in Costa Rica

AGRICULTURE AND FORESTS

Low-carbon agriculture

Brazil has an ambitious programme to encourage low-carbon agriculture. Scaling the solution up would deliver carbon cuts exceeding the present annual emissions of Peru while supporting rural communities and protecting soil and water.

Climate impact

Brazil has introduced an ambitious programme to reduce emissions from agriculture. The goal is to achieve as much as 160 Mt in avoided emissions by 2020.

The programme can be scaled up to developing countries with each focusing on options relevant to their circumstances. This would result in emission reductions of 72 to 142 Mt per year by 2025 and 111 to 219 Mt in 2030.

Success factors

Brazil launched its Low-Carbon Agriculture Programme, also referred to as the ABC Plan (Programa Agricultura de Baixo Carbono), in 2010 to tackle the country's second largest source of emissions: agriculture. The aim of the programme is to promote low-carbon sustainable agricultural practices that would also improve the resilience of rural communities.

The programme encourages six types of activities by offering farmers lines of credit that help reduce emissions or increase carbon sinks. These include:

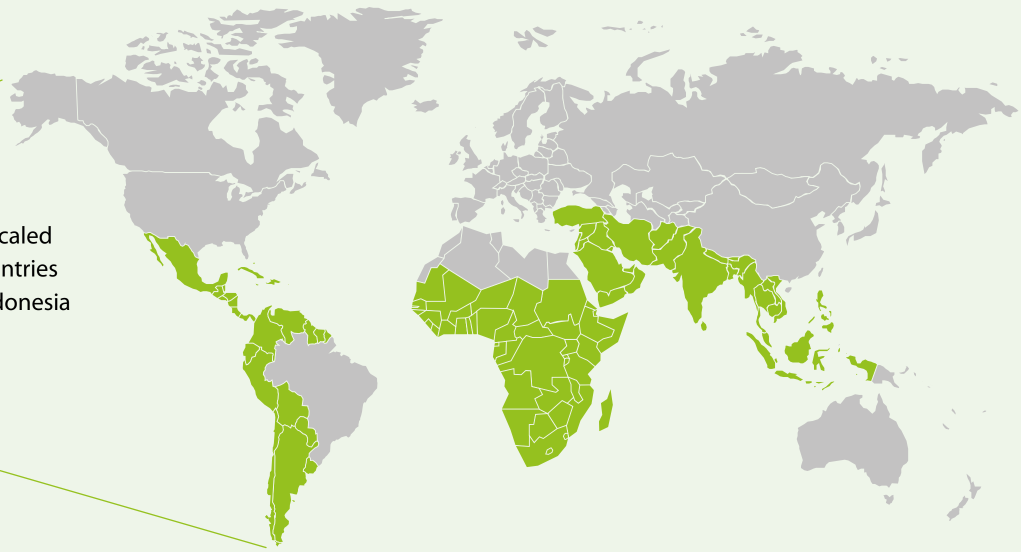
1. No-till agriculture
2. Rehabilitation of degraded pastures
3. Integrated crop–livestock–forest systems
4. Planting of commercial forest
5. Biological nitrogen fixation to reduce fertiliser use
6. Animal waste treatment.

The programme further encourages better management of natural resources by improving efficiency. With the goal of achieving 134 to 160 Mt in avoided emissions in 2020, ABC is considered the world's most ambitious mitigation plan on agriculture.

Costs

The cost of reducing emissions through low-carbon agriculture can be estimated at 11 $/t$CO_2$e. Scaling up the solution among developing countries would cost $1.2 to $2.4 billion a year by 2030.

The solution can be scaled up to developing countries such as Colombia, Indonesia and South Africa



Co-benefits

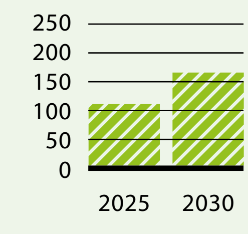
Sustainable agricultural practices have various ecological benefits. They protect and enhance ecosystem services through preserving forests, soil and water.

The subsidies provided through the ABC Plan directly target rural development. The programme makes communities more resilient by strengthening their sources of income.

Barriers and drivers

- Measures need to be attractive for farmers. The Brazilian programme got off to a slow start because more attractive loans were available with less stringent environmental requirements. Later the environmental requirements were eased and interest rates were lowered.
- Monitoring performance and compliance can be challenging. This requires administrative capacity and good governance.
- Farmers need to be informed about programmes. Communications campaigns can help increase awareness and public engagement.
- New farming practices often require training. The Brazilian plan established support for training farmers.

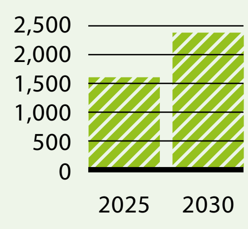
"Sustainable agricultural practices enhance ecosystem services."



Emission reductions potential

165

$MtCO_2e$/year



Median abatement costs

1,777

Million $

AGRICULTURE AND FORESTS

Cutting food waste

Denmark has cut its food waste by a quarter. Scaling up the solution could reduce emissions by as much as the combined yearly emissions of the Netherlands and Luxembourg while helping people on low incomes.

Climate impact

Since 2010 Denmark has cut its food waste by 25%, or by 150,000 tonnes per year. That has driven cuts in emissions of about 0.14 Mt per year.

Scaling up this solution to other high-income countries would yield an annual emissions reduction of 12 Mt in 2030. Applying the solution additionally to upper middle-income countries would increase the impact significantly, to 240 Mt per year in 2030 because the food waste in these countries is so much larger.

Success factors

Denmark has adopted a Waste Strategy with a vision of a future without waste. The strategy applies various interventions, including public-private partnerships.

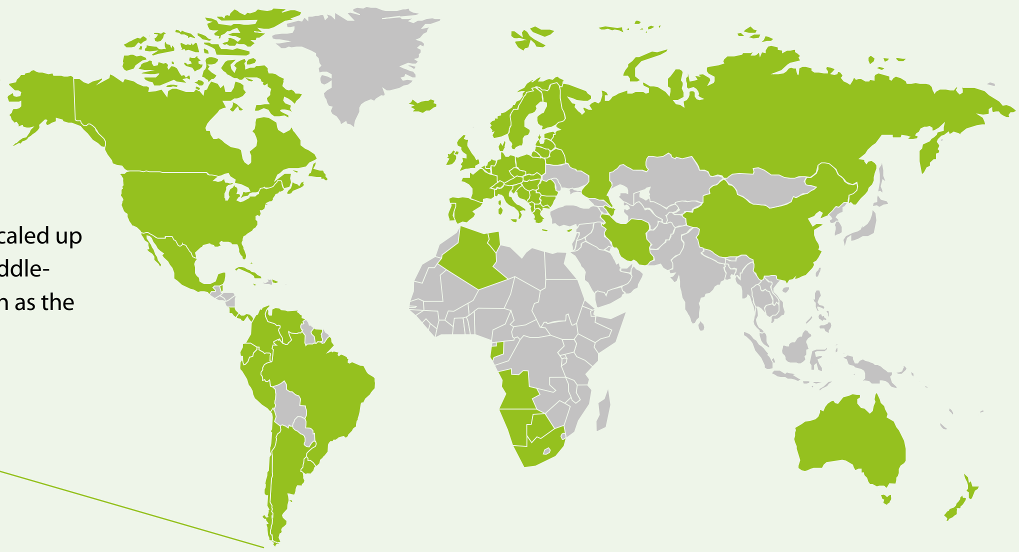
Public policies are supported by other initiatives. These include: public awareness-raising campaigns; food waste reduction strategies across all Danish supermarket chains; the adoption of “doggy bags” by more than 300 restaurants as members of the REFOOD label against food waste; and establishment of the world’s first international think tank against food waste.

Costs

Scaling up this solution saves money, yielding a negative abatement cost of –17 $/tCO$_2$e. The total avoided costs from applying the solution in high-income countries is estimated at $210 million per year in 2030. Additional scaling up to upper middle-income countries would drive annual savings of $4.2 billion in 2030.

Co-benefits

Cutting food waste can relieve economic pressure on low-income families, if they get food at lower prices or for



The solution can be scaled up to high and upper middle-income countries such as the USA, China and Brazil

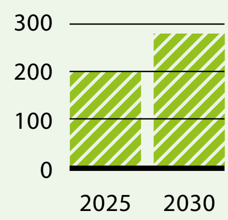
free. It avoids the direct economic costs and environmental impacts associated with food loss and waste treatment.

Additional systemic benefits can come from reduced food demand. This can for example include relieved pressure on forests and lower food prices.

"Cutting food waste can relieve economic pressure on low-income families."

Barriers and drivers

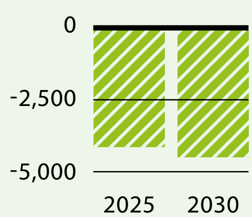
- Awareness raising and better education are the core drivers of Denmark's success. Campaigns and educational programmes can be accompanied by incentives for consumers and companies.
- Health and safety regulations can block supermarkets and restaurants from donating food to charities. Creating more supportive regulations would enable the food sector to participate more fully in cutting waste.
- Food sharing can be more difficult in hot and humid climates where food spoils more quickly. Food preservation technologies exist that could foster the solution in such climates.



Emission reductions potential

238

$MtCO_2e$/year



Median abatement costs

-4,160

Million $

AGRICULTURE AND FORESTS

Reducing deforestation

Brazil has been able to reduce deforestation by about four fifths. Scaling up the solution could yield carbon cuts close to the annual emissions of India while preserving biodiversity and defending the livelihoods of indigenous peoples.

Climate impact

Between 2004 and 2012 Brazil reduced annual deforestation from 27,700 km^2 to 4,600 km^2, or by 84%, resulting in annual emission savings of about 3,575 Mt. In 2013 deforestation rebounded slightly to 5,900 km^2.

The Brazilian programme can be scaled up to other middle- and low-income, tropical and subtropical countries with significant deforestation rates. Such scaling up could reduce annual emissions by as much as 1,400-3,500 Mt in 2025 and 1,600-4,000 Mt in 2030. While remarkably large, the results are broadly in line with previous studies.

Success factors

Since 2004, the Brazilian government has been implementing at both the federal and state level a plan to reduce deforestation. The Action Plan for Prevention and Control of Deforestation in the Amazon (PPCDAm) is aimed at reducing illegal cutting of forests.

PPCDAm is based on a three-pillar strategy: (1) territorial and land-use planning; (2) environmental control and monitoring; and (3) fostering sustainable production activities. Brazil applied various policies to curb deforestation, including law enforcement, interventions in soy and beef supply chains, restricted access to credit and expansion of protected areas.

To increase the resources devoted to deforestation reduction policies, the government created the Amazon Fund. Funding has been provided by international donors and by the Brazilian state oil company Petrobras.

Costs

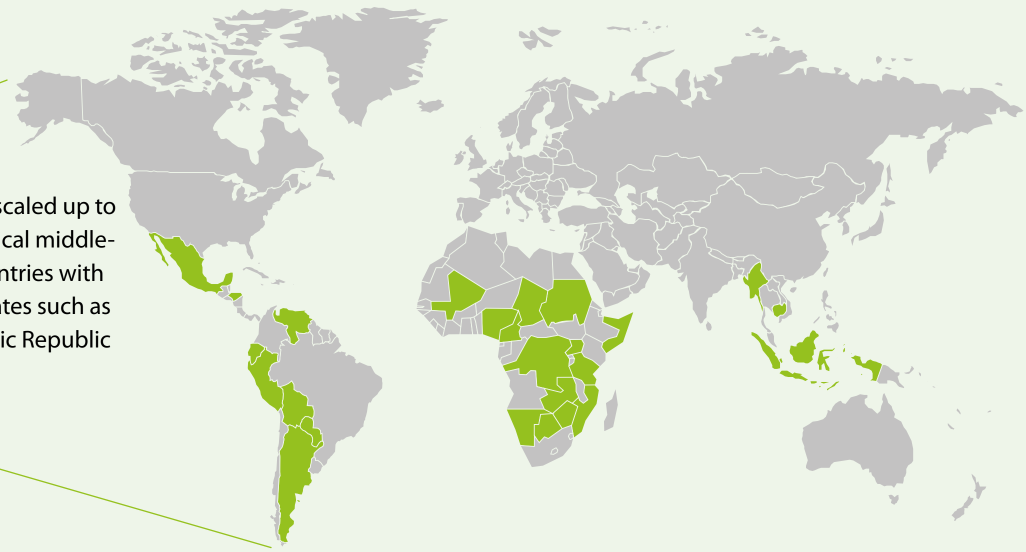
Cutting emissions through reduced deforestation has been estimated to cost around 13 \$/tCO_2e. Scaling up the solution to comparable countries would cost around \$18 to \$45 billion per year in 2025 and \$20 to \$53 billion in 2030.

Co-benefits

Reducing deforestation preserves species diversity and strengthens the provision of ecosystem services. Rainforests host one of the highest concentrations of biodiversity in the world. They also regulate the water cycle and prevent soil erosion.

Deforestation programmes reinforce collective land tenure rights of indigenous peoples and protect them

The solution can be scaled up to tropical and subtropical middle- and low-income countries with high deforestation rates such as Indonesia, Democratic Republic of Congo and Peru

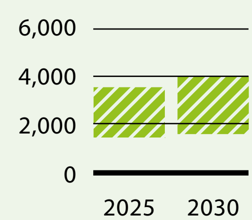


from illegal logging. Brazilian policies have also brought financial benefits: the state purchases sustainable forest products from family farms and has created a cash allowance for families living in extreme poverty in protected areas.

Barriers and drivers

- In many rainforest countries a challenge is to establish land registries. The Brazilian government made it easier to determine land ownership and, as a result, prevent illegal forest use. Both government officials and farmers needed training to use the newly introduced electronic tools.
- A key barrier in poor countries is a lack of dedicated resources. Many countries will therefore need financing from the international community.
- Curbing deforestation requires capacity for co-ordination and a clear mandate. In Brazil, the Executive Office of the President co-ordinating activities has been an important success factor.
- The involvement and empowerment of sub-national governments is required from the outset to reduce conflicts.
- Timely monitoring of trends in deforestation is also required. Brazil created a satellite system to improve surveillance.

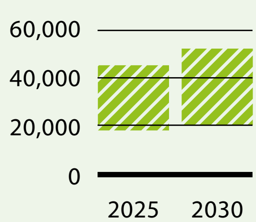
"Deforestation programmes reinforce collective land tenure rights of indigenous peoples."



Emission reductions potential

2,782

$MtCO_2e$/year



Median abatement costs

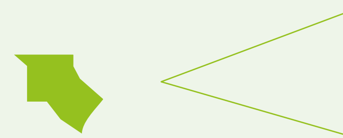
36,504

Million $

AGRICULTURE AND FORESTS

Afforestation and reforestation

Costa Rica has been able to grow its forested area by two and a half times using ecosystem service payments. Scaling up the solution could reduce emissions by nearly as much as Canada produces every year while preserving biodiversity and improving rural incomes.



Climate impact

The forest cover in Costa Rica has returned to over a half of the country's land area from just a fifth in the 1980s. As a result, the country's land use sector has moved from emitting 2.4 Mt emissions annually in 1990 to removing 3.5 Mt in 2005.

The Costa Rican programme can be scaled up to all countries with afforestation potential. This could result in annual emission reductions of 294 to 882 Mt in 2025 and 441 to 1,323 Mt in 2030 globally.

Success factors

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 twin objectives: to increase the provision of ecosystem services and to reduce poverty.

To this end, PES gives payments to landowners who provide environmental services. The PES programme has five categories: 1) forest protection; 2) commercial reforestation; 3) agroforestry; 4) sustainable forest management; and 5) regeneration of degraded areas.

The programme to date covers nearly one million hectares of forest. Farmers get annual payments for protection ($64-80 per hectare), reforestation ($980-1,410 per hectare) and agroforestry ($1.3-1.9 per tree). Differentiated payments take into account the environmental importance of the area and use of native species.

Costs

Afforestation has an estimated abatement cost of 13.5 $/tCO_2e$. Scaling up the solution would therefore cost $4 to $12 billion in 2025 and $6 to $18 billion in 2030 per year.

Co-benefits

The PES programme protects and promotes biodiversity and ecosystem services. By conserving and expanding forests the programme prevents land degradation, landslides and soil erosion. Forests also help in preserving water resources and protecting against floods and drought.

The programme provides support to landowners especially in vulnerable rural areas. Local people benefit by earning money in timber production or tourism. In Costa

The solution can be scaled up to countries with afforestation potential such as China, India and the USA

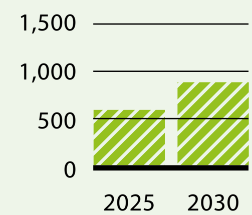
The solution has been scaled up using regional data. The map indicates all the regions with scale-up potential, but the solution may not be applicable to all countries within the region. For more information, please refer to the technical report.

Rica's Osa Peninsula, half of the environmental-service sellers were found to have moved above the poverty line. For them, PES represented on average 16% of annual household income.

"Half of the environmental-service sellers were found to have moved above the poverty line."

Barriers and drivers

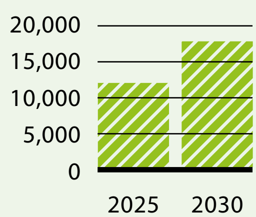
- Major difficulties include assigning tenure rights and overcoming high administrative costs. The key to success in Costa Rica was clear governance. Farmers must have a technical management plan approved by the authorities.
- Landowners need to be convinced that they get economic benefits and that the programme does not mean taking away their land rights. This requires information, transparency and training.
- Paying for ecosystem services on a continuous basis also requires significant funding. Creating markets for ecosystem services and channelling international funding can help in particular poorer countries in implementation.



Emission reductions potential

882

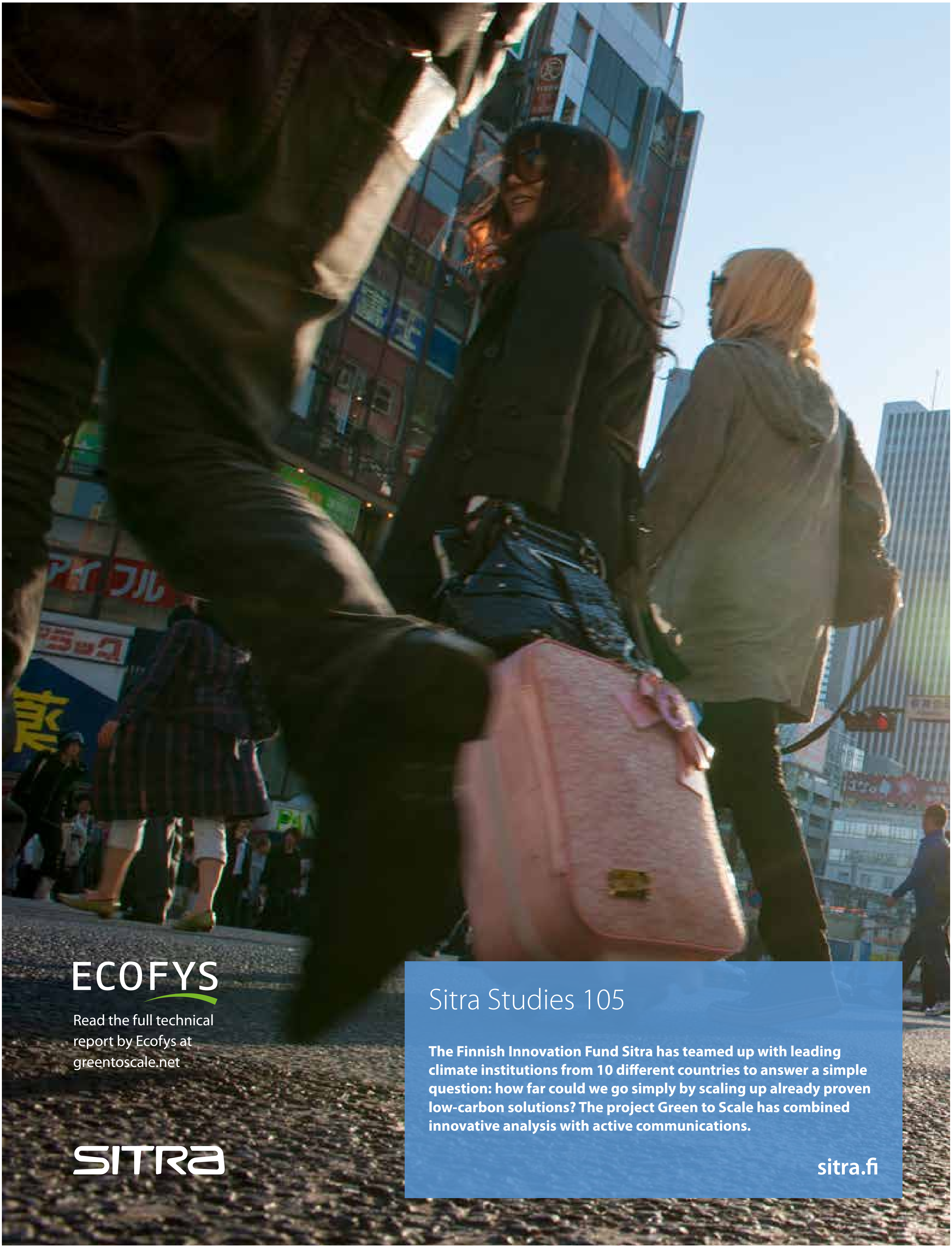
$MtCO_2e$/year



Median abatement costs

11,863

Million $



ECOFYS

Read the full technical report by Ecofys at greentoscale.net

SITRA

Sitra Studies 105

The Finnish Innovation Fund Sitra has teamed up with leading climate institutions from 10 different countries to answer a simple question: how far could we go simply by scaling up already proven low-carbon solutions? The project Green to Scale has combined innovative analysis with active communications.

sitra.fi