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Pathways to a Low-Carbon Economy

Version 2 of the Global Greenhouse Gas Abatement Cost Curve

McKinsey&Company

Preface

Leaders in many nations are discussing ambitious targets for reducing emissions of greenhouse gases (GHGs). Some regions have already set reduction targets. The EU, for example, has set a target that 2020 emission levels should be 20% lower than those of 1990, and has stated its intention of aiming for a 30% reduction if other countries with high emissions also commit to comparable emission cuts. At the same time, an intense debate is underway regarding the technical and economic feasibility of different target levels, which emission reduction opportunities should be pursued, and the costs of different options for meeting the targets.

To provide a quantitative basis for such discussions, McKinsey & Company, supported by ten leading companies and organizations across the world, has developed a global greenhouse gas abatement data base. The abatement data base is comprised of an in-depth evaluation of the potential, and the costs, of more than 200 greenhouse gas abatement opportunities across 10 sectors and 21 world regions, and in a 2030 time perspective. This study builds on the earlier version of the global GHG abatement data base, conducted by McKinsey together with the Swedish utility Vattenfall, and published in January 2007. The current report incorporates updated assessments of the development of low-carbon technologies, updated macro-economic assessments, a significantly more detailed understanding of abatement potential in different regions and industries, an assessment of investment and financing needs in addition to cost estimates, and the incorporation of implementation scenarios for a more dynamic understanding of how abatement reductions could unfold. The financial crisis at the time of writing has not been taken into account in our analysis, based on the assumption that it will not have a major effect on a 2030 time horizon. This version of the report also reflects a deeper understanding by McKinsey into greenhouse gas abatement economics, gained through conducting 10 national greenhouse gas abatement studies during the last two years.

This study intentionally avoids any assessment of policies and regulatory choices. Instead, its purpose is to provide an objective and uniform set of data that can serve as a starting point for corporate leaders, academics, and policy makers when discussing how best to achieve emission reductions.

We would like to gratefully thank our sponsor organizations for supporting us with their expertise as well as financially: the Carbon Trust, ClimateWorks, Enel, Entergy, Holcim, Honeywell, Shell, Vattenfall, Volvo, and the World Wide Fund for Nature. We would also like to thank the members of our Academic Review Panel for their invaluable advice on the methodology and content of this study. Individual members of the panel might not necessarily endorse all aspects of the report: Dr. Fatih Birol (IEA, France), Prof. Mikiko Kainuma (NIES, Japan), Dr. Jiang Kejun (ERI, China), Dr. Ritu Mathur (TERI, India), Dr. Bert Metz (IPCC, Netherlands), Prof. Stephen Pacala (Princeton University, USA), Prof. Jayant Sathaye (LBNL, USA), and Prof. Lord Nicholas Stern (LSE, UK). Furthermore we thank the International Energy Agency for giving us access to their greenhouse gas emissions baseline. Finally we would like to thank our many colleagues within McKinsey who have helped us with advice and support.

Tomas Nauclér
Director

Per-Anders Enkvist
Principal

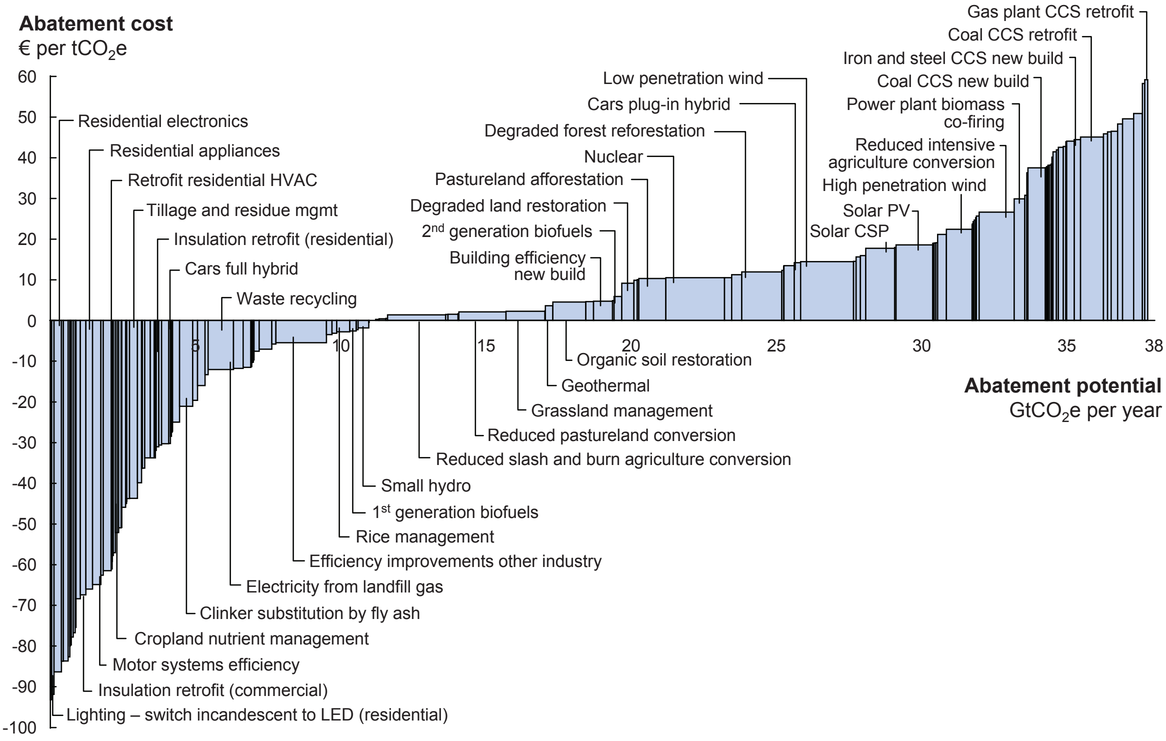
Summary of findings

Leaders in many nations are discussing ambitious targets for reducing emissions of greenhouse gases (GHGs) in order to mitigate the worst impact of climate change on the environment, human societies, and our economies. Many scientists and policy makers, including those in the European Union, believe that holding the rise in global mean temperatures below 2 degrees Celsius compared with pre-industrial times is an important aim, as they see this as a threshold when the implications of global warming become very serious.

McKinsey & Company's greenhouse gas abatement cost curve provides a quantitative basis for discussions about what actions would be most effective in delivering emissions reductions, and what they might cost. It provides a global mapping of opportunities to reduce the emissions of GHGs across regions and sectors (Exhibit 1).

Exhibit 1

Global GHG abatement cost curve beyond business-as-usual – 2030



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

Our analysis finds that there is *potential* by 2030 to reduce GHG emissions by 35 percent compared with 1990 levels, or by 70 percent compared with the levels we would see in 2030 if the world collectively made little attempt to curb current and future emissions. This would be sufficient to have a good chance of holding global warming below the 2 degrees Celsius threshold, according to the Intergovernmental Panel on Climate Change (IPCC).[1]

Capturing enough of this potential to stay below the 2 degrees Celsius threshold will be highly challenging, however. Our research finds not only that all regions and sectors would have to capture close to the full potential for abatement that is available to them; even deep emission cuts in some sectors will not be sufficient. Action also needs to be timely. A 10-year delay in taking abatement action would make it virtually impossible to keep global warming below 2 degrees Celsius.

What would such an effort cost? We find that, if the most economically rational abatement opportunities are pursued to their full potential – clearly an optimistic assumption – the total worldwide cost could be €200 to 350 billion annually by 2030. This is less than 1 percent of forecasted global GDP in 2030, although the actual effect on GDP of such abatement efforts is a more complex matter that depends, among other things, on the financing of such abatement efforts. Turning to financing, the total upfront investment in abatement measures needed would be €530 billion in 2020 per year or €810 billion per year in 2030 – incremental to business-as-usual (BAU) investments. This corresponds to 5 to 6 percent of BAU investments in fixed assets in each respective year. As such, the investment required seems to be within the long-term capacity of global financial markets (as long as the current credit squeeze doesn't have significant consequences in this time horizon). Indeed, many of the opportunities would see future energy savings largely compensate for upfront investments.

1 The primary source of the climate science in this report is *Climate Change 2007, Fourth IPCC Assessment Report*, Intergovernmental Panel on Climate Change. We are also grateful to scientists Michel den Elzen, Detlef van Vuuren, and Malte Meinshausen for their contributions.

Potential exists to contain global warming below 2 degrees Celsius

This study focuses on technical abatement opportunities costing less than €60 per tonne of CO_2 equivalent (tCO_2e), and these are the opportunities shown on our "GHG abatement cost curve" (see "How to read the Greenhouse Gas abatement cost curve").[2] We have defined technical abatement opportunities as not having a material effect on the lifestyle of consumers and our results are therefore consistent with continuing increases in global prosperity. We have made high-level estimates of the size of more expensive technical opportunities, as well as changes in the behavior of consumers, which could potentially offer further potential for abatement. However, because these prospects are subject to a high degree of uncertainty, we have made no attempt to quantify their cost.

How to read the Greenhouse Gas abatement cost curve

McKinsey's global greenhouse gas abatement "cost curve" summarizes the technical opportunities (i.e., without a material impact on the lifestyle of consumers) to reduce emissions of greenhouse gases at a cost of up to €60 per tCO_2e of avoided emissions. The cost curve shows the range of emission reduction actions that are possible with technologies that either are available today or offer a high degree of certainty about their potential in a 2030 time horizon.

The width of each bar represents the potential of that opportunity to reduce GHG emissions in a specific year compared to the business-as-usual development (BAU). The potential of each opportunity assumes aggressive global action starting in 2010 to capture that specific opportunity, and so does not represent a forecast of how each opportunity will develop. The height of each bar represents the average cost of avoiding 1 tonne of CO_2e by 2030 through that opportunity. The cost is a weighted average across sub-opportunities, regions, and years. All costs are in 2005 real Euros. The graph is ordered left to right from the lowest-cost abatement opportunities to the highest-cost. The uncertainty can be significant for individual opportunities for both volume and cost estimates, in particular for the Forestry and Agriculture sectors, and for emerging technologies.

The priority in our research has been to look at the global emission reduction opportunities with one consistent methodology, rather than to deep dive in any individual emission reduction opportunity.

Therefore, the curve should be used for overall comparisons of the size and cost of different opportunities, the relative importance of different sectors and regions, and the overall size of the emission reduction opportunity, rather than for predictions of the development of individual technologies. It can also be used as a simulation tool, testing for different implementation scenarios, energy prices, interest rates and technological developments.

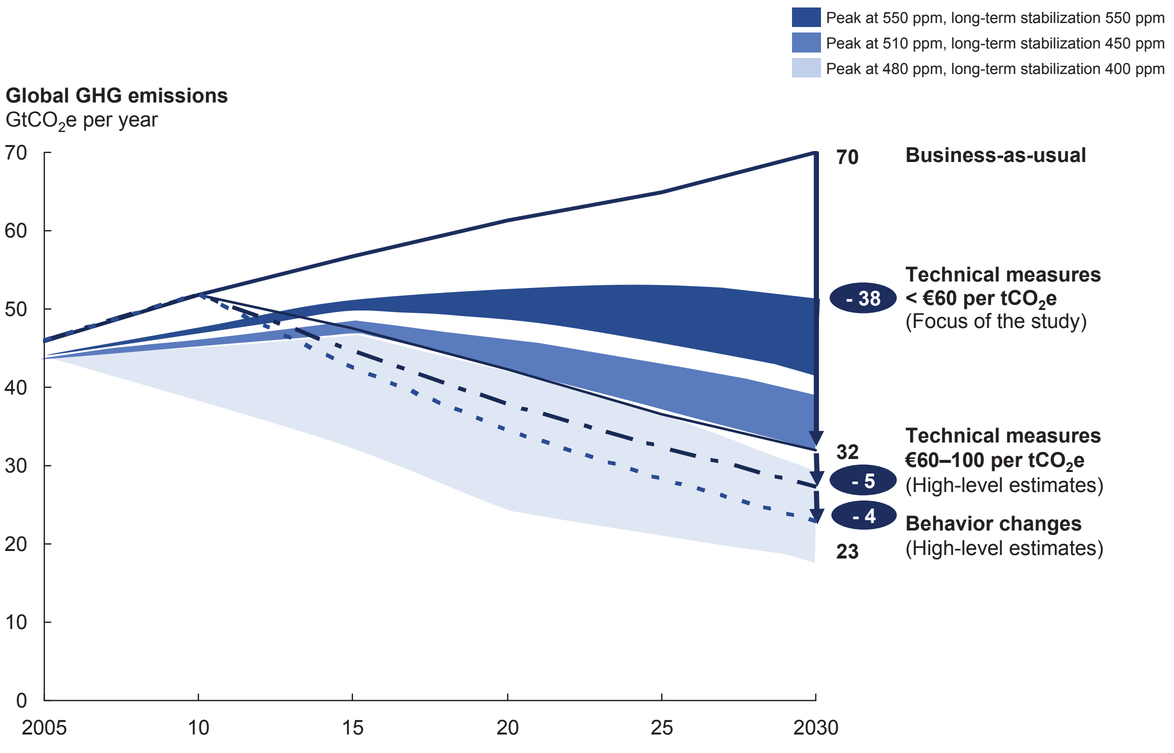
The reader should also bear in mind that the cost of abatement is calculated from a societal perspective (i.e., excluding taxes, subsidies, and with a capital cost similar to government bond rates). This methodology is useful because it allows for comparisons of opportunities and costs across countries, sectors and individual opportunities. However, it also means that the costs calculated are different from the costs a company or consumer would see, as these decision makers would include taxes, subsidies, and different interest rates in their calculations. Therefore, the curve cannot be used for determining switching economics between investments, nor for forecasting CO_2 prices. The cost of each opportunity also excludes transaction and program costs to implement the opportunity at a large scale, as these are highly dependent on how policy makers choose to implement each opportunity.

2 Using IPCC terminology, we studied the economic potential below €60 per tCO_2e of technical emission reduction opportunities. We chose an economic cut-off to enable us to compare the size of opportunities within different sectors and regions in an objective way. We chose €60 per tCO_2e as higher-cost measures tend to be early-stage technologies with development paths that are difficult to project.

The cost curve identifies a potential abatement of 38 $GtCO_2e$ (Exhibit 2) in 2030, relative to BAU emissions of 70 $GtCO_2e$. Our high-level estimates of additional potential from more expensive technical measures and changes in behavior, adds up to an additional 9 $GtCO_2e$. Theoretically, capturing the full abatement potential across sectors and regions starting in 2010, 2030 emissions would be between 35 and 40 percent lower than they were in 1990, the reference year for the Kyoto Protocol and many current discussions. Relative to the 2030 business-as-usual (BAU) emissions[3], emissions would decrease by 65 to 70 percent. These emission levels would be broadly consistent with an emissions pathway that would see the atmospheric concentration of GHGs peaking at 480 parts per million (ppm) and then start decreasing. According to the IPCC's analysis, such a pathway would result in a likely average increase of the global mean temperature of just below 2 degrees Celsius.

Exhibit 2

Emissions relative to different GHG concentration pathways



Note: As a reference, 1990 total emissions were 36 Gt CO_2e

Source: Global GHG Abatement Cost Curve v2.0; Houghton; IEA; IPCC; den Elzen; Meinshausen; OECD; US EPA; van Vuuren

Capturing the full abatement potential is a major challenge

It is one thing to have the *potential* to make deep cuts in GHG emissions; it is another for policy makers to agree on and implement effective emission reduction policies, and for companies, consumers and the public sector to take action to make this reduction a reality. Capturing all the opportunities would entail change on a huge scale. In Transport, for instance, the assumption in our study is that 42 million hybrid vehicles (including plug-ins) could be sold by 2030 – that's a full 40 percent of all new car sales.

3 To build a comprehensive BAU projection, we combined the projections of the International Energy Agency's (IEA) World Energy Outlook 2007 for CO_2 emissions from energy usage, Houghton's projections for CO_2 emissions from land use and land-use change, and the US Environmental Protection Agency's (EPA) projections for non-CO_2 GHGs. See chapter 2 for details.

In Forestry, the assumption is that we could until 2030 avoid the deforestation of 170 million hectares, equivalent to twice the land area of Venezuela, and plant new forests on 330 million hectares of currently marginal land – the equivalent of foresting much of India. In Power, the share of low-carbon generation technologies such as renewables, nuclear and carbon capture and storage have could rise to about 70 percent of global electricity production from 30 percent in 2005. After careful analysis, we believe such change would be feasible if there was concerted global action to go after each opportunity – this is the potential we aim to portray in our curve – but implementing all of the opportunities on our curve to their full extent clearly represents a massive change.

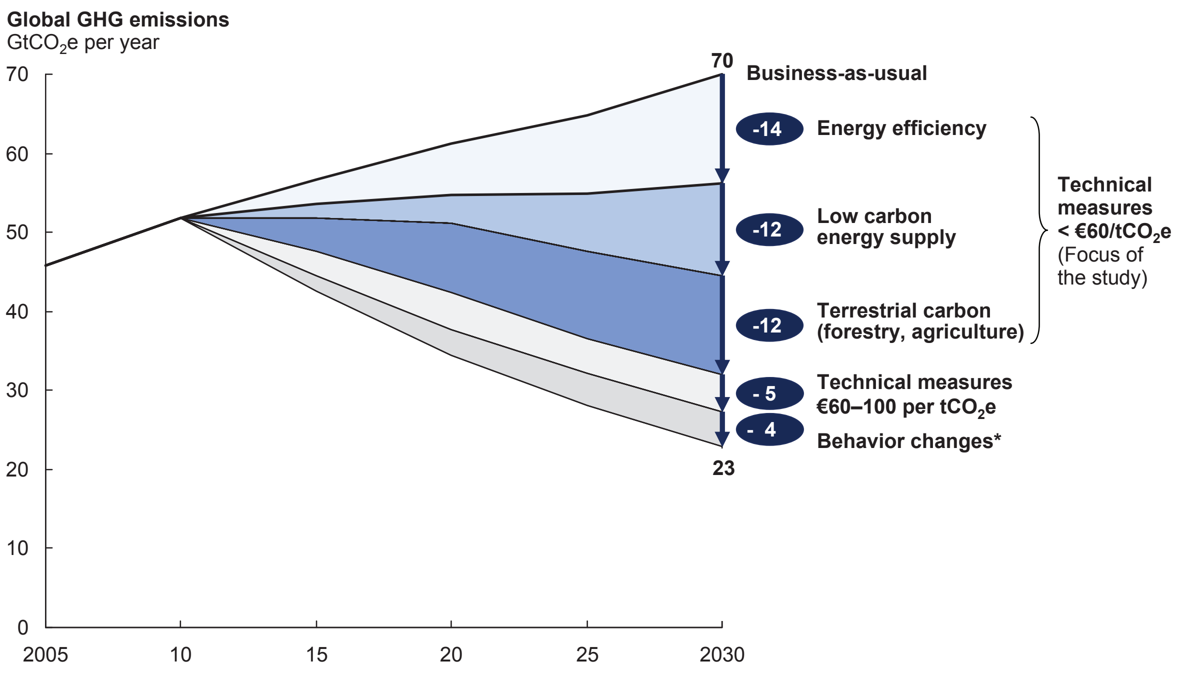
Another way to illustrate the challenge is to look at carbon productivity – the amount of GDP produced per unit of CO_2 emitted. In the period from 2005 to 2030, emissions would need to decrease by 35 to 50 percent to attain a pathway likely to achieve the 2 degrees Celsius threshold. As the world economy is set to more than double during the same time period, this implies almost quadrupling the global carbon productivity. This corresponds to increasing the annual global carbon productivity gains from 1.2 percent in the BAU, to 5 to 7 percent.

Four major categories of abatement opportunities

The abatement opportunities in the period between now and 2030 fall into four categories: energy efficiency, low-carbon energy supply, terrestrial carbon (forestry and agriculture), and behavioral change. The first three, technical abatement opportunities which are the focus of our study, add up to a total abatement opportunity of 38 $GtCO_2e$ per year in 2030 relative to annual BAU emissions of 70 $GtCO_2e$ (Exhibit 3)[4]:

Exhibit 3

Major categories of abatement opportunities



* The estimate of behavioral change abatement potential was made after implementation of all technical levers; the potential would be higher if modeled before implementation of the technical levers.
Source: Global GHG Abatement Cost Curve v2.0; Houghton; IEA; US EPA

4 Key abatement data for 2020 can be found in the appendix.

- **Energy efficiency (opportunity of 14 GtCO_2e per year in 2030).** There are a large number of opportunities to improve the energy efficiency of vehicles, buildings, and industrial equipment, thereby reducing energy consumption. More fuel-efficient car engines, better insulation of buildings, and efficiency controls on manufacturing equipment are just a few of the possibilities. If all energy efficiency opportunities identified in our research were captured, annual growth in global electricity demand between 2005 and 2030 would be reduced from 2.7 percent per year in the BAU case to about 1.5 percent.
- **Low-carbon energy supply (opportunity of 12 GtCO_2e per year in 2030).** There are many opportunities to shift energy supply from fossil fuels to low-carbon alternatives. Key examples include electricity production from wind, nuclear, or hydro power, as well as equipping fossil fuel plants with carbon capture and storage (CCS), and replacing conventional transportation fuel with biofuels. If these low-carbon alternatives were to be fully implemented, we estimate that they have the potential to provide about 70 percent of global electricity supply by 2030 compared with just 30 percent in 2005; and that biofuels could provide as much as 25 percent of global transportation fuel by 2030. This would constitute a major shift in global energy supply. Several of these low-carbon energy technologies are too expensive today to deploy on a large scale without financial incentives, emphasizing the need to provide sufficient support to make them travel down the learning curve allowing them to contribute to their full potential.[5]
- **Terrestrial carbon – forestry and agriculture (opportunity of 12 GtCO_2e per year in 2030).** Forests and soils act as natural sinks for carbon. Halting ongoing tropical deforestation, reforesting marginal areas of land, and sequestering more CO_2 in soils through changing agricultural practices would increase carbon sequestration. This would lead to negative net emissions of CO_2e into the atmosphere from these sectors in the period we have studied (implying that more carbon is stored than is released from these sinks), a major abatement opportunity versus the BAU in which deforestation continues. However, capturing these opportunities would be highly challenging. More than 90 percent of them are located in the developing world, they are tightly linked to the overall social and economic situation in the concerned regions, and addressing the opportunities at this scale has not before been attempted. Our estimate of the feasibility and cost of this opportunity is therefore subject to significant uncertainty. We also note that terrestrial carbon opportunities are temporary in nature because the sinks would saturate between 2030 and 2050, so that, at the end of this period, there would be few additional areas of marginal land left available for re-forestation.

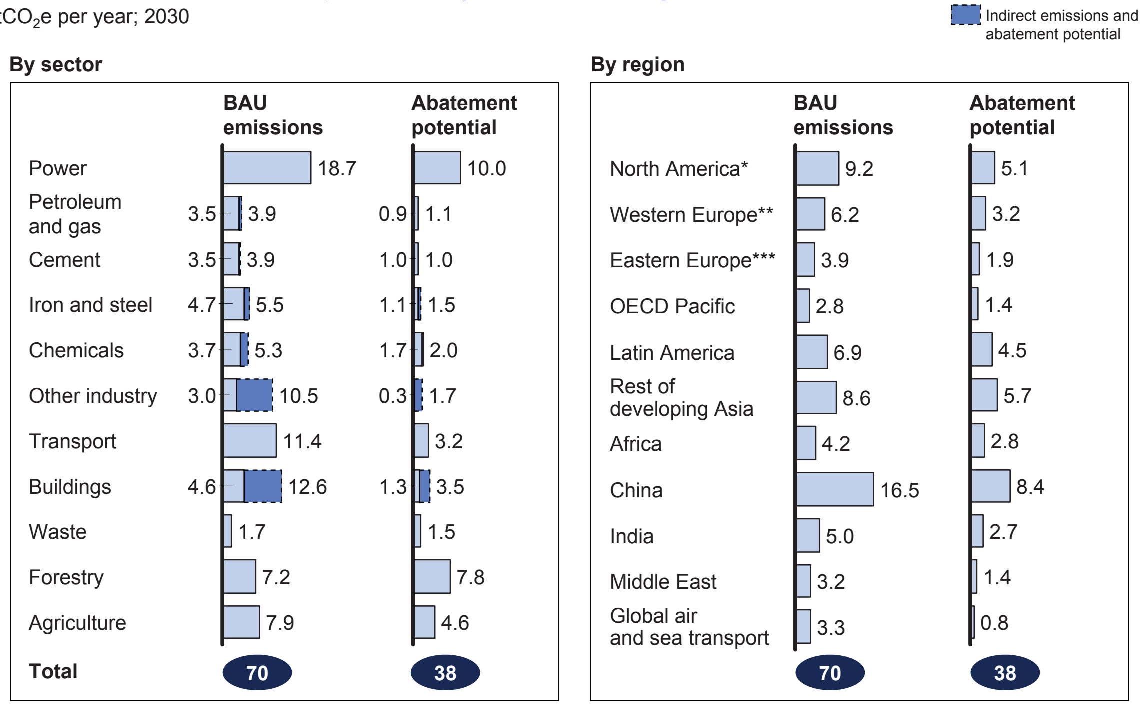
Abatement opportunities in these three categories are spread across many sectors of the economy. Approximately 29 percent of the total is in energy supply sectors (electricity, petroleum and gas), 16 percent in the industrial sector, 22 percent in sectors with significant consumer influence (transportation, buildings, waste), and the remaining 33 percent in land-use related sectors (forestry and agriculture). Some 30 percent of the total opportunity is located in the developed world and 70 percent in the developing world (Exhibit 4). A key driver for the high share of abatement potential in developing regions is the fact that a very large share of the opportunity in forestry and agriculture resides there. It should be noted that the relative share of abatement potential in different regions does not imply anything about who should pay for emissions reduction.

5 We have only included technologies in our curve that we see as technologically proven, that could credibly have costs lower than €60 per tCO_2e abated in 2030, and that we can envisage having a major abatement impact by 2030. There are also many technologies that did not pass our criteria to be included in the curve since they are too early in their development stage, but that could also have a major impact in the period after 2030.

Exhibit 4

Emissions and abatement potential by sector and region

$GtCO_2e$ per year; 2030



* United States and Canada
** Includes EU27, Andorra, Iceland, Lichtenstein, Monaco, Norway, San Marino, Switzerland
*** Russia and non-OECD Eastern Europe
Note: To obtain the total BAU emissions, only direct emissions are to be summed up. To obtain total abatement potential, indirect emission savings need to be included in the sum.
Source: Global GHG Abatement Cost Curve v2.0; Houghton; IEA; UNFCCC; US EPA

We estimate that another 3.0–6.0 $GtCO_2e$ per year of technical abatement opportunities in these three categories are available at a cost of between €60 and €100 per tCO_2e. This range of higher cost abatement has not been the focus of our research, and the level of uncertainty in our estimates is much higher than for the lower cost opportunities. Examples of these more expensive abatement opportunities include retiring relatively young fossil fuel based power plants and replacing them with low-carbon options and in heavy industry, additional energy efficiency measures are possible if the cost threshold is increased.

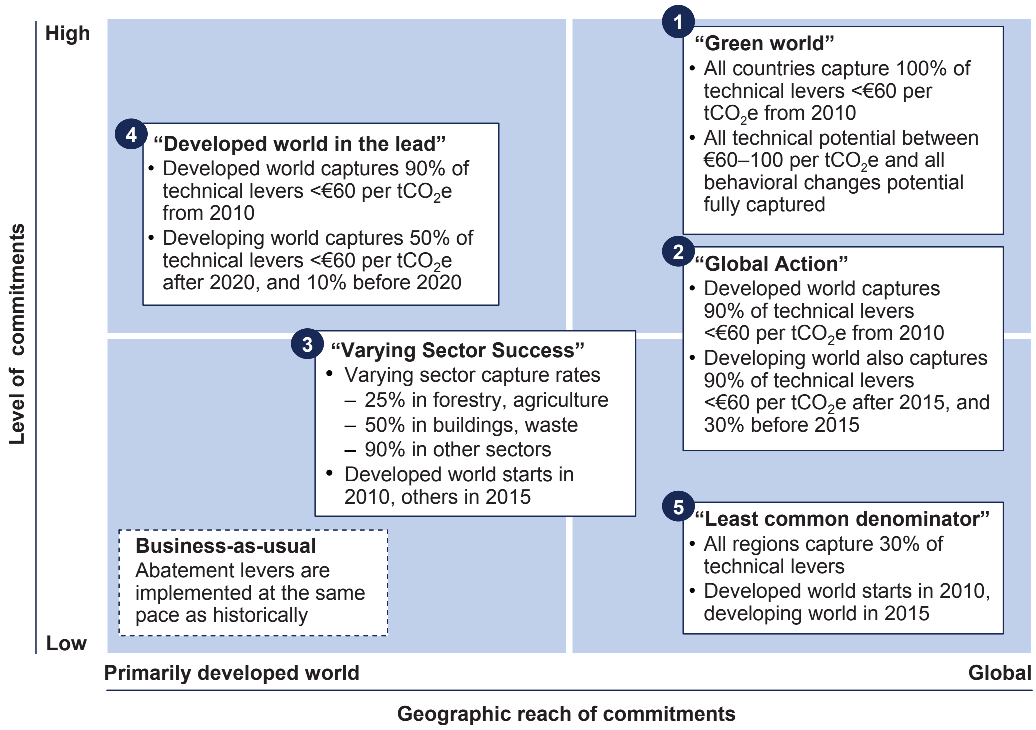
The fourth category of abatement opportunity is behavioral change. In an optimistic case – and there is a high degree of uncertainty in these estimates – this could yield between another 3.5–5.0 $GtCO_2e$ per year of abatement in 2030. Key opportunities include reducing business and private travel, shifting road transport to rail, accepting higher domestic temperature variations (reducing heating/cooling), reducing appliance use, and reducing meat consumption. Changing behavior is difficult and the abatement realized would depend heavily on whether, and to what extent, policy makers establish effective incentives.

All regions and sectors need to maximize their capture of the emissions potential

The fragmentation of the opportunity across sectors and regions demonstrates the importance of global cross-sector action to cut emissions, regardless of who pays for such efforts. The 38 $GtCO_2e$ of abatement on our 2030 cost curve is a maximum potential estimate that assumes the effective implementation of all abatement opportunities, starting promptly in 2010. In reality, there will likely be delays in policy action, and varying ambition levels and success rates of businesses and consumers when going after the opportunities. Our analysis of five different implementation scenarios finds that, if there are significant shortfalls in any major sector or region, measures in other sectors or regions – even at a higher cost – would only partly be able to compensate (see Chapter 6 of this report for detail on the five scenarios and Exhibit 5 for a summary).

Exhibit 5

Integrated implementation scenarios 2010–2030



Source: Global GHG Abatement Cost Curve v2.0

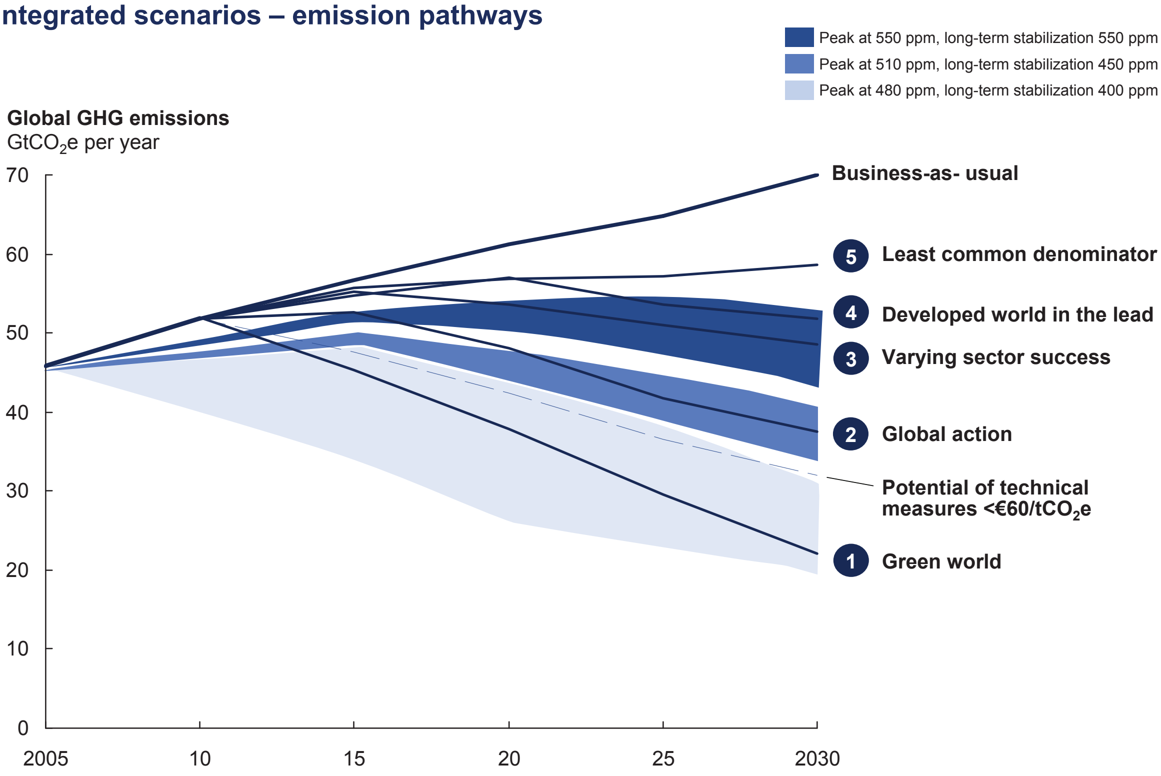
We find that only our "Green World" and "Global Action" scenarios, both of which assume an aggressive global commitment to abate GHGs across regions and sectors, would achieve pathways with a significant chance of containing global warming below 2 degrees Celsius (Exhibit 6). The three other scenarios would put the world on track to achieve a 550 ppm pathway or higher that would offer only a 15–30 percent likelihood of limiting global warming to below 2 degrees Celsius, according to the external estimates we have used.

Delaying action for 10 years would mean missing 2 degrees Celsius aim

If policy makers aim to stabilize global warming below 2 degrees Celsius, time is of the essence. Our model shows that if global abatement action were to start in 2020 instead of 2010, it would be challenging to achieve even a 550 ppm stabilization path, even if more expensive technical measures and behavioral changes were also implemented (Exhibit 7).

Exhibit 6

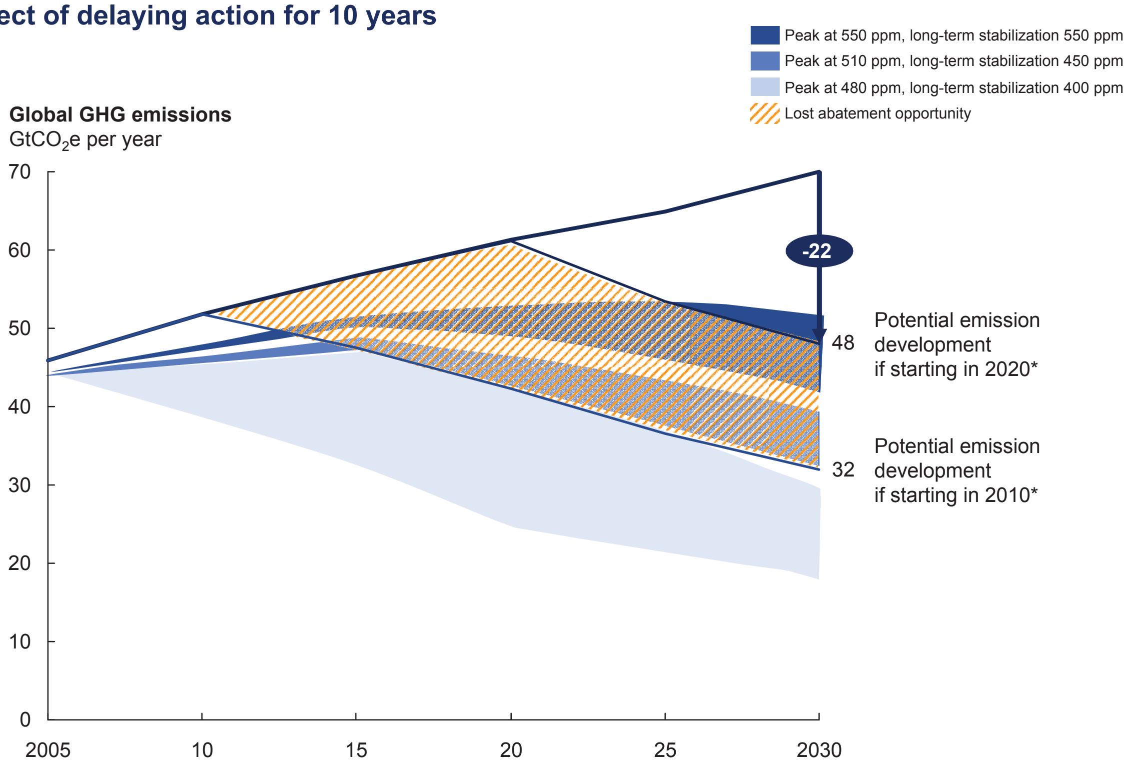
Integrated scenarios – emission pathways



Source: Global GHG Abatement Cost Curve v2.0; Houghton; IEA; IPCC; den Elzen; Meinshausen; OECD; US EPA; van Vuuren

Exhibit 7

Effect of delaying action for 10 years



* Technical levers <€60/tCO_2e

Source: Global GHG Abatement Cost Curve v2.0; Houghton; IEA; OECD; EPA; den Elzen; van Vuuren, Meinshausen

First, and most obvious, delay would mean that emissions would continue to grow according to the BAU development instead of declining. Second, building high-carbon infrastructure in sectors such as Buildings, Power, Industry, and Transport would lock in higher energy use for decades to come. In our model, the effective lifetime of carbon-intense infrastructure across sectors is, on average, 14 years. The result is that by delaying action for one year, an estimated 1.8 $GtCO_2e$ of abatement would be lost in that specific year[6]. Consequently, the world would be committed to cumulative emissions over the next 14 years of 25 $GtCO_2e$. In terms of atmospheric concentration, the continued BAU emissions growth coupled with the lock-in effect would lead to a 5 ppm higher expected peak CO_2e concentration.[7]

Future energy savings could largely pay for upfront investments

If the world were to successfully implement every measure on the cost curve, in strict order from low-cost to higher-cost in sequence – in other words be more economically rational than reality would normally suggest – the theoretical average cost of the abatement opportunities would be €4 per tCO_2e in 2030, and the total cost for realizing the whole curve would be some €150 billion. Transaction and program costs, that are not part of our curve[8], are often estimated at an average of between €1 and 5 per tCO_2e abated, making a total of approximately €40 to 200 billion for the 38 $GtCO_2e$ of abatement opportunities on our cost curve. This would make the total annual global cost approximately €200 to 350 billion by 2030. This estimate should be treated with significant caution for two reasons: One, the assumption that opportunities would effectively be addressed from left to right in our curve is a highly optimistic one. Two, there would in reality be significant dynamic effects in the economy from a program of this magnitude – effects that could work to either increase or decrease the cost depending on how they were implemented and that have not been taken into account in our analysis.

A large share of the abatement opportunities involves investing additional resources upfront to make existing or new infrastructure more carbon efficient – including all energy efficiency measures and much of the renewable energy measures – and then recouping part or all of that investment through lower energy or fuel spending in the future. There is about 11 $GtCO_2e$ per year of abatement potential in 2030 in which energy savings actually outweigh the upfront investment. In short, these measures would have a net economic benefit over their lifetime, even without any additional CO_2 incentive. If there are such substantial opportunities with net economic benefits over time, why haven’t consumers and entrepreneurs already captured this potential? The reason is that a range of market imperfections, such as agency issues, act as a barrier and disincentive to making the necessary investments. As an example, builders have little incentive to add insulation beyond technical norms to new homes when it is the home-owner, not the builder, who will enjoy lower energy bills during the next decades.

6 Calculated as the difference in emissions caused by infrastructure built in the year 2010 in the BAU versus if all low-carbon options according to our curve were pursued.

7 The effect of a 10-year delay is that 2030 emissions end up in middle of the stabilization path that peaks at 550 ppm, instead of at the high end of the path that peaks at 480 ppm. Rounding the difference to 50 ppm (to account for the fact that emissions end up in the middle of the 550 ppm scenario and the high end of the 480 ppm scenario) makes the effect 5 ppm per year.

8 The reason for this is that such costs reflect political choices about which policies and programs to implement and vary from case to case. It is therefore not possible to incorporate these costs in the abatement curve in an objective way and maintain the ability to compare abatement potentials across regions and sectors.

Globally, financing looks manageable, but individual sectors will face big challenges

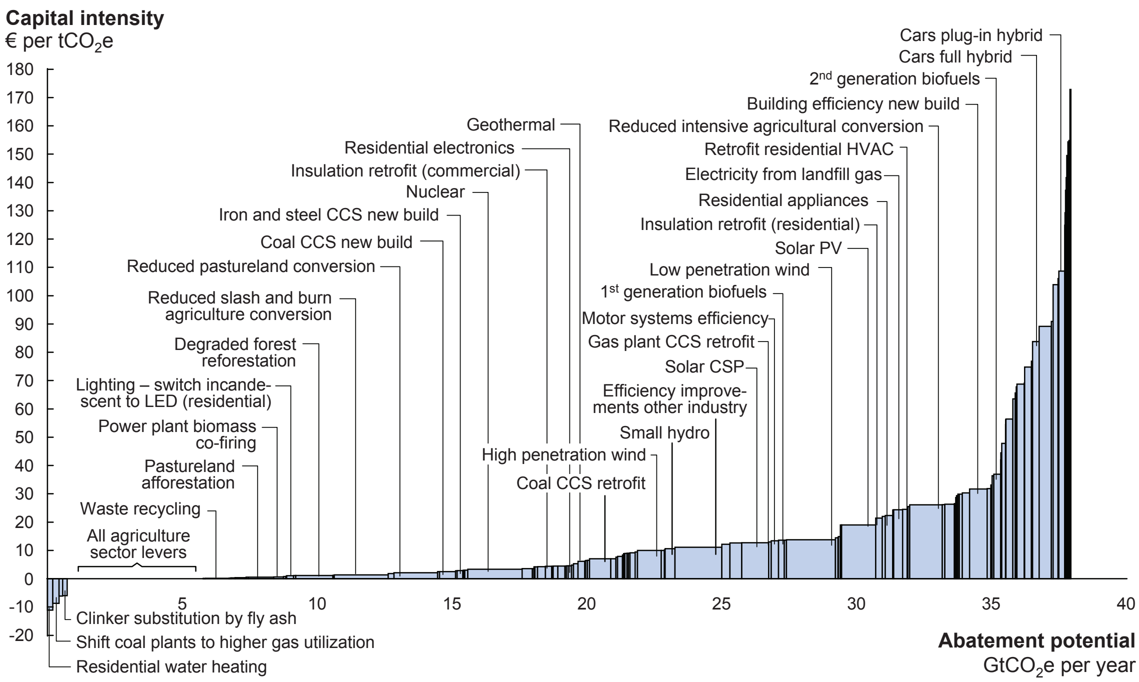
The total investment to achieve all the measures on our cost curve amounts to €530 billion per year in 2020 and €810 billion per year in 2030, on top of BAU investments that would happen anyway. This corresponds to 5 to 6 percent of the BAU investments in fixed assets in each respective year. While financing is a major test in the current credit squeeze, it seems unlikely to us that, at the global level, financing these additional investments would be a bottleneck to action on reducing emissions in a 2030 time horizon.

A more detailed view at the investments required highlights possible financing challenges at a sector and regional level. Indeed, over 60 percent of the investments required in addition to the BAU turn out to be needed in the Transport and Buildings sectors, and close to 60 percent of the total investments turn out to be needed in developing countries. Although the net additional cost of investing in fuel-efficient vehicles and energy-efficient houses is typically low, as much of the investment is regained through energy savings, finding effective ways to incentivize and finance the (sometimes considerable) additional upfront expenditure may not be easy.

When analyzing the capital intensity[9] of individual abatement opportunities, it becomes clear that the cheapest abatement opportunities are not always those with the lowest capital spend (Exhibit 8).

Exhibit 8

Capital intensity by abatement measure



Source: Global GHG Abatement Cost Curve v2.0

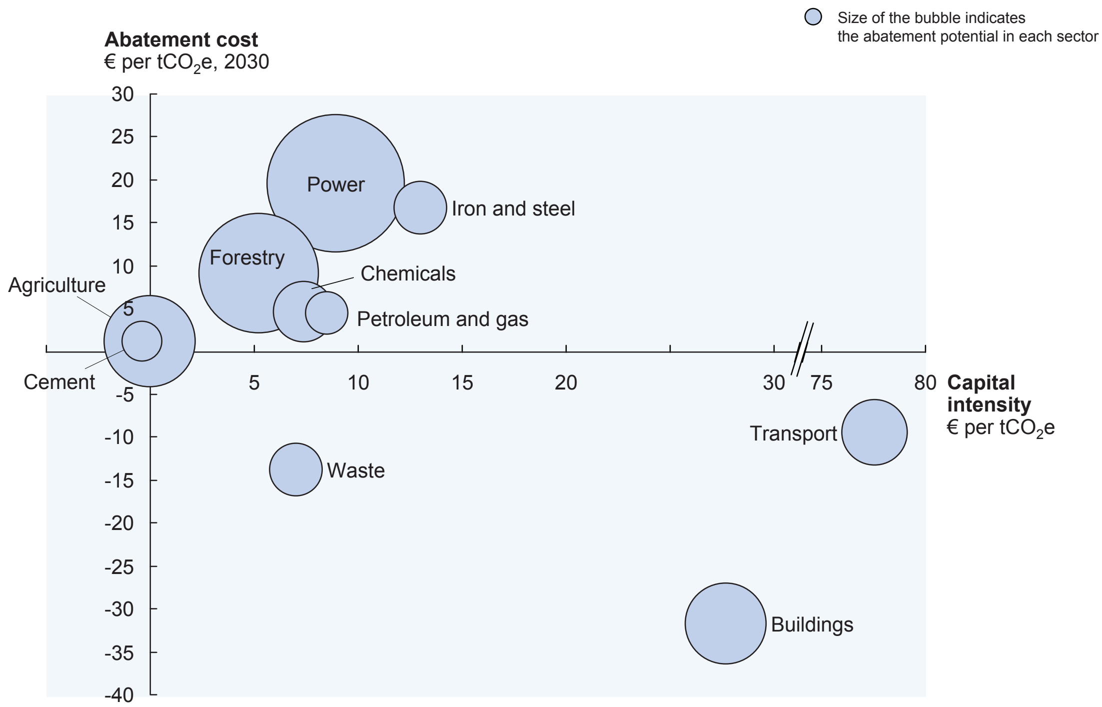
9 We define the capital intensity of an abatement measure as the additional upfront investment relative to the BAU technology, divided by the total amount of avoided emissions over the lifetime of the asset. For a more fuel efficient car, for instance, the capital intensity would be calculated as the additional upfront investment compared to the BAU technology, divided by the amount of CO_2 saved through lower fuel consumption during the lifetime of the car. The main difference with abatement cost is that the capital intensity calculation does not take financial savings through lower energy consumption into account.

For instance, many energy-efficiency opportunities that appear on the left-hand side of the cost curve end up much further to the right in the capital intensity curve. This demonstrates the different priorities that could emerge in a capital-constrained environment. Investors might choose to fund the opportunities with the lowest capital intensity rather than the ones with lowest cost over time. This would make the cost of abatement substantially higher over time.

Comparing the abatement cost and investments shows that the implementation challenges will be very different across sectors (Exhibit 9). In Transport and Buildings, upfront financing might be challenging but the cost is actually low once investments have been made. In several of the industrial sectors, average abatement costs are relatively high whereas upfront investments are lower. Making the abatement happen in these sectors is likely more a question about compensating companies for the high costs, than it is about financing the investments. Finally, in Forestry and Agriculture, both costs and investments are relatively low. Here, the implementation challenges are practical rather than economical, namely, designing effective policy and an effective way of measuring and monitoring the abatement.

Exhibit 9

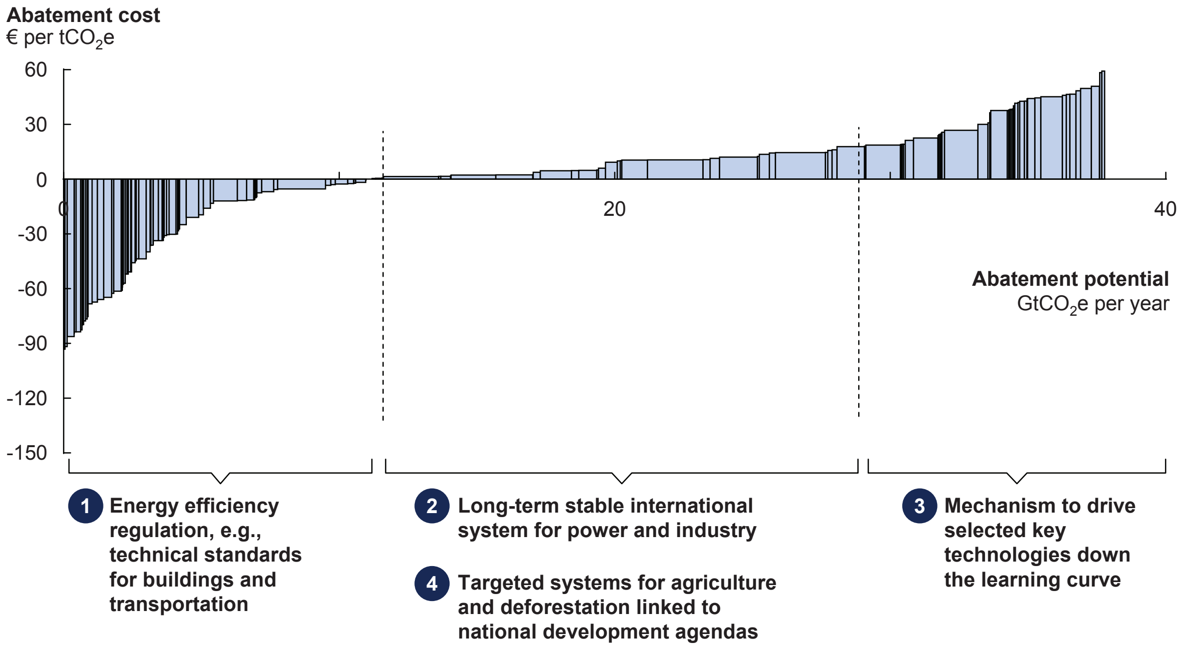
Capital intensity and abatement cost



Source: Global GHG Abatement Cost Curve v2.0

Exhibit 10

Key areas of regulation



Source: Global GHG Abatement Cost Curve v2.0

Four areas of regulation will be key to achieving low-cost emission reduction

Achieving the deep emission cuts deemed necessary by the IPCC to stabilize global temperatures presents a huge policy challenge. Although we do not take a view on what policies decision makers should implement, we highlight four policy areas that we believe will be important to reduce emissions at the lowest possible cost (Exhibit 10):

1. Implementing regulation to overcome the market imperfections that prevent the energy efficiency opportunities with net economic benefits from materializing, e.g., through technical norms and standards;
2. Establishing stable long-term incentives to encourage power producers and industrial companies to develop and deploy greenhouse gas efficient technologies, e.g., in the form of a CO_2 price or a CO_2 tax;
3. Providing sufficient incentives and support to improve the cost efficiency of promising emerging technologies; and
4. Ensuring that the potential in forestry and agriculture is effectively addressed, primarily in developing economies, linking any system to capture abatement closely to their overall development agenda.

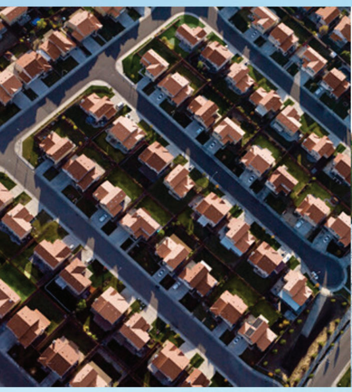
* * *

This study does not take a view on current climate science, but rather focuses on providing an objective, globally consistent data set on opportunities to reduce GHG emissions and their likely cost and investments. We hope that this analysis will serve as a useful starting point for discussions among companies, policy makers, and academics on how best to manage the transition to a low-carbon economy.

McKinsey & Company is a global management consulting firm which helps the world's leading organisations address their strategic challenges. With consultants deployed in 50 countries across the globe, McKinsey advises on strategic, operational, organizational and technological issues.

McKinsey's "Climate Change Special Initiative" supports clients on climate change-related topics, and develops new thinking on the economics and business implications of climate change.

Download the full report at www.mckinsey.com/globalGHGcostcurve



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