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Policies for Funding a Response to Climate Change

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Abstract

This paper asserts that a significant increase in public funding for climate change research and development (R&D) is needed in the United States. While additional public R&D funding alone is unlikely to provide a sufficient policy response to climate change, it is a critical policy component in an effective long-run strategy. Different possibilities for generating additional public revenues for R&D funding are considered. The analysis demonstrates that quite modest taxes on carbon emissions or gasoline could fund a significant increase in public R&D funding for clean energy. As an alternative to tax instruments, the paper also considers a program of voluntary retirement contributions to a clean energy fund. These clean energy retirement accounts (CERAs) would allow individuals to directly contribute to a fund that would be used exclusively to support climate change-related R&D. Specifically, the paper suggests that CERA funds be used to offer low-interest loans to private firms and to form private-public partnerships pursuing the long-term development of clean energy technologies. Loan repayment and the eventual profitability of some partnerships will at least partially fund payments to CERA holders when they retire. Using reasonable assumptions, a simulation analysis demonstrates the financial feasibility of the program and the conditions in which the program would be fully self-funding.

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Introduction

Global emissions of carbon dioxide, the primary greenhouse gas, have risen about 30 percent since 1990. Projections indicate that in the absence of effective climate change policies global CO_2 emissions could increase a further 60 to 70 percent by 2030, with continued growth in emissions beyond that (US Department of Energy, 2006a; International Energy Agency, 2005). It is becoming increasingly clear that the global growth of CO_2 emissions needs to be halted and eventually reversed during the 21^{st} century in order to avoid potentially catastrophic effects from global climate change. The recent much-publicized *Stern Review on the Economics of Climate Change* notes that climate stabilization at an atmospheric concentration of 550 parts per million CO_2-equivalent would require global emissions to peak in the next ten to twenty years and then fall to 25 percent below current levels by 2050, with further declines thereafter (Stern, 2006). Climate stabilization even at this level could result in significant negative effects including reduced crop yields, increased water shortages, and ecological damages.

Thus there exists a large 'mitigation gap' between projected carbon emissions and the level of emissions necessary to achieve climate stabilization that moderates the risk of adverse climate change. Closing this gap will require significant, coordinated, and wide-ranging policy action. However, the most comprehensive policy response to climate change to-date, the Kyoto Protocol, will produce only a limited beneficial impact, especially since the United States has withdrawn from the treaty. The U.S. is the world's largest emitter of greenhouse gases, yet current federal policy does not place any limits on emissions of CO_2. The George W. Bush administration has instead pursued voluntary and incentive-based programs, while U.S. emissions of CO_2 continue to increase. U.S. Department of Energy projections estimate a 36 percent increase in total CO_2 emissions between 2006 and 2030 (US Department of Energy, 2006b).

An effective global response to climate change will require much stronger policy efforts in the U.S. The Bush administration has tended to focus on the potential of technological advances, using policy to 'encourage research breakthroughs that lead to technological innovation' (Office of the Press Secretary, 2001). In his 2007 State of the Union speech, the President stated the importance of diversifying U.S. energy supply and that 'the way forward is through technology'. While significant progress on reducing carbon emissions will undoubtedly require much more sweeping measures, such as comprehensive carbon cap-and-trade legislation, technological innovations are clearly a critical component of an adequate response to the challenge of global climate change. This paper argues that a significant increase in U.S. public funding for climate change research and development (R&D) is needed. While additional public R&D funding alone is unlikely to provide a sufficient policy response, it is a critical policy component in an effective long-run strategy. Different possibilities for generating additional public revenues for R&D funding are considered. The analysis demonstrates that quite modest taxes on carbon emissions or gasoline could fund a significant increase in public R&D funding for clean energy. As an alternative to tax instruments, the paper also considers a program of voluntary retirement contributions to a clean energy fund.

Public Policy Responses to Climate Change

Two types of market failure prevent an adequate response to climate change from unregulated private markets (US Congressional Budget Office, 2006). First, the negative externalities associated with carbon emissions are not reflected in market prices. The most common proposal to address this market failure is carbon taxation at a level that reflects the social costs of carbon emissions, or a cap-and-trade system with comparable effects on carbon pricing. The second market failure is an insufficient level of private research and development on clean energy technologies because the benefits of such innovations cannot be fully captured by the innovating firm. This market failure suggests the need to supplement private R&D with public R&D funding for technologies that could potentially promote climate stabilization.

The emphasis of most policy proposals to address climate change is on carbon pricing. Economic models estimating the relative effectiveness of carbon taxation and R&D subsidies suggest that pricing policies alone are much more cost effective than R&D subsidies alone but that overall cost effectiveness is achieved by a combination of both policies (US Congressional Budget Office, 2006). While public R&D funds promote the development of new technologies, in the absence of higher carbon prices there may not exist any incentive to adopt those technologies (Popp, 2004).

Even in the presence of a socially optimal price for carbon, private R&D on clean energy technology will still be undersupplied. One problem is that in the case of climate change the benefits of private investment may accrue outside of the short-term planning horizon of most firms. Thus many technologies that could make a significant contribution to carbon mitigation in the long term may fail to be commercialized without determined policy intervention (International Energy Agency, 2006b).

Second, the benefits of innovations do not fully accrue to the innovating firm. Beneficiaries also include other firms and society as a whole. Research suggests that the social rates of return on R&D investments can be in the range of 30 to 50 percent while private rates of return fall in the range of 7 to 15 percent (Popp, 2004). The gap between social and private rates of return is likely to be greatest in the case of basic research:

> Federal support would probably be most cost-effective if it went toward basic research on technologies that are in the early stages of development. Such research is more likely to be underfunded in the absence of government support because it is more likely to create knowledge that is beneficial to other firms but that does not generate profits for the firm conducting the research. (US Congressional Budget Office, 2006, p. 2)

Similarly, a review article by Salter and Martin (2001) states that 'the limited evidence gathered to date indicates that publicly funded basic research does have a large positive payoff' (p. 514) although they note methodological difficulties in estimating the benefits quantitatively.

A third problem is that there exists considerable uncertainty regarding which technologies will prevail in a low-carbon society. Given that some technologies will fail for technical or economic reasons, a portfolio approach to clean energy investment is required. Directed public R&D investments could ensure research on the widest range of technologies, not just those that present the greatest possibility of short-term profits. Numerous technological advances will be required for a sustainable future and a portfolio approach will greatly reduce the risks should some technologies fail (International Energy Agency, 2006a).

The Stern Review advocates a complementary approach of higher carbon taxes and increased public R&D funding. The report notes that despite growing concern over climate change, both private and public energy R&D is generally declining. Public energy R&D funding by the 26 industrial nations of the International Energy Agency (IEA) peaked at about $18 billion annually (in 2004 dollars) in 1980 in response to the energy crises of the 1970s. Funding by these countries has since fallen to about half this level. The Stern Review promotes a doubling of public R&D funding for low-carbon technologies as an initial step (Stern, 2006).

Public energy investment should be seen as complementary to, rather than competitive with, private investment. In particular, public R&D should focus on clean energy technologies that are currently far from market feasibility but that offer the greatest potential for substantial carbon reductions. Private investment, particularly in the presence of higher carbon prices, will tend to focus on technologies that offer near-term market profitability. For example, private R&D might focus on the development of more efficient gas-electric hybrid engines while public R&D would concentrate on the development of hydrogen fuel cells as a replacement power plant for vehicles. This complementary process is already occurring as energy market liberalization has motivated private firms to concentrate more on short-term R&D while government research shifts towards a longer-term focus (International Energy Agency, 2003a).

The IEA notes that a future scenario of rapid technological development does not necessarily imply reduced economic growth. In a scenario of significant technological change responding to environmental concerns:

Growth would be slower at the beginning in developed countries, due to the increased costs of providing energy in a more environmentally compatible way. However, as the system responds and technology advances, the net increase in energy prices may not be that big. Furthermore, technological innovation by creating successful new industries and environment-friendly products would foster new economic growth. (International Energy Agency, 2003b, p. 92)

In this IEA scenario, governments aim to improve technologies through a 'mix of government-industry partnerships in R&D and regulation'. Again, a long-term perspective is required that stresses basic research on a broad range of technological options. Even if a concerted technology push were to begin immediately, successful new technologies might not be introduced into the market until at least 2020. A simulation model by Edenhofer, et al. (2005) produces similar results regarding the relationship between economic growth and climate policy – investment in technological change in the renewable energy and carbon capture sectors significantly reduces the costs of climate protection and allows ambitious climate goals to be met, while still permitting stable economic growth.

In the IEA scenario referred to above, the US is not expected to participate in the Kyoto process in the near term. Yet if the US adopts a long-term climate change policy emphasizing aggressive technological development, it may be able to speed up the introduction of new technologies that will eventually bring down the price of carbon mitigation and lead to a more successful international accord subsequent to the Kyoto Protocol. Countries that have ratified the Kyoto Protocol, meanwhile, may face greater pressure to take short-term measures to meet their Kyoto targets. Thus, the U.S. refusal to participate in the Kyoto Protocol could, ironically, offer it a unique opportunity to take a leadership role in developing long-term technological innovations to address climate change.

Public and Private Energy R&D Funding

In 2006 public energy R&D funding in the IEA countries was $10.9 billion (in 2006 dollars). As seen in Figure 1, R&D funding among industrial countries is dominated by Japan and the United States. In the United States, public R&D energy funding peaked in 1979 at $8.5 billion (in 2006 dollars) but in 2006 stood at only 37 percent of this amount, or $3.2 billion. Since the early 1990s Japan has been the world's leader in public R&D energy funding, with a 2006 total of $3.6 billion. In 2006 Japan and the United States accounted for 62 percent of the total public R&D energy funding among the 26 nations of the IEA. Only a few industrial countries are consistently increasing R&D energy funding. The IEA country with the greatest recent increase in funding is South Korea, which increased its public R&D energy funding by 258 percent between 2002 and 2006.

The decline in energy research funding in the United States is even more pronounced for private R&D. Between 1985 and 1999 private R&D energy expenditures declined by 66 percent in real terms, from $4.1 billion to $1.4 billion (World Energy Council, 2001). Dooley (1998) suggests that energy market deregulation is driving the decline in private R&D in the U.S. In a deregulated market, private energy companies are directing their remaining R&D towards proprietary technologies with the potential for short-term payback. Thus there is likely to be little private investment in such technologies as advanced solar and wind energy since few firms are currently profitable enough to maintain research programs on these technologies without public funding assistance. Dooley also indicates the importance of continuity in funding energy research. A crash public program to develop low-carbon energy technologies is unlikely to produce satisfactory results because of its dependency on a wide range of scientific disciplines.

Public R&D funding appears to be particularly important with respect to renewable energy. For example, of fourteen key innovations in the field of photovoltaic energy where the funding source could be identified, nine were developed totally with public funding, four as a result of public-private partnerships, and only one solely from private funding (Norberg-Bohm, 2000). A strength of public U.S. R&D funding for photovoltaic energy has been the attention paid to a wide range of research activities, including basic research. But progress has been limited partly due to the inconsistency of funding.

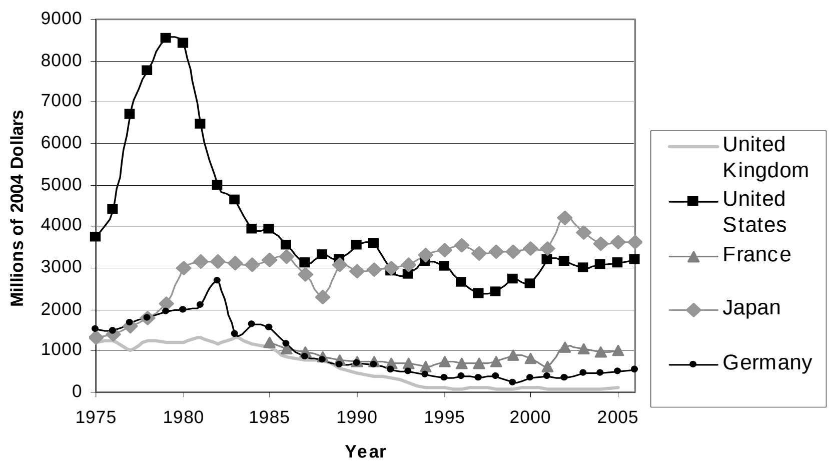

Figure 1 Public R&D Energy Funding, Selected IEA Countries, 1975- 2006
Source: Online IEA R&D Statistics Database, 2007 Edition.

The Role of Technology and R&D Funding in U.S. Climate Policy

Under the George W. Bush administration the United States set a goal of reducing greenhouse gas intensity by eighteen percent by 2012 as compared to 2002 levels. Greenhouse gas intensity is measured as total emissions divided by economic output. Reducing greenhouse gas intensity does not imply actually reducing emissions. Instead, it merely implies that emissions grow less rapidly than economic output. Analysis by the Pew Center on Global Climate Change (2002) indicates that the administration's plan would allow actual emissions to increase 12 percent over the 2002-2012 period. Further, given that greenhouse gas intensity fell by 21 percent during the 1980s and by 16 percent in the 1990s, the plan essentially amounts to a business-as-usual approach.

The United States has developed a strategic plan on the role of technology in addressing climate change (US Climate Change Technology Program, 2006). The climate change response of the United States "places special emphasis on the fundamental importance of science and technology as a means of achieving climate goals" (p. 2). Like the IEA scenarios, the strategic plan also recognizes the compatibility of technological advancement and economic growth:

'… accelerated advances in technology have the potential to facilitate progress towards meeting climate change goals and, under certain assumptions, to significantly reduce the cost of such progress over the course of the 21st century, compared to what otherwise would be the case without accelerated advances in technology. Further, it is expected that the new technologies would create substantial opportunities for economic growth.' (US Climate Change Technology Program, p. 7)

Among the goals set forth in the plan is the objective of increasing basic scientific research, including innovating research that offers the potential for breakthrough technologies. The strategic plan recognizes the need for a portfolio approach that hedges against risk by investing in a wide array of technologies. In addition, the plan seeks to "encourage further formation of public-private partnerships as a common mode of conducting R&D portfolio planning and program execution" (p. 215). However, in contrast to the recommendations of the Stern Review and the IEA, the US strategic plan does not specifically call for an increase of public R&D funding.

The President's Council of Advisors on Science & Technology (PCAST) under President Clinton did call for an increase in R&D funding related to environmental threats:

'<u>PCAST believes that the United States is underinvesting in the R&D needed to understand, anticipate, adapt to, and mitigate emerging environmental threats</u>.[1] In addition to sustaining or increasing its own R&D investments, the Federal government will need to forge new partnerships with the many businesses, industries, and nongovernmental organizations that are working today to advance sustainable development through substantial R&D investments, strategic planning, effective environmental management systems, and outreach programs.' (PCAST, 1997)

The bipartisan National Commission on Energy Policy (2004) has recommended a doubling of US public funding of energy R&D while promoting effective private-pubic partnerships. Nemet and Kammen (2007) conclude that increasing public energy R&D by a factor of two or more is necessary and feasible in light of previous large-scale government R&D efforts such as the Manhattan Project and Apollo Program.

Scenario For Increased Us Public R&D Funding Related To Climate Change

The case for a significant increase in US public R&D funding to address climate change appears compelling. If we accept that the U.S. is under-investing in climate

[1] Emphasis from original.

change R&D, by how much should funding levels be increased? This paper considers three alternative funding levels. First, following the recommendations of Stern and the National Commission on Energy Policy, a doubling of U.S. public R&D funding would require an additional $3.2 billion per year. Second, returning to the peak U.S. annual investment in energy R&D achieved in 1979 would require a $5.0 billion/year increase in funding. Finally, we consider an ambitious scenario in which the US unilaterally commits to undertake the global recommendation of the Stern Review – doubling global R&D funding – with an increased expenditure of $11.0 billion/year. We now consider alternatives for raising the additional funds for each of these funding increases.

Before considering alternatives for raising the necessary funds under these different scenarios, it is worthwhile to place these values in context. Additional federal spending of $3.2-$11.0 billion annually is quite minor when compared to total federal spending ($2,568 billion in 2006) and spending for other priorities (for example, the war in Iraq cost over $90 billion in 2006 according to the Congressional Budget Office). A relatively minor adjustment of federal spending priorities could shift an additional $3.2-$11.0 billion towards climate change R&D. Another approach would be to obtain the additional funds with a broad-based but small tax increase. For example, raising an additional $3.2 billion in taxes would equate to an additional $28 annually per US household. Or, as discussed below, the funds could be obtained through voluntary retirement contributions.

Increasing R&D Funding Using Environmental Taxes

One option for generating additional R&D funding is carbon taxation, either as a direct carbon tax or as revenue from the auctioning of carbon permits under a cap-and-trade scheme. Numerous studies have provided estimates of the socially optimal level of carbon taxation by calculating the present value of damages from carbon emissions. A literature review by Tol (2005) found large variance in carbon damage estimates. Based on 28 studies, the mean carbon damage estimate was $93 per ton but the median was only $14/ton, and the 90 percent confidence interval was -$10 to $350/ton.[2] The primary reason for the large difference in carbon damage estimates was the variation in researchers' choice of a discount rate. Tol concludes that it 'is unlikely that the marginal damage costs of carbon dioxide emissions exceed $50/tC and are likely to be substantially smaller than that' (Tol, 2005, p. 2073). This conclusion has been disputed by other analysts (see e.g. Ackerman and Finlayson, 2006). The Stern Review, for example, estimates the social cost of carbon at over $300/ton. To put these figures in context, a carbon tax of $10/ton would increase the price of oil by about 1%, the price of natural gas by about 3%, and the price of coal by about 23% (Harris and Roach, 2007).

Carbon taxation has met with considerable resistance in the U.S., and instituting a significant broad carbon tax appears unlikely in the immediate future. This analysis considers whether a less ambitious carbon tax could raise the funds necessary to permit a

[2] Note that a tax of $14/ton of carbon would equate to a tax of $3.81/ton of CO_2.

dramatic increase in public funding for energy R&D. Total carbon dioxide emissions in the U.S. in 2006 were 5.9 billion tons (US Department of Energy, 2008). Assuming all carbon emissions could be taxed, a doubling of US energy R&D funding could be met with a carbon tax of only about 50 cents per ton (See Table 1). Even in the most ambitious scenario, where the US alone doubles global energy R&D funding, a tax of only $1.87/ton of carbon dioxide would be necessary. Thus even a relatively small tax on carbon emissions in the U.S., well below most estimates of the socially efficient carbon tax, could be used to fund a large increase in public funding for climate change research.

For reasons of practicality and administration, it may not be feasible to tax all carbon emissions. Table 1 also considers the effect of taxing only commercial and industrial emissions, currently about 2.7 billion tons annually. Again, the carbon tax levels necessary to raise additional R&D funds are relatively modest, and significantly below most estimates of carbon damages.

The final policy option considered in Table 1 is a tax solely on gasoline. Unlike carbon taxation, a tax on gasoline would not require monitoring of all carbon emissions. The current federal tax on gasoline is 18.4 cents per gallon, with state taxes ranging from six to 42 cents per gallon (American Petroleum Institute, 2006). Total gasoline consumption in the U.S. in 2006 was 9,233 thousand barrels per day, or 142 billion gallons annually (US Department of Energy, 2007). Thus US funding of energy R&D could be doubled with a new gasoline tax of only about two cents per gallon. Alternatively, the U.S. could effectively double global R&D funding with a gasoline tax of 7.8 cents per gallon. As with carbon taxation, an additional gas tax of two to eight cents per gallon would still leave gas taxes in the U.S. well below socially efficient levels (Parry and Small, 2004).

Policy Option	**Funding Increase of $3.2 Billion**	**Funding Increase of $5.0 Billion**	**Funding Increase of $11.0 Billion**
Tax all CO_2 emissions	$0.54/ton CO_2	$0.85/ton CO_2	$1.87/ton CO_2
Tax all commercial and industrial emissions	$1.17/ton CO_2	$1.83/ton CO_2	$4.02/ton CO_2
Tax on only gasoline	2.3 cents/gal.	3.5 cents/gal.	7.8 cents/gal.

Table.1 Cost of Increased Public Energy R&D Funding

Clean Energy Retirement Accounts

The estimates cited above suggest that a dramatic increase in public funding for climate change R&D in the US could be paid for with relatively minor taxes applied to carbon emissions or gasoline. Of course, any of these new taxes could be countered by a decrease in existing taxes to make the policy revenue neutral. But recognizing the political difficulties of instituting new taxes in the US, we will consider a final option for raising the necessary revenue to permit an increase in public R&D funding for climate change research. The proposal is that individuals could voluntarily set up clean energy retirement accounts (CERAs) similar to existing Individual Retirement Accounts (IRAs). Like IRAs, contributions to CERAs would offer tax advantages and provide retirement income. But while IRA contributions are made using various private investment instruments such as stocks and mutual funds, contributions to CERAs would be made to the federal government. The revenue raised would then be used solely to address global climate change. CERAs would also offer individuals a simple opportunity to increase personal savings, something that is particularly needed given the recent decline in savings in the US.

Most Americans indicate that climate change is a serious problem and that the country is currently not doing enough to address the problem. In a January 2007 poll by CBS News, 70 percent of Americans stated that they believed climate change is an environmental problem currently having a serious impact (pollingreport.com, 2007). In a March 2006 ABC News poll, 68 percent of Americans said that 'the federal government should do more than it's doing now to try to deal with global warming.' The public is overwhelmingly in favor of federal policies promoting R& D on issues related to climate change. In a March 2006 Gallup poll, 85 percent favored spending government money to develop alternative fuel sources for automobiles and 77 percent favored spending government money to develop solar and wind power. In a January 2007 UPI-Zogby International poll 55 percent of respondents said that 'increased government investment in looking into alternative sources would be the best way to encourage development of renewable forms of energy' (United Press International, 2007). Another 27 percent of respondents to this survey favored tax breaks to small business or individuals who purchase a hybrid vehicle as the best way to encourage renewable energy development.

These surveys suggest that broad support exists for public funding of climate change-related R&D, but people are less enthusiastic when it comes to paying higher taxes to support such funding – in the ABC News poll mentioned above only 19 percent approved of addressing climate change with higher electricity taxes and 31 percent approved of setting higher gasoline taxes. CERAs offer an opportunity to raise additional revenue for climate change-related R&D without raising current taxes or shifting federal spending priorities.

CERA Revenue Potential

Some idea of the amount of revenue that could be generated from CERAs can be obtained by looking at charitable contributions in the U.S. In 2003 charitable contributions to environmental causes totaled $7 billion (US State Department, 2005) and in 2005 environmental contributions grew by 16 percent, faster growth than most other sectors (Giving USA, 2006). Public willingness to pay to avert significant climate change may actually be much higher than these figures imply. In a 1997-98 contingent valuation survey by Cameron (2005), average willingness to pay to prevent noticeable climate change, in terms of higher prices and/or taxes, was $228 per month. In another contingent valuation survey by Berrens, et al. (2004), households were willing to pay an average of $200 to $1,760 annually, depending on the sample and modeling approach, in terms of higher energy and gasoline prices to support US ratification of the Kyoto Protocol. These surveys suggest that the willingness to pay to prevent climate change among US citizens is well above the $3.2-$11.0 billion assumed in the three scenarios proposed here for increasing energy R&D funding. Of course, these surveys only present costs to respondents while the proposed CERA program would offer the potential for financial gains.

It is also useful to consider how much U.S. taxpayers currently contribute to voluntary retirement programs. According to IRS statistics, in 2000 contributions to IRA plans, including traditional IRAs, Roth IRAs, and SEP IRAs, totaled $36.5 billion (Sailer and Nutter, 2004). In 2001 payments to defined contribution plans, such as 401(k)s and 403(b)s, exceeded $200 billion (US Census Bureau, 2007). The evidence also suggests that IRA plans are significantly underutilized. In 2000 less than ten percent of all tax filers who were eligible for IRA contributions actually made contributions (Sailer and Nutter, 2004). IRA participation rates are particularly low for lower-income and young taxpayers. Only six percent of those with adjusted gross incomes below $50,000 contributed to an IRA in 2000. The contribution rate for tax payers under age 40 was seven percent.

The underutilization of IRAs reflects a broader trend towards reduced personal savings. The personal savings rate in the United States has been less than one percent, or even negative, since early 2005 (US Bureau of Economic Analysis, 2008). About 44 percent of American households did not save in 2004, up from 41 percent in 2001 (Bucks, et al., 2006). The lack of sufficient voluntary savings for retirement may be exacerbated in the future as a result of a projected shortfall in Social Security payments beginning in 2040 (US Social Security Administration, 2006). All these data suggest an important need to increase retirement savings, particularly for lower- and middle-income households (Duflo, et al., 2005).

CERAs present a retirement-savings instrument that could offer several unique features. First, unlike other retirement plans, a CERA would be oriented around a public policy issue with broad support. While CERAs would offer the opportunity for financial returns, as discussed in more detail below, contributions to the plan would also be an investment in long-term environmental quality. In recent years there has been a growing interest in investments screened for social and environmental performance. Socially-responsible investments have become an increasing share of total U.S. mutual fund assets (Social Investment Forum, 2006). CERAs would represent another option for savers to integrate their financial objectives with their personal values.

The CERA program should be structured to offer an uncomplicated opportunity for investing. With existing IRA and voluntary supplemental retirement programs, participation rates may be adversely affected by administrative requirements. Consider the results of one study showing that participation rates in a large company's 401(k) went from around 50 percent to 90 percent when the company switch from voluntary enrollment to automatic enrollment with an opt-out, without changing any other characteristics of the plan (Madrian and Shea, 2001). Participation rates in CERAs could be maximized by allowing contributions through automatic deductions from one's paycheck and/or direct allocations when completing one's federal income tax form.

A CERA program could appeal to both ends of the political spectrum. The plan offers individuals the opportunity to maintain personal accounts to supplement Social Security – a concept that many conservatives endorse. Of course, CERA contributions would be used to combat climate change rather than invested in the stock market. But CERAs still offer individuals an additional personal choice regarding their retirement portfolio. Another appealing feature to conservatives is that the plan does not require an increase in current taxes. Conservatives have also tended to prefer a technology-based approach to responding to climate change as opposed to an approach based on carbon pricing. On the other hand, the CERA program should appeal to environmentalists seeking to increase the US response to climate change. CERAs could move the US into an international leadership role in planning for a future based on renewable energy sources.

As proposed here, the CERA program would have a limited duration. The objective would be to advance low-carbon technologies to the point of financial competitiveness with fossil fuels or sufficient market penetration to put the US well along a path of lower overall carbon emissions. Eventually CERA contributions would be phased out, but since CERAs are retirement plan instruments, payments to CERA holders would still need to be made beyond the point when contributions cease. As with IRAs, withdrawals from CERAs would not be permitted without penalty until the account holder reaches a specific age. For example, withdrawals from IRAs are generally not permitted without penalty until the holder reaches age 59½. Thus in the early years of a CERA program, payments to account holders would be negligible, but then gradually increase as account holders reached retirement age.

CERA Financial Returns

Participation rates in a CERA program would depend on the possibility of positive financial rates of return. One way to encourage participation would be to guarantee a minimum rate of return, essentially transferring most risk from the investor to the federal government. As one example, the minimum return could be set equal to the implicit rate of return on Social Security taxes. Implicit nominal rates of return for current retirees are around four percent but rates vary widely according to one's income level and demographic characteristics (US Government Accountability Office, 1999). Another approach would be to set the minimum rate of return equal to the interest rate on long-term government bonds, about 4.5 percent in nominal terms as of early 2008. Younger savers could be targeted by offering them slightly higher minimum rates of return as compared to older savers.

The program should also offer the possibility of rates of return above any minimum guaranteed levels. The possibility for higher rates of return would depend on the potential for public investments in clean energy technologies to generate future government revenues. The government would use the money contributed to CERAs solely to address climate change but the money would not simply expand existing R&D programs. Two particular uses of CERA funds offer the potential to yield financial returns that could then be used to fund payments to CERA holders when they retire. One possibility is that CERA revenue could be used to provide low-interest loans to existing or start-up private companies pursing climate mitigation technologies. These loans would ideally allow long payback periods, and possibly grace periods. Once the loans are repaid, the money would then be used to provide payments to CERA holders when they retire.

But the greater potential for the CERA program to generate positive financial returns may rest with the success of public-private partnerships. As mentioned above, the U.S. strategic plan on climate change emphasizes the role of public-private partnerships, broadly defined as the joint provision of goods or services by collaboration between public and private entities. In certain circumstances, public-private partnerships will lead to greater social benefits than would occur solely as a result of private investment (Scott, 2000). These circumstances include the development of infrastructure, research on generic technologies, projects with a large potential for spillover benefits, and the pursuit of social, rather than purely market-based, goals. Unfortunately, there is little empirical evidence regarding the benefits of public-private partnerships. A noteworthy exception is a study by Audretsch, et al. (2002) which evaluates the effectiveness of the U.S. Department of Defense's Small Business Innovation Research (SBIR) program. They find that the SBIR program clearly led to firms undertaking research that would not have taken place without the program. In reference to the funded projects, firms reported an expected present value rate of return in the absence of SBIR support of 25 percent, a rate below their reported minimum private return hurdle of 33 percent. In other words, in the absence of SBIR funding the firms would not have deemed the projects financially viable. However, firms that received SBIR support reported an ex post average rate of return of 76 percent for the supported projects, well above the hurdle point. The large gap between the ex post rate of return and minimum acceptable rate (76 percent versus 33 percent) suggests that even if the government received some payback in cases when public support produced profitable outcomes, private firms would still receive net benefits from public support.

While the SBIR results cannot be considered representative of all public R&D investments, they suggest that large financial and social gains can accrue. Thus public R&D funding related to climate change using public-private partnerships may ultimately produce financial rates of return well above the minimum levels necessary to attract firms to such partnerships. Given this possibility, a condition of the partnership could be that the government will share in the financial returns that accrue as a result of partnership. The situation could be likened to a venture capitalist firm that funds risky business opportunities in order to receive a financial return. Not all investments would yield a positive return but others would likely be highly profitable. In fact, private venture capital investments in clean energy are growing rapidly and could comprise ten percent of all venture capital investments by 2009, up from one to three percent during 1999-

2001 (Parker and O'Rourke, 2006). Government investments from CERAs should be designed to complement, rather than crowd out, private investments.

To ensure an efficient use of CERA funds (and limit cronyism), it is recommended the distribution of funds be managed by an independent panel comprised of experts with backgrounds in such fields as energy technology, climate science, and socially responsible investing. The government would eventually sell its stock holdings in private equity markets to fund retirement payments to CERA holders. Thus in the long run the government would phase out all ownership of equities.

The potential for CERA investment to yield positive rates of return will depend on the ability of low-carbon energy technologies to compete with fossil fuel energy in the future. The analysis by Anderson (2006) indicates that even in the long run (more than 20 years) most low-carbon technologies will not be directly competitive with fossil fuel energy sources. Only in the presence of substantial carbon pricing would low-carbon technologies gain a competitive advantage. Other results, however, suggest that some renewable technologies may already be competitive with fossil fuel energy. The Nuclear Energy Agency, et al. (2005) estimates the current costs of generating electricity from wind power to be $35-$95 per Mwh, overlapping with the costs of coal ($25-$50) and gas ($37-$60). Analysis by the American Wind Energy Association (2001) also shows wind energy to currently be cost competitive with higher-carbon electricity technologies.

While loan repayments and public-private partnerships can provide funds to make payments to retired CERA holders, it is possible that the program will not be self-funding and additional revenue will need to be raised to make payments to CERA holders when they retire. Rather than raising the revenue for any shortfall from income or other broad taxes, this paper suggests that the gap be filled by future taxes on carbon-based energy. Any necessary taxes would be minimal towards the start of the CERA program but then gradually increase as more CERA holders retire. The idea that carbon taxes should gradually increase over time is widely accepted in the economics literature (Nordhaus, 2006).

CERA Simulation Model

This section of the paper explores the potential costs of the CERA program over time using a simple simulation model. The simulation estimates the annual withdrawals made by CERA holders over time. Most withdrawals are made once CERA holders retire, although some withdrawals are made prior to retirement as described below.

Analysis of the CERA program must consider the age of those who contribute. Following published IRS data on IRA contributions, US taxpayers are divided into age-based cohorts of five years each (less than 15 years old, 15–20 years old, etc.). Within each age cohort, all individuals are assumed to contribute into a CERA at the mid-point age in the cohort. The maximum age at which contributions to a CERA are permitted is assumed to be 59½ years. Similar to IRAs, it is assumed that CERA holders can withdraw funds at any time but that withdrawals made before age 59½ are generally subject to a 10% penalty.

Real rates of return are assumed fixed for CERA contributions made by each age cohort but vary across cohorts in order to attract younger investors. For the simulation, only the scenario of a $5 billion in additional R&D funding is analyzed. As mentioned above, a CERA program of limited duration is anticipated. It is assumed that the program attracts $5 billion (in real terms) in investment each year for 25 years, after which no further contributions are allowed. The allocation of the $5 billion annual investment across cohorts is based on the distribution of IRA contributions by age group (Sailer and Nutter, 2004) but is slightly modified to represent a younger distribution of investors. Table 2 indicates the percentage of annual CERA contributions received from investors in each age cohort. The table also shows the assumed real rates of return applied to each cohort, ranging from two to three percent in real terms.

The withdrawal of funds by CERA holders of different ages is developed based on IRS statistics on the withdrawal of IRA funds (Sailer and Nutter, 2004). As shown in Figure 2, about 25-30% of IRA withdrawals are made by those younger than age 59½, which in most cases incurs a 10% penalty. The simulation model includes withdrawals made prior to retirement age, adjusted for each age cohort based on the IRS data. The penalties for early withdraw are returned to the CERA program. Figure 2 also shows that only about one percent of IRA withdrawals are made by those over age 80. In the simulation it is assumed that all CERA accounts are depleted by age 85.

Age Cohort	**Percentage of Annual Contributions**	**Annual Contributions (Millions)**	**Real Financial Rate of Return**
Under 15	1%	50,000	3.0%
15-20 Years	1%	50,000	3.0%
20-25 Years	4%	200,000	3.0%
25-30 Years	7%	350,000	3.0%
30-35 Years	12%	600,000	2.7%
35-40 Years	14%	700,000	2.7%
40-45 Years	18%	900,000	2.3%
45-50 Years	18%	900,000	2.3%
50-55 Years	15%	750,000	2.0%
55-60 Years	10%	500,000	2.0%
Total	100%	5,000,000	

Table 2 Assumptions of CERA Simulation

The simulation is run until all payments to CERA account holders have been made, which is 97 years from the start of the program (the youngest investors are age twelve at the start of the simulation; such investors contribute for each year until Year 25, then they withdraw CERA funds until they reach age 85).

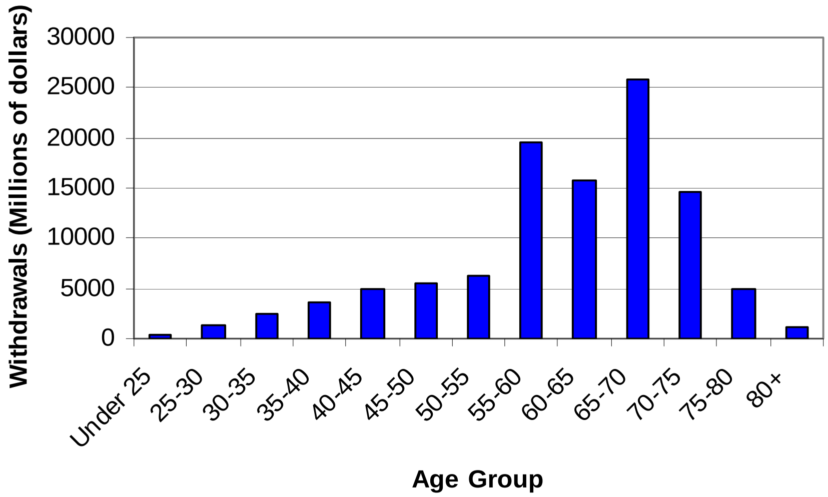

Figure 2 IRA Withdrawals by Age Cohort, 2000 data
Source: Sail and Nutter (2004)..

The results are presented in Figure 3. Total withdrawals start off low as most CERA contributors are less than retirement age. Withdrawals reach \$2.0 billion after 13 years, \$3.0 billion after 18 years, and \$4.0 billion after 23 years. Recall that the simulation assumes annual contributions of \$5.0 billion for 25 years. By the time contributions cease annual withdraws are approximately \$4.7 billion. Thus at the end of the 25 years withdrawals are nearly equal to annual CERA contributions. When contributions cease in the 25th year, withdrawals continue to increase, reaching \$4.8 billion in the 32nd year. Then withdrawals steadily decline, falling below \$1.0 billion in the 65th year and reaching zero in the 98th year. Total withdrawals by CERA holders over the entire simulation period are \$200 billion in real terms.

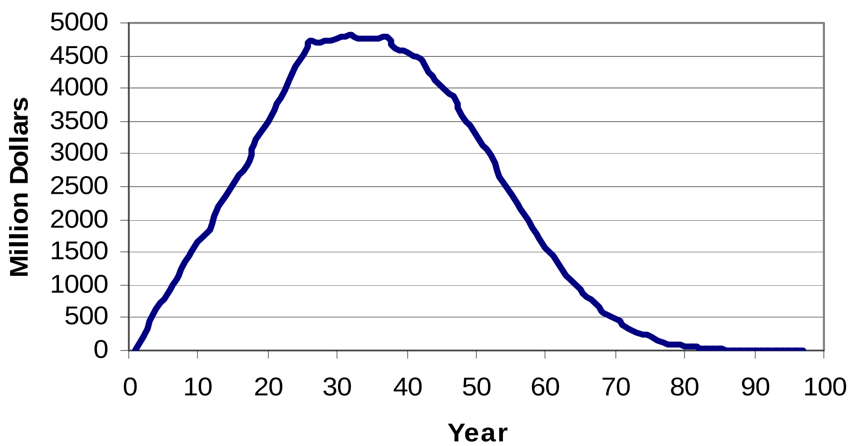

Figure 3 Simulated Annual Withdrawals from CERA Program (Millions of real dollars)

As mentioned previously, revenues from loan repayments and public-private partnerships are expected to at least partially fund payments to CERA holders. The analysis now considers how much revenue could be generated under different assumptions. It is assumed that revenue from these two sources would begin only after a lag period to allow time for new technologies to be introduced to markets and become profitable. A lag period of 10 years is assumed between the time CERA contributions are made and the time returns begin to be generated from those contributions. Also, it is assumed that not all the public-private ventures begun as a result of the CERA program will be viable – some ventures will fail and generate no future revenues. This analysis considers three revenue scenarios:

1. returns on 30 percent of CERA contributions; rate of return of 5 percent for 15 years
2. returns on 50 percent of CERA contributions; rate of return of 10 percent for 15 years
3. returns on 60 percent of CERA contributions; rate of return of 12 percent for 20 years

For example, in the second scenario a return of 10 percent is obtained on half of a CERA contribution of $5 billion made in Year 1 beginning in Year 11 and continuing until Year 25 ($250 million per year). Note that the returns are calculated as a percentage of the initial CERA contribution and that the calculations do not include repayment of any principal. Thus the rate of return in the first two scenarios does not even reflect a return sufficient to payback the original investment. Figure 4 displays the revenue streams generated under each of these three assumptions, along with the estimated withdrawals copied from Figure 3.

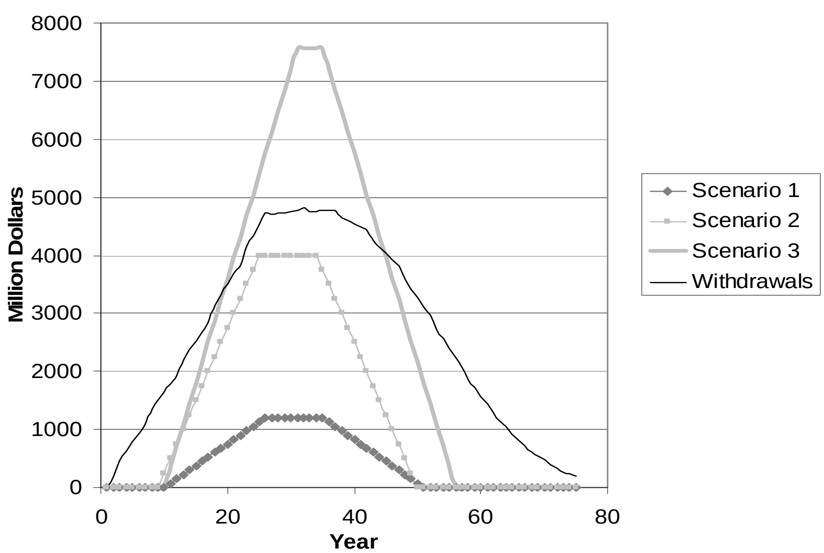

Figure 4 CERA Revenues under Alternative Assumptions

Figure 4 illustrates that the first two revenue scenarios clearly do not fully fund CERA withdrawals by account holders. In the first scenario, revenues from loan repayments and public-private partnerships fund only about 15 percent of CERA payments. In the second scenario, revenues are sufficient to fund half of CERA obligations throughout the life of the program. Yet in the third scenario, with the most optimistic revenue assumptions, CERA payment obligations are fully met with the generated revenues and the program is essentially self-funding. Note that in the third scenario withdrawals exceed revenues during the first 19 years of the program, then revenues exceed withdrawals for years 20-44, and withdrawals exceed revenues beyond the 44th year. Thus the government would need to borrow against future revenues for the early years of the program but then be able to invest excess revenues in the middle years of the program, creating a “trust fund” that would then be used to fund CERA payments towards the latter years of the program.

In the first two revenue scenarios other revenue sources would be required to meet the estimated shortfall. Again, this analysis considers taxes on carbon emissions or gasoline. One possibility is to estimate the required taxes as a constant rate throughout the duration of the program. However, given that the ability of the CERA program to generate revenues through loan repayments and public-private partnerships would be unknown at the beginning of the program, any tax set at inception would most likely need to be adjusted once actual returns were known. Instead, the required tax rates are calculated each year as the amount necessary to close the gap between CERA revenues and withdrawals in Figure 4. In addition to the two scenarios above which would require closing a funding gap, a worst-case scenario is considered in which the CERA program generates no revenues at all from loan repayments and public-private partnerships. For simplicity, the analysis holds carbon emissions and gasoline consumption constant at current levels.

Table 3 displays the results. The maximum tax is the required tax rate at the largest annual gap between withdrawals and revenues. The average tax is calculated over the 97-year duration of the CERA program. These estimates can be compared to the taxes required to fund a $5 billion annual increase in R&D without the CERA program shown in Table 1. Of course, the tax rates in Table 3 are lower than those in Table 1 because of the long duration of the program. Under the worst-case scenario in which no CERA returns are generated, the required carbon taxes average well below $1.00 per ton CO_2 and the average gas tax is only 1.5 cents per gallon. In the scenarios with some CERA returns, the required taxes are quite low – if the shortfall were met through a tax on all gasoline consumption, an average tax of only around one cent per gallon would be necessary.

Conclusions

One component of an adequate U.S. response to climate change would be a significant increase in public R&D funding related to climate change. This paper has demonstrated the financial feasibility of at least doubling such R&D funding. One approach to raising the necessary public revenue would be to institute a tax on carbon emissions or to increase gasoline taxes. The tax levels required to fund a dramatic increase in climate change R&D would still be well below most estimates of socially efficient tax levels.

Scenario	Tax All Carbon Emissions		Tax Industrial and Commercial Carbon Emissions		Tax Solely on Gasoline	
	Max. Tax	**Average Tax**	**Max. Tax**	**Average Tax**	**Max. Tax**	**Average Tax**
No CERA returns	\$0.82/ ton CO_2	\$0.35/ ton CO_2	\$1.72/ ton CO_2	\$0.74/ ton CO_2	3.4¢/ gallon	1.5¢/ gallon
Returns on 30% of contributions; 5% rate of return for 15 years	\$0.61/ ton CO_2	\$0.30/ ton CO_2	\$1.35/ ton CO_2	\$0.63/ ton CO_2	2.7¢/ gallon	1.3¢/ gallon
Returns on 50% of contributions; 10% rate of return for 15 years	\$0.55/ ton CO_2	\$0.17/ ton CO_2	\$1.17/ ton CO_2	\$0.37/ ton CO_2	2.3¢/ gallon	0.7¢/ gallon

Table.3 Required Taxes to Fund CERA Shortfall under Alternative Assumptions

An alternative to raising current taxes would be to institute a program of Clean Energy Retirement Accounts. Through voluntary contributions to CERAs individuals could boost savings for retirement while supporting U.S. efforts to combat climate change. An appealing aspect of the CERA program is that most of the costs, in terms of payments made to retirees, are deferred until the future. Most economic analyses of climate change suggest little deviation from a business-as-usual strategy because even relatively low discount rates diminish future climate change damages while costs must be paid now (Ackerman and Finlayson, 2006). The CERA program allows costs to be distributed over a longer time horizon. While the CERA program might eventually require minor taxes on carbon emissions or gasoline, those taxes would be paid by those directly benefiting from efforts to reduce climate change, and more likely to have access to low-carbon technologies.

The CERA program may be considered an unnecessary bureaucratic complication compared to, for example, simply raising gas taxes a few cents per gallon or obtaining the revenue out of general tax funds. But another potential advantage of a CERA program is that it gives individuals a direct stake in the success of climate change efforts. Given that CERA returns will depend on the success of ventures funded by the program, those who invest in CERAs will have an incentive to support clean energy technologies when they are introduced to markets. A CERA program can also be viewed as a means of increasing democratic participation by empowering citizens to direct resources towards a specific public concern. Similar to the concept of participatory budgeting, whereby public budget allocations are determined by a democratic exchange of stakeholders rather than by elected officials[3], a CERA program would create a new public arena for active citizenship.

The evidence that humanity needs to reverse the increase in carbon emissions is compelling. Global efforts to address climate change have so far been inadequate to the task. Breakthrough technologies that could significantly reduce global emissions of carbon do not appear to be forthcoming in the immediate future. The time lag between basic scientific research and the widespread commercial availability of alternatives to high-carbon technologies is likely to be measured in decades. Thus an intensified search for low-carbon alternatives is needed immediately. A country that takes the lead in the development of low-carbon technologies will likely be in an enviable competitive position in a future which is characterized by higher carbon prices, whether driven by carbon reduction policies or by market developments including depletion of oil reserves. The analysis presented here indicates that the U.S. could take such a leadership position at surprisingly little cost.

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[3] See Novy and Leubolt (2005) for an application of participatory budgeting in Brazil.

REFERENCES

Ackerman, Frank and Ian Finlayson (2006), 'The Economics of Inaction on Climate Change: A Sensitivity Analysis', *Climate Policy,* **6** (5): 509–526.

American Petroleum Institute (2006), *State Motor Fuel Excise Tax Rate Report*, October 2006.

American Wind Energy Association (2001), 'Comparative Costs of Wind Energy and Other Energy Sources', http://www.awea.org/pubs/factsheets/Cost2001.PDF.

Anderson, Dennis (2006), 'Cost and Finance of Abating Carbon Emissions in the Energy Sector', paper commissioned as part of *The Stern Review on the Economics of Climate Change*.

Audretsch, David B., Albert N. Link, and John T. Scott (2002), 'Public/Private Technology Partnerships: Evaluating SBIR-supported Research', *Research Policy,* **31**: 145–158.

Berrens, Robert P., Alok K. Bohara, Hank C. Jenkins-Smith, Carol L. Silva, and David L. Weimer (2004), 'Information and Effort in Contingent Valuation Surveys: Application to Global Climate Change using National Internet Samples', *Journal of Environmental Economics and Management*, **47** (2):331–363.

Bucks, Brian K., Arthur B. Kennickell, and Kevin B. Moore (2006), 'Recent Changes in U.S. Family Finances: Evidence from the 2001 and 2004 Survey of Consumer Finances', *Federal Reserve Bulletin*, 22 March.

Cameron, Trudy Ann (2005), 'Individual Option Prices for Climate Change Mitigation', *Journal of Public Economics*, **89** (2 –3):283–301.

Dooley, J. J. (1998), 'Unintended Consequences: Energy R&D in a Deregulated Energy Market', *Energy Policy* **26** (7):547–555.

Duflo, Esther, William Gale, Jeffrey Liebman, Peter Orzag, and Emmanuel Saez (2005), 'Savings Incentives for Low- and Middle-Income Families: Evidence from a Field Experiment with H&R Block', National Bureau of Economic Research Working Paper 11680, September 2005.

Edenhofer, Ottmar, Nico Bauer, and Elmar Kriegler (2005), 'The Impact of Technological Change on Climate Protection and Welfare: Insights from the Model MIND', *Ecological Economics,* **54** (2–3):277–292.

Giving USA (2006), 'Charitable Giving Rises 6 Percent to More than $260 Billion in 2005', Press Release, June 19, 2006.

Harris, Jonathan M. and Brian Roach (2007), *The Economics of Global Climate Change*, http://www.ase.tufts.edu/gdae/education_materials/modules.html

International Energy Agency (2006a), *Energy Technology Perspectives: Scenarios and Strategies to 2050*.

International Energy Agency (2006b), *World Energy Outlook 2006*. Paris, France.

International Energy Agency (2005), *30 Key Energy Trends*.

International Energy Agency (2003a), 'Integrating Energy and Environmental Goals', Report prepared for the Italian government by the IEA for the Ninth Conference of the Parties of the UNFCCC.

International Energy Agency (2003b), *Energy to 2050: Scenarios for a Sustainable Future*. Paris, France.

Madrian, Brigitte C., and Dennis F. Shea (2001), 'The Power of Suggestion: Inertia in 401(k) Participation and Saving Behavior', *Quarterly Journal of Economics*, **116** (4):1149–1187.

Nemet, Gregory F., and Daniel M. Kammen. 2007. "U.S. Energy Research

and Development: Declining Investment, Increasing Need, and the

Feasibility of Expansion," *Energy Policy* **35**:746-755.

Norberg-Bohm, Vicki (2000), 'Creating Incentives for Environmentally Enhancing Technological Change: Lessons from 30 Years of U.S. Energy Technology Policy', *Technological Forecasting and Social Change*, **65** (2):125–148.

Nordhaus, William (2006), "The 'Stern Review' on the Economics of Climate Change," NBER Working Paper 12741, December 2006.

Novy, Andreas, and Berhnhard Leubolt (2005), 'Participatory Budgeting in Porto Alegre: Social Innovation and the Dialectical Relationship of State and Civil Society', *Urban Studies* **42**(11):2023-2036.

Nuclear Energy Agency, International Energy Agency, and Organisation for Economic Co-operation and Development (2005), 'Projected Costs of Generating Electricity, 2005 Update', Paris, France.

Office of the Press Secretary (2001), 'President's Statement on Climate Change', 13 July 2001, http://www.whitehouse.gov/news/releases/2001/07/20010713-2.html.

Parker, Nicholas and Anastasia O"Rourke (2006), 'The Cleantech Venture Capital Report – 2006'.

Parry, Ian W.H. and Kenneth A. Small (2004), 'Does Britain or the United States Have the Right Gasoline Tax?', RFF Discussion Paper 02-12, September 2004.

Pew Center on Global Climate Change (2002), 'Analysis of President Bush's February 14th Climate Change Plan', February 2002, Pew Center website, http://www.pewclimate.org/policy_center/analyses/response_bushpolicy.cfm.

Pollingreport.com (2007), Environment web page, http://www.pollingreport.com/ enviro.htm.

Popp, David (2004), 'R&D Subsidies and Climate Policy: Is There a Free Lunch?', NBER Working Paper 10880, October 2004.

President's Committee of Advisors on Science and Technology (1997), 'R&D Priorities for Sustainable Development', January 1997.

Sailer, Peter J., and Sarah E. Nutter (2004), 'Accumulation and Distribution of Individual Retirement Arrangements, 2000', IRS Statistics of Income Bulletin, Spring 2004.

Salter, Ammon J., and Ben R. Martin (2001), 'The Economic Benefits of Publicly Funded Basic Research: A Critical Review', *Research Policy* **30**(3):509-532.

Scott, John T. (2000), 'Strategic Research Partnerships: What Have We Learned?', Dartmouth College Working Paper 00-21, November 2000.

Social Investment Forum (2006), 2005 Report on Socially Responsible Investing Trends in the United States, January 24, 2006.

Stern, Nicholas (2006), *The Economics of Climate Change: The Stern Review*.

Tol, Richard S.J. (2005), 'The Marginal Damage Cost of Carbon Dioxide Emissions: An Assessment of the Uncertainties', *Energy Policy* **33**:2064-2074.

United Press International (2007), 'UPI Poll: More R&D on Alternative Energy', January 24, 2007 press release.

United States Bureau of Economic Analysis (2008), Personal Savings Rate, http://www.bea.gov/briefrm/saving.htm.

United States Census Bureau (2007), The Statistical Abstract of the United States, 2007.

United States Climate Change Technology Program. (2006), Strategic Plan. September 2006.

United States Congressional Budget Office (2006), Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions, September 2006.

United States Department of Energy, Energy Information Administration (2006a), International Energy Outlook 2006.

United States Department of Energy, Energy Information Administration (2006b), Annual Energy Outlook 2006 with Projections to 2030.

United States Department of Energy, Energy Information Administration (2007), Annual Energy Review 2006, June 2007.

United States Department of Energy, Energy Information Administration. 2008. Online U.S. Greenhouse Gas Emissions Data.

United States Environmental Protection Agency (2006), Fast Facts: The U.S. Greenhouse Gas Emissions Inventory.

United States General Accounting Office (1999), Social Security: Issues in Comparing Rates of Return with Market Investments, August 1999.

United States Social Security Administration (2006), The 2006 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds, 1 May 2006.

United States State Department (2005), 'U.S. Charitable Contributions Top $240 Billion in 2003', USINFO, 17 February 2005.

World Energy Council (2001), Energy Technologies for the 21st Century, report by a study group of the World Energy Council, August 2001.

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