Executive summary

Consensus is growing among scientists, policy makers and business leaders that concerted action will be needed to address rising greenhouse gas (GHG) emissions. The discussion is now turning to the practical challenges of where and how emissions reductions can best be achieved, at what costs, and over what periods of time.

Starting in early 2007, a research team from McKinsey & Company worked with leading companies, industry experts, academics, and environmental NGOs to develop a detailed, consistent fact base estimating costs and potentials of different options to reduce or prevent GHG emissions within the United States over a 25-year period. The team analyzed more than 250 options, encompassing efficiency gains, shifts to lower-carbon energy sources, and expanded carbon sinks.

THE CENTRAL CONCLUSION OF THIS PROJECT

The United States could reduce greenhouse gas emissions in 2030 by 3.0 to 4.5 gigatons of CO_2e *using tested approaches and high-potential emerging technologies.*[1] *These reductions would involve pursuing a wide array of abatement options available at marginal costs less than $50 per ton, with the average net cost to the economy being far lower if the nation can capture sizable gains from energy efficiency. Achieving these reductions at the lowest cost to the economy, however, will require strong, coordinated, economy-wide action that begins in the near future.*

Although our research suggests the net cost of achieving these levels of GHG abatement could be quite low on a societal basis, issues of timing and allocation would likely lead various stakeholders to perceive the costs very differently -- particularly during the transition to a lower carbon economy. Costs will tend to concentrate more in some sectors than others, and involve "real" up-front outlays that would be offset by "avoided" future outlays. Given the timing of investments relative to savings, the economy might well encounter periods of significant visible costs, with the costs and benefits shared unequally among stakeholders. Nonetheless, a

1 CO_2e, or "carbon dioxide equivalent," is a standardized measure of GHG emissions designed to account for the differing global warming potentials of GHGs. Emissions are measured in metric tons CO_2e per year, i.e., millions of tons (megatons) or billions of tons (gigatons). All emissions values in this report are per-year CO_2e amounts, unless specifically noted otherwise. To be consistent with U.S. government forecasts, the team used the 100-year global warming potentials listed in the Intergovernmental Panel on Climate Change's Second Assessment Report (1995).

concerted, nationwide effort to reduce GHG emissions would almost certainly stimulate economic forces and create business opportunities that we cannot foresee today and that may accelerate the rate of abatement the nation can achieve, thereby reducing the overall cost.

We hope that the fact base provided in this report will help policymakers, business leaders, academics and other interested parties make better informed decisions and develop economically sensible strategies to address the nation's rising GHG emissions.

RISING EMISSIONS POSE AN INCREASING CHALLENGE

Annual GHG emissions in the U.S. are projected to rise from 7.2 gigatons CO_2e in 2005 to 9.7 gigatons in 2030 – an increase of 35 percent – according to an analysis of U.S. government reference forecasts.[2] The main drivers of projected emissions growth are:

- Continued expansion of the U.S. economy
- Rapid growth in the buildings-and-appliances and transportation sectors, driven by a population increase of 70 million and rising personal consumption
- Increased use of carbon-based power in the electric-power generation portfolio, driven by projected construction of new coal-fired power plants without carbon capture and storage (CCS) technology.

Growth in emissions would be accompanied by a gradual decrease in the absorption of carbon by U.S. forests and agricultural lands. After rising for 50 years, carbon absorption is forecast to decline from 1.1 gigatons in 2005 to 1.0 gigatons in 2030.

On this path – with emissions rising and carbon absorption starting to decline – U.S. emissions in 2030 would exceed GHG reduction targets contained in economy-wide climate-change bills currently before Congress by 3.5 to 5.2 gigatons.[3]

2 The research team used the "reference" scenario in the U.S. Energy Information Administration's Annual Energy Outlook 2007 report as the foundation of its emissions reference case for emissions through 2030, supplementing that with data from Environmental Protection Agency and Department of Agriculture sources: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005; Global Anthropogenic non-CO_2 Greenhouse Gas Emissions: 1990-2020; Global Mitigation of non-CO_2 Greenhouse Gases; and Forest Service RMRS-GTR-59 (2000). Our analyses excluded HCFCs, which are being retired under the Montreal Protocol.

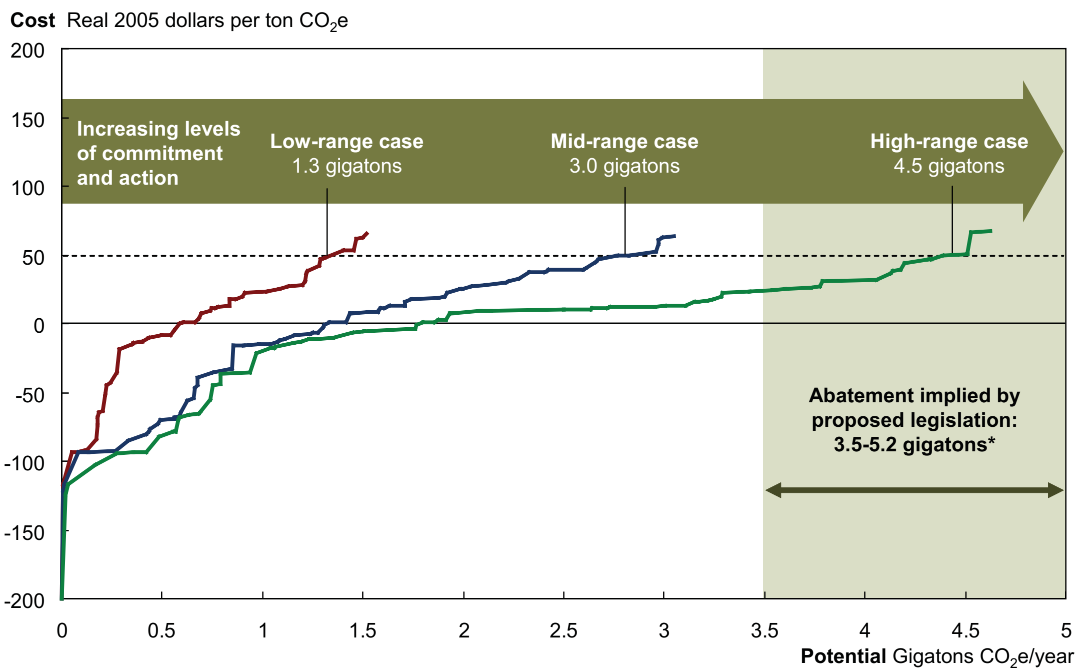
3 The research team defined an illustrative range of GHG reduction targets relative to the emissions reference case using a sampling of legislation that had been introduced in Congress at the time this report was written. The team focused on bills that address global warming and/or climate change on an economy-wide basis and contain quantifiable reduction targets. Use of these possible targets as reference points should not be construed as an endorsement of those targets nor the policy approaches contained in any particular legislative initiative.

SIGNIFICANT POTENTIAL TO REDUCE U.S. EMISSIONS

We analyzed resource costs and abatement potentials for more than 250 opportunities to reduce or prevent GHG emissions.[4] We projected a range of three outcomes for each option and, for analytical purposes, integrated the values into three abatement supply curves. The supply curves are not optimized scenarios, rather they represent different approximations of national commitment (e.g., degree of incentives, investments, regulatory reforms, and urgency for action) and different rates for innovation, learning, and adoption of various technologies. We have called the three curves "cases": the low-range case involves incremental departures from current (i.e., reference case) practices; the mid-range case involves concerted action across the economy; and the high-range case involves urgent national mobilization. In this way, the cases illustrate an envelope of abatement potential for the United States by 2030 (Exhibit A).[5]

Exhibit A

U.S. GREENHOUSE GAS ABATEMENT POTENTIALS – 2030



* Based on bills introduced in Congress that address climate change and/or GHG emissions on an economy-wide basis and have quantifiable targets; targets calculated off the 2030 U.S. GHG emissions of 9.7 gigatons CO_2e/year (reference case)

Source: McKinsey analysis

4 The cost of an abatement option reflects its resource (or techno-engineering) costs – i.e., capital, operating, and maintenance costs – offset by any energy savings associated with abating 1 ton of CO_2e per year using this option, with the costs/savings levelized over the lifetime of the option using a 7-percent real discount rate. We excluded transaction costs, communication/information costs, taxes, tariffs, and/or subsidies. We also have not assumed a "price for carbon" (e.g., a carbon cap or tax) that might emerge as a result of legislation, nor any impact on the economy of such a carbon price. Hence, the per-ton abatement cost does not necessarily reflect the total cost of implementing that option.

5 Only the high-range case reaches the target levels of GHG abatement (3.5 to 5.2 gigatons in 2030) suggested by our sampling of proposed federal legislation that addresses climate change on an economy-wide basis. For this reason, we focus most of our abatement analysis on the upper part of the envelope, from 3.0 gigatons (mid-range case) to 4.5 gigatons (high-range case).

Relying on tested approaches and high-potential emerging technologies, the U.S. could reduce annual GHG emissions by as much as 3.0 gigatons in the mid-range case to 4.5 gigatons in the high-range case by 2030. These reductions from reference case projections would bring U.S. emissions down 7 to 28 percent below 2005 levels, and could be made at a marginal cost less than $50 per ton,[6] while maintaining comparable levels of consumer utility.[7]

We made no assumptions about specific policy approaches that might be taken – e.g., a carbon cap or tax, mandates, or incentives – nor responses in consumer demand that might result. Nonetheless, unlocking the full abatement potential portrayed in our mid- and high-range curves would require strong stimuli and policy interventions of some sort. *Without a forceful and coordinated set of actions, it is unlikely that even the most economically beneficial options would materialize at the magnitudes and costs estimated here.*

Our analysis also found that:

- **Abatement opportunities are highly fragmented and widely spread across the economy (Exhibit B).** The largest option (CCS for a coal-fired power plant) offers less than 11 percent of total abatement potential. The largest sector (power generation) only accounts for approximately one-third of total potential.

- **Almost 40 percent of abatement could be achieved at "negative" marginal costs,** meaning that investing in these options would generate positive economic returns over their lifecycle. The cumulative savings created by these negative-cost options could substantially offset (on a societal basis) the additional spending required for the options with positive marginal costs. Unlocking the negative cost options would require overcoming persistent barriers to market efficiency, such as mismatches between who pays the cost of an option and who gains the benefit (e.g., the homebuilder versus homeowner), lack of information about the impact of individual decisions, and consumer desire for rapid payback (typically 2 to 3 years) when incremental up-front investment is required.

- **Abatement potentials, costs, and mix vary across geographies.** Total abatement available at less than $50 per ton ranges from 330 megatons in the Northeast to 1,130 megatons in the South (mid-range case). These potentials are roughly

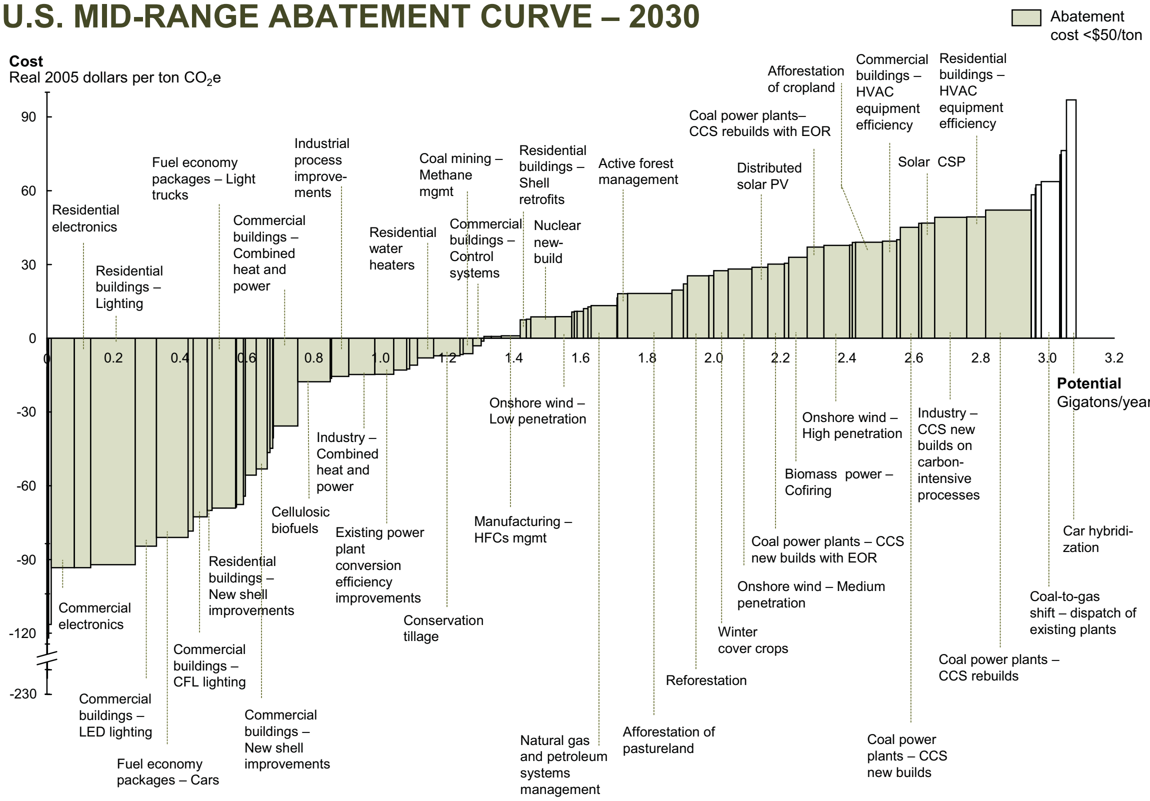
6 The team set an analytical boundary at $50 per ton in marginal cost after considering consumer affordability and the estimated long-term cost for adding carbon capture and storage to an existing coal-fired power plant, a solution that, if successfully deployed, would likely set an important benchmark for emission-control costs. Abatement costs are expressed in 2005 real dollars. The team examined a number of options with marginal costs between $50 and $100 per ton, but did not attempt a comprehensive survey of options in this range. For simplicity of expression in this report, we refer to the threshold with the phrase "below $50 per ton."

7 By "consumer utility" we mean functionality or usefulness for people, including level of comfort; in this context, holding consumer utility constant would imply, e.g., no change in thermostat settings or appliance use; no downsizing of vehicles, homes, or commercial space; traveling the same mileage annually relative to levels assumed in the government reference case. In a strict economic sense, maintaining constant consumer utility assumes a constant economic surplus for the consumer while delivering against a common benefit. We have not attempted to calculate potential changes in utility that might result from energy price changes associated with pursuing the options outlined in our abatement curve.

proportional to total GHG emissions from the regions, but there are significant variations relative to GDP and population.

Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030



Source: McKinsey analysis

Reducing GHG emissions would require capital spending increases and a change in investment patterns relative to the government reference case. For example, the incremental capital costs associated with capturing the 3.0 gigatons of abatement in our mid-range case would average approximately $50 billion annually through 2030. Cumulative net new investment through 2030 would be $1.1 trillion, or roughly 1.5 percent of the $77 trillion in real investment the U.S. economy is expected to make over this period. This number would be higher if our projected savings from energy efficiency gains do not materialize and/or if the nation chooses to achieve emissions reductions by mandating higher-cost options. These incremental investments would be highly concentrated in the power and transportation sectors; if pursued, they would likely put upward pressure on electricity prices and vehicle costs. Policymakers and legislators would need to weigh these added costs against the energy efficiency savings, opportunities for technological advances, and other societal benefits.

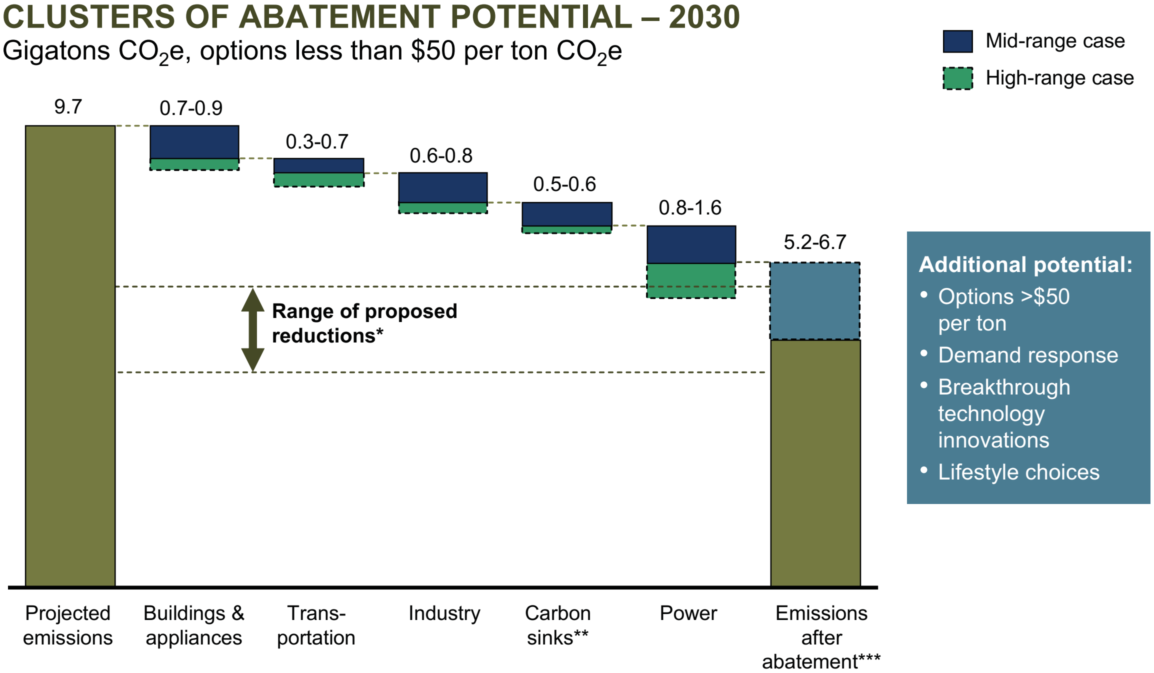
FIVE SECTORS OFFER CLUSTERS OF ABATEMENT POTENTIAL

Five clusters of initiatives, pursued in unison, could create substantial progress – 3.0 gigatons (mid-range case) to 4.5 gigatons (high-range case) of abatement per year – against proposed GHG-reduction targets for 2030 (Exhibit C). We will discuss these clusters in order, from least to highest average cost.

Exhibit C

CLUSTERS OF ABATEMENT POTENTIAL – 2030

Gigatons CO_2e, options less than $50 per ton CO_2e



* Based on bills introduced in Congress that address climate change and/or GHG emissions on an economy-wide basis and have quantifiable targets; targets calculated off the 2030 U.S. GHG emissions of 9.7 gigatons CO_2e/year (reference case)

** Including abatement in the agriculture sector

*** Adjusted for cumulative rounding errors

Source: U.S. EIA; EPA; USDA; McKinsey analysis

1. **Improving energy efficiency in buildings and appliances – 710 megatons (mid-range) to 870 megatons (high-range).** This large cluster of negative-cost options includes: lighting retrofits; improved heating, ventilation, air conditioning systems, building envelopes, and building control systems; higher performance for consumer and office electronics and appliances, among other options. While this category of abatement options would cost the least from a societal point of view, persistent barriers to market efficiency will need to be overcome.

2. **Increasing fuel efficiency in vehicles and reducing carbon intensity of transportation fuels – 340 megatons to 660 megatons.** Improved fuel efficiency could provide 240 megatons to 290 megatons of abatement: much of the benefit would come from fuel

economy packages (e.g., lightweighting, aerodynamics, turbocharging, drive-train efficiency, reductions in rolling resistance) and increased use of diesel for light-duty vehicles. Though the savings from fuel efficiency may offset the incremental cost of the abatement option over a vehicle's 12- to 15-year lifecycle, these options require up-front investment by automakers and thus higher vehicle costs for consumers. Lower-carbon fuels, such as cellulosic biofuels, could abate 100 megatons to 370 megatons of emissions, though this potential is highly dependent on innovation rates and near-term commercialization of these technologies. Plug-in hybrid vehicles offer longer-term potential if vehicle cost/performance improves and the nation moves to a lower-carbon electricity supply.

3. **Pursuing various options across energy-intensive portions of the industrial sector – 620 megatons to 770 megatons.** This potential is in addition to 470 megatons assumed in the government reference case. It involves a multitude of fragmented opportunities within specific industries (e.g., equipment upgrades, process changes) and across the sector (e.g., motor efficiency, combined heat and power applications). Despite offering direct bottom-line benefit, these options must compete for capital and, without clear incentives to control GHG emissions, may not receive funding.

4. **Expanding and enhancing carbon sinks – 440 megatons to 590 megatons.** Increasing forest stocks and improving soil management practices are relatively low-cost options. Capturing them would require linkages to carbon-offset mechanisms to access needed capital, plus improved monitoring and verification.

5. **Reducing the carbon intensity of electric power production – 800 megatons to 1,570 megatons.** This potential derives from a shift toward renewable energy sources (primarily wind and solar), additional nuclear capacity, improved efficiency of power plants, and eventual use of carbon capture and storage (CCS) technologies on coal-fired electricity generation. Options in the power sector were among the most capital-intensive ones evaluated. These options also tend to have the longest lead times, given bottlenecks in permitting, materials and equipment manufacturing, and design, engineering, and construction.

The theme of greater energy productivity pervades these clusters. Improving energy efficiency in the buildings-and-appliances and industrial sectors, for example, could (assuming substantial barriers can be addressed) offset some 85 percent of the projected incremental demand for electricity in 2030, largely negating the need for the incremental coal-fired power plants assumed in the government reference case. Similarly, improved vehicle efficiency could roughly offset the added mobility-related emissions of a growing population, while providing net economic gains.

NEED FOR STRONG, ECONOMY-WIDE APPROACHES

The U.S. will need to develop and implement a strong, coordinated program of economy-wide abatement actions in the near future, if it is to achieve emissions reductions proposed (in bills currently before Congress) for 2030 at the lowest cost to the economy.

We believe a comprehensive abatement program for the U.S. should be built on three principal actions:

1. **Stimulate action through a portfolio of strong, coordinated policies to capture GHG reductions efficiently across industry sectors and geographies.** These policies would need to support development of:

   - Visible, sustained signals to create greater certainty about the price of carbon and/or required emissions reductions; this will help encourage investment in options with long lead times and/or lifecycles
   - A coordinated economy-wide abatement program or set of programs. Because abatement options are highly fragmented and widely distributed across sectors and geographies, any approach that does not simultaneously unleash a full range of abatement options risks missing proposed 2030 reduction targets and/or driving up total cost to the economy
   - Exchange mechanisms (e.g., trading schemes, offsets, tax credits) to create fungibility across fragmented markets, create greater market transparency, and drive least-cost solutions
   - Verification, monitoring, management, and enforcement systems to ensure sustained abatement impact
   - Safeguards against "leakage" and transfer of GHG-emitting activities overseas.

2. **Pursue energy efficiency and negative-cost options quickly.** Many of the most economically attractive abatement options we analyzed are "time perishable": every year we delay producing energy-efficient commercial buildings, houses, motor vehicles, and so forth, the more negative-cost options we lose. The cost of building energy efficiency into an asset when it is created is typically a fraction of the cost of retrofitting it later, or retiring an asset before its useful life is over. In addition, an aggressive energy efficiency program would reduce demand for fossil fuels and the need for new power plants. These energy efficiency savings are not being captured today, however, suggesting that strong policy support and private sector innovation will be needed to address fundamental market barriers. Policy support might consist of standards, mandates and/or incentives to promote carbon-efficient buildings, appliances, and vehicles. Mechanisms to better align all stakeholders (e.g., end users, manufacturers, utilities, and supporting businesses) should also be considered.

3. **Accelerate development of a low-carbon energy infrastructure.** Transitioning to a lower-carbon economy will require significant changes in the country's energy infrastructure. To accelerate development of a lower-carbon energy infrastructure, the U.S. would need to:

   - **Encourage research and development of promising technologies and stimulate deployment.** Of the options we analyzed, some 25 percent (e.g., solar photovoltaics, plug-in hybrid electric vehicles, cellulosic biofuels, CCS) would require additional R&D investment and/or cost compression to achieve the learning rates and scale required to accelerate widespread adoption. This support might include gap-closing financial incentives (e.g., investment tax credits, feed-in tariffs, or direct subsidies) and/or industry or regulatory standards to help achieve scale economies as soon as possible.

   - **Streamline approval and permitting procedures.** Many energy infrastructure investments (e.g., nuclear power, transmission lines, and pipelines) have long lead times and can face substantial delays in getting necessary approvals. Permitting and approval delays can substantially increase the risk and cost to investors and, if not specifically addressed, may inhibit pursuit of these capital-intensive abatement options. Some emerging technologies, such as geologic storage of CO_2, currently have no defined approval and permitting process. Anticipating and addressing potential regulatory hurdles – e.g., siting, liability, and monitoring issues associated with permanently storing large amounts of CO_2 – and developing public and technical review processes to address those issues will be essential to avoid impeding the pursuit of these capital-intensive abatement options.

To address rising GHG emissions comprehensively, the nation would also need to consider abatement options outside the scope of this project. Additional reductions could be achieved by encouraging changes in consumer lifestyles and behaviors (e.g., driving habits, spending decisions) through measures such as price signals or education and awareness campaigns; they could also be achieved by pursuing abatement options with marginal costs greater than $50 per ton. Finally, we are confident that, in the years ahead, many new ideas and innovations not included in our analysis will emerge. These new technologies, products, processes, and methods could well offer additional abatement potential and lower overall costs.

* * *

This project evaluated the costs and potentials of more than 250 abatement options available in the U.S. We did not examine economy-wide effects associated with abating greenhouse gases, such as shifts in employment, impact on existing or new industries, or changes in the global competitiveness of U.S. businesses. The project did not attempt to assess the benefits to society from reducing global warming. The report also did not attempt to address other societal benefits from abatement efforts, such as improved public health from reducing atmospheric pollution or improving national energy security. Policymakers would undoubtedly want to weigh these factors – and possibly others – when developing comprehensive approaches for reducing GHG emissions in the U.S.

Creating comprehensive approaches will be challenging: they will need to combine durable policies and a slate of strong near-term actions that mobilize economic sectors and geographies across the U.S. The pursuit of GHG abatement, however, will undoubtedly stimulate new businesses and economic opportunities not covered by our cost-focused analysis.