THE HAMILTON PROJECT

Advancing Opportunity, Prosperity and Growth

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# A U.S. Innovation Strategy for Climate Change Mitigation

IN THE YEARS AHEAD, the United States will need to reduce its greenhouse gas emissions to help mitigate global climate change. Technological advances in energy efficiency and clean energy sources will be crucial to meeting emissions targets, yet the level of investment in such new technologies is too low because firms and consumers do not directly bear the social costs of their carbon emissions and because researchers cannot capture the full social benefits of their innovations. As a result, government intervention is needed, but there is considerable debate both about the appropriate level of support and about which specific public policies can foster technological change as efficiently as possible.

In a discussion paper for The Hamilton Project, economist Richard G. Newell of Duke University's Nicholas School of the Environment proposes a technology innovation strategy to increase both private and public sector investments in clean technology in a cost-effective manner. To induce private sector innovation, Newell recommends an economy-wide price on greenhouse gases, reinforced by permanent research and development (R&D) tax credits. Newell also proposes that the federal government roughly double its funding of climate mitigation R&D to about $8 billion a year by 2016, focusing on basic research the private sector is least likely to undertake. Newell cautions that quickly increasing funding beyond his proposed $8 billion a year could yield significantly diminishing returns and potentially crowd out other R&D. A portion of the new funding would be directed toward innovation inducement prizes targeting specific technological breakthroughs. Newell recommends improving the management and coordination of federal research in order to maximize the impact of this increased funding. Newell argues that his comprehensive plan would be the most efficient way to generate the climate mitigation technologies necessary to meet our emissions goals.



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> Effective innovation in climate mitigation technology has the potential to reduce the cost of attaining our emissions goals dramatically.

## THE CHALLENGE

Current energy usage in the United States is contributing to growing levels of global greenhouse gas (GHG) emissions. Fossil fuels such as oil, coal, and natural gas account for 85 percent of U.S. energy consumption and roughly the same share of U.S. GHG emissions. Without any policy intervention, these emissions are projected to grow 16 percent by 2030, further increasing the concentration of GHGs in the atmosphere.

According to the Nobel-Prize winning Intergovernmental Panel on Climate Change (IPCC), even maintaining current emission levels could cause significant climate damages. The concentration of GHGs in the atmosphere has already increased from 280 parts per million (ppm) of $CO_2$ equivalent in preindustrial times to 450 ppm today, and is increasing at a rate of about 3 ppm a year at current emissions levels. The IPCC estimates that going up to 550 ppm, a rough doubling of concentrations from preindustrial levels, could cause global average temperatures to increase approximately 5.4°F. At levels above 550 ppm, there is a heightened risk of potentially devastating consequences from rising sea levels, extreme drought and flooding, and changing weather patterns.

Since the United States is responsible for about one-fifth of world GHG emissions, it will have to make large cuts if worldwide concentrations are to be maintained in the 450 ppm to 550 ppm range that many scientists have recommended. These reductions will be costly. A variety of modeling scenarios of cost-effective global and U.S. climate mitigation policy reviewed by Newell puts the annual cost at between one-third of 1 percent and 3 percent of GDP—between $50 billion and $500 billion in today's dollars—through 2050, depending on the stringency of emissions targets and various other modeling assumptions.

Effective innovation in climate mitigation technology has the potential to reduce dramatically the cost of attaining our emissions goals. For example, among the scenarios referenced above, those that assume successful development of ambitious new technology are 50 to 60 percent less expensive than those premised on modest technological change. Breakthroughs in energy efficiency, renewable energy, nuclear power, and carbon capture and storage are just a few examples of technologies that would make it easier to reduce GHG emissions. Innovation in climate change mitigation technology can thus reduce the cost of U.S. GHG mitigation by tens to hundreds of billions of dollars annually.

Despite the social benefits of climate mitigation technology, two market problems lead to low levels of R&D investment. The first problem is the environmental externality of global climate change. While GHG emissions impose climate costs on current and future generations, households and firms do not currently have to pay for the damage that their emissions impose on others. Firms and households have little incentive to reduce emissions and therefore have low demand for GHG-reducing technologies. Thus, there is too little incentive for companies to invest in climate mitigation technology, despite the large social benefits this technology might bring.

The second problem applies generally to the market for innovations: private companies invest too little in innovation because the benefits of a given innovation to that firm are generally lower than the total social benefits. Specifically, the benefits of innovation usually extend beyond the innovating company, spilling over to other technology producers and to consumers. A range of studies shows that the social return to R&D averages between two and four times the private return, and that this difference is largest for basic research where it is difficult for the private sector to appropriate the benefits.

There are several reasons why this innovation problem is especially acute for climate mitigation technology. First, the private returns to climate mitigation R&D require credible long-term government commitments to GHG reductions. Second, the large uncertainties about the future impacts of climate change make it difficult to value the potential benefit of related innovations, especially for the most high-cost, transformative solutions that might only make sense in the worst-case scenario. Third, many innovations to address climate change would also address concerns related to energy security and local pollution, driving an even greater wedge between their social and private benefits. Finally, since climate change is a global problem, successful domestic R&D efforts could have significant benefits for other countries, driving a wedge between the national and global social benefits.

Given these market failures, private investment in mitigation R&D will be too low even in the best case situation. But to make matters worse, public and private R&D have actually declined in recent decades. Private sector energy R&D as a percent of GDP fell by 75 percent in the 1990s and has since stabilized at a low level. Meanwhile, federal energy R&D spending as a percent of GDP fell by 50 percent in the 1990s and has yet to rebound. This decline in government R&D investment is especially detrimental to basic research, since the private sector devotes only 5 percent of its climate change R&D investment to this initial stage of innovation.

## A NEW APPROACH

To harness the full potential of technological innovation, Newell proposes a comprehensive strategy comprising five concrete steps that will reverse recent declines and induce greater and more-targeted investment from both the public and private sectors. To induce private sector innovation, he recommends a GHG-emissions price and permanent R&D tax credits. In the public sector, he proposes an increase in investment through more federal R&D spending on basic climate mitigation research, a new commitment to innovation prizes, and improved management of federal spending.

> There is too little incentive for companies to invest in climate mitigation technology, despite the large social benefits this technology might bring.

### Inducing Private Sector Innovation

Newell argues that the first part of a cost-effective mitigation strategy is to harness the efficiency and flexibility of the private sector. He proposes a national emissions price to address the environmental externality associated with carbon emissions as well as a permanent R&D tax credit to address knowledge spillover problems.

**Institute an economy-wide emissions price.** Newell recommends a carbon tax or a cap-and-trade system that would establish a price for GHG emissions. An emissions price would give firms and households an incentive to adopt the most cost-effective technologies for reducing emissions while giving businesses an incentive to invest in developing new, low-cost, climate-friendly technologies.

According to Newell, the emissions price should cover the whole economy in order to effectively induce innovations. It also should be credible

## Key Highlights

### The Challenge

Effective innovation in climate mitigation technology has the potential to reduce the cost of meeting our GHG emissions targets dramatically. Despite the large benefits of technological advances, two market problems lead to low levels of mitigation R&D:

- Climate change is an environmental externality. Firms and households do not have to pay for the damage their emissions impose on others, reducing demand for GHG-mitigating technologies.
- Knowledge is a public good. The benefits of innovation extend beyond the innovating company to other technology producers as well as to consumers. This knowledge spillover reduces the private incentive to innovate because the innovating company cannot capture all the benefits of its R&D.

### A New Approach

Richard Newell proposes a comprehensive strategy to induce greater R&D investment for GHG emissions. The first part of his strategy focuses on inducing private sector innovation. Newell calls for the following:

- Institute an economy-wide carbon tax or cap-and-trade system that would establish a price on GHG emissions. It would give firms and households an incentive to adopt cost-effective technologies for reducing emissions and would give businesses a long-term incentive to develop new climate-friendly technologies.
- Establish a permanent R&D tax credit to reinforce climate-related innovation in the private sector.

The second part of Newell's strategy complements private innovation with effective federal investments. He would do the following:

- Double federal climate mitigation R&D funding to approximately $8 billion per year over the next eight years. This funding should focus on the basic research the private sector is least likely to undertake on its own.
- Allocate a small portion of increased R&D funding to innovation prizes for specific breakthroughs.
- Improve the management and coordination of federal funding to ensure increased outlays are efficiently allocated. The most urgent reform is to improve coordination within the DOE.

over the long term and should therefore specify increasingly stringent targets through 2050. If a cap-and-trade system is chosen, provisions for banking and borrowing of allowances (whereby allowances can be saved and used in future years or borrowed from future years and used in the present) and price floors and price ceilings would help create a more consistent price signal, argues Newell.

**Establish a permanent R&D tax credit.** Even with an emissions price, the knowledge spillover problem means that private firms will not be able to appropriate all of the benefits of climate mitigation technologies and will therefore underinvest in them. To tackle this problem, Newell proposes a permanent R&D tax credit that would increase the private return to innovation.

The current R&D tax credit is temporary, although Congress has renewed it more than ten times since its inception in 1981. Such a temporary tax credit makes it difficult to plan long-term investments. In addition, since it is not refundable—i.e., a firm without tax liability in the current year cannot claim the credit—it fails to provide incentives to firms with little taxable income, such as startup companies.

Newell recommends enacting a permanent tax credit with appropriate reforms, which could include making the tax credit refundable. Several years after the permanent tax credit takes effect, he would ask the National Academy of Sciences to evaluate the effectiveness of these new provisions and propose modifications to provisions that seek to specifically increase R&D relevant to GHG mitigation and other energy-related goals.

## Complementing Private Innovation with Effective Federal Investments

According to Newell, the second part of a cost-effective climate mitigation innovation strategy is to increase public sector investments to complement private sector efforts.

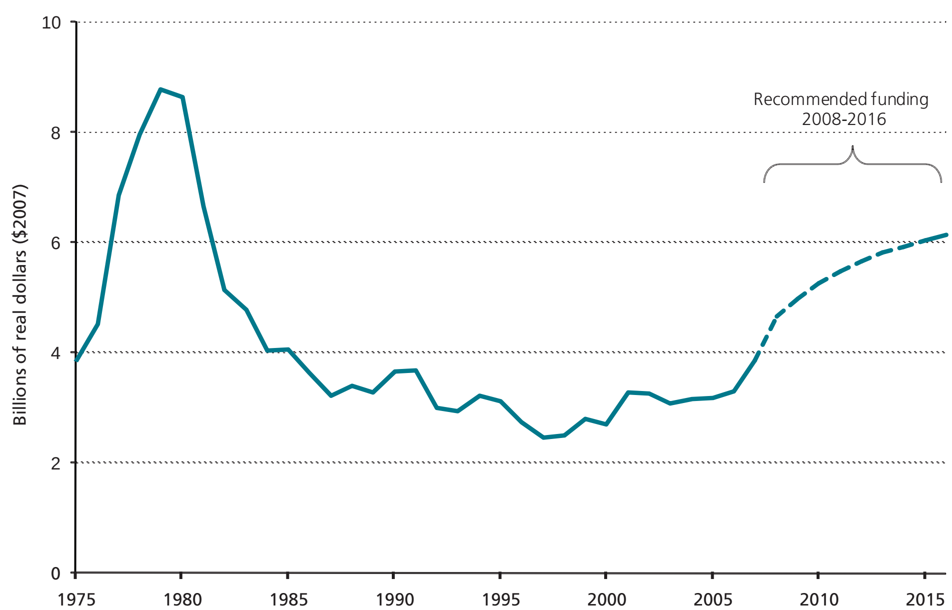
> Climate technology policy should complement rather than substitute for emissions pricing.

**Double federal climate mitigation R&D spending.** Given the opportunity for innovation to reduce the cost of mitigating GHG emissions, and the shortfall in private sector incentives for investing in basic research, Newell recommends that the federal climate mitigation R&D budget be roughly doubled over the next eight years to $8 billion per year. Newell argues that ramping up R&D spending at a more rapid pace runs the risk of outstripping the capacity of R&D managers and researchers to effectively allocate and absorb additional resources, which would lead to waste. Figure 1 shows the time path of the proposed funding increase. The increased funding would come with periodic, external, independent evaluations and would be expanded if justified.

Newell would focus public funding on what he calls "use-inspired" or "strategic" basic research, which is research that seeks knowledge and fundamental understanding, but is also inspired by practical needs related to developing GHG mitigation technologies. An example of such research is finding better ways to store electrical energy. This work would develop new fundamental knowledge, but it would also help to use electricity as a substitute for oil in transportation.

Newell would use the funding of strategic basic research to invest in the next generation of scientists and engineers. He suggests this could be accomplished by prioritizing additional funding to universities. Finally, given the unique challenge posed by climate change and the uncertainties regarding its potential impacts, some of this funding should be dedicated to exploratory research that examines high-risk, out-of-the-box concepts such

**FIGURE 1**
**U.S. Federal Energy R&D Spending (1975–2007) with Recommended Funding Projections**




Source: Newell (2008)
Note: The projections assume a 3 percent inflation rate so that $8 billion in nominal terms in 2016 is equivalent to $6.1 billion in real terms.

as energy from high-altitude wind kites, direct removal of $CO_2$ from the atmosphere, and advanced biologically-based methods for producing energy and sequestering $CO_2$. This funding stream would have to tolerate greater project failures in return for greater potential returns.

Newell's recommended increase in R&D spending is to a large degree already authorized by the Energy Policy Act of 2005 and the 2007 America Competes Act. However, there remain significant legislative hurdles with respect to securing adequate appropriations. Recent cap-and-trade proposals in the U.S. Congress have sought to fill the funding gap by targeting part of the value of emissions allowances to supporting low-GHG technologies. According to Newell, these bills do not meet his objective because almost all of the funding would be dedicated to commercial technology deployment rather than to the type of strategic basic research that he emphasizes.

**Use innovation prizes to target specific technological breakthroughs.** Newell recommends allocating a small portion of the increased federal R&D funding to innovation inducement prizes. These prizes would offer financial rewards for achieving specific innovation objectives that have been determined in advance. There are several benefits to increased use of prizes for innovation. First, prizes allow the government to reward innovation outputs rather than inputs; the prize is only paid if the objective is attained. Second, prizes allow for flexibility for researchers by defining specific objectives without specifying how the goal is to be accomplished. This encourages innovation along many different paths simultaneously. Finally, prize competitors select themselves based on their knowledge of their likelihood for success, saving government officials from having to make difficult choices among competing grant applicants. In order to capture the full benefits of innovation prizes, government officials will have to carefully select appropriate prize topics and craft new rules for this relatively novel type of research support.

**Improve the management and coordination of federal funding.** Newell cautions that the doubling of the federal climate R&D budget must be coordinated and managed efficiently. Currently within the DOE, the Office of Science is in charge of basic research while the program offices (fossil, nuclear, renewables, and end-use efficiency) focus on applied R&D.

Given his recommended focus on strategic basic research, Newell argues that the most important reform is to improve the currently weak communication and coordination between the Office of Science and the individual program offices within the DOE. These changes are necessary because strategic basic research requires identifying both what basic knowledge is needed and what innovations could be useful for mitigating GHGs. For example, there should be a coordinated process and comprehensive reviews to identify research agendas that fulfill both criteria of strategic basic research.

Taken as a whole, Newell's comprehensive innovation strategy would create powerful incentives for increased climate mitigation innovation. The emissions price would create demand for new technology, and the permanent R&D tax credit would reinforce these incentives by lowering firms' costs of innovation. Doubling government funding for basic R&D would support the type of strategic basic research that the private sector will not adequately provide. This funding would be better managed and coordinated through stronger central organization and improved collaboration among the relevant offices.

## Alternative Approaches

Some commentators have proposed establishing a separate, focused, large-scale government innovation initiative akin to the Manhattan and Apollo Projects of the past. But Newell points out there are key differences between the challenges associated with those projects—developing a nuclear weapon and putting a man on the moon, respectively—and the current challenge of creating a diverse set of cost-effective climate mitigation technologies. In the previous cases, the government was the sole customer for a well-defined objective, whereas in the climate context there are a diverse set of users (indeed, every firm and individual in the United States and, potentially, the world) and many different technologies involved. Previously, since government was the sole customer and the technologies were deemed absolutely necessary, cost was not a major concern, but in the climate context the goal is developing cost-effective technologies that can compete on the open market. Finally, previous efforts generated a short-term burst to tackle a discrete problem, whereas climate change requires a steady, long-term effort over many decades.

## CONCLUSION

Newell's proposed innovation strategy is designed to encourage the development of new technologies that can help lower the cost of GHG emissions reductions. He explains, however, that poorly designed government policies can actually raise rather than lower the social costs of climate change mitigation. For example, policies that set arbitrary targets for specific technological mixes and specify from which sectors of the economy emissions reductions should come tend to increase the cost of meeting a given reduction goal. That is why an economy-wide emissions price is a central piece of Newell's innovation strategy: it gives firms and individuals the incentive and flexibility to pursue every cost-effective option for reducing emissions.

Newell emphasizes that climate technology policy should complement rather than substitute for emissions pricing. Innovation policy can help increase the supply of new technology, but will have limited impact without an emissions price. At the same time, an emissions price without public and private sector technology policy would miss out on important low-cost mitigation options because of the market failures that lead to underinvestment in climate-related R&D. In order to generate the technological breakthroughs necessary to reduce the cost of achieving our climate goals, Newell argues that a comprehensive policy approach that includes both emissions pricing and focused technology policy is needed.



## Learn More About This Proposal

This policy brief is based on The Hamilton Project discussion paper, *A U.S. Innovation Strategy for Climate Change Mitigation*, which was authored by:

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Professor Newell, also a Research Associate of the National Bureau of Economic Research and a University Fellow of Resources for the Future, has written on the economics of climate change policy, energy policy, energy technologies and energy efficiency, and market-based environmental policy.

## Additional Hamilton Project Proposals

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### A U.S. Cap-and-Trade System to Address Global Climate Change

This discussion paper proposes a cap-and-trade system for carbon emissions that would achieve specific emission reduction targets using market mechanisms. The paper develops the details of an environmentally sound, cost effective, and distributionally fair cap-and-trade system.

### A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change

A tax on greenhouse gas emissions would give businesses and consumers incentives to reduce emissions cost-effectively. The proposal would use revenue from the tax to offset the burden of higher energy prices on low-income consumers.

### An Economic Strategy to Address Climate Change and Promote Energy Security

The United States needs a comprehensive strategy to reduce its own emissions and encourage global climate cooperation while also improving energy security through reduced oil consumption. This strategy paper argues that the U.S. should start by putting a price on carbon, providing an economic incentive to reduce emissions and develop clean technologies. It should then follow up with a targeted approach to R&D policy.

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