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A Climate Solution Concept

Jonathan Pershing, Ph.D.
Robert Bradley

Progressive Ideas for a Strong, Just, and Free America

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by Jonathan Pershing, Ph.D. and Robert Bradley

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Executive Summary

While climate change is one of the most pressing problems facing the world, it is also proving to be one of the most intractable. Political, economic and cultural differences between countries have led to different policy choices. This paper examines several alternatives that might be considered as supplements to the evolving international, legally binding climate regime.

In particular, this paper proposes sub-global options – and focuses particular attention on examples of these that might be promoted by a Climate Working Group established by the Group of Eight industrialized nations (G8) to include G8 member countries plus a number of key developing countries such as China, India and Brazil. Two categories are discussed: technology options and the evolution of emissions markets outside of the Kyoto framework. Within the technology arena, numerous alternatives might be worth concerted attention of a Climate Working Group. This paper evaluates three:

- *Cleaning up coal*. Today's coal-fired utilities largely employ a technology that makes capture of carbon dioxide (CO_2) from the waste stream extremely difficult. Supporting the penetration of a new, although more expensive, technology – integrated gasification combined cycle (IGCC) – would allow significant reduction in these capture costs. Combined with the development of technologies to sequester carbon (still untested at commercial scales), a switch to this new technology could yield major CO_2 savings: if all new coal fired power in the United States, China and India by 2030 were IGCC with carbon capture, nearly 900 million tons CO_2 could be saved annually (or approximately 10 percent of these countries' annual CO_2 emissions from power generation). This paper suggests that changes in policies on loan guarantees (e.g., in G8 countries Export Credit Agencies) could spur a shift to such new technology.

- *Promoting Biofuels*. The transport sector accounts for approximately a third of global greenhouse gas (GHG) emissions. A successful switch away from fossil fuels and toward renewable energy sources such as biofuels could dramatically reduce global emissions. One option to promote such fuel switching would be to redirect current national agricultural subsidies away from food crops and to energy crops. Such a change would not only provide incentives for the production of biofuels, but would simultaneously reduce global distortions in the international agricultural commodities market. At scale, such an effort could lead to major emissions reductions: converting currently subsidized crops in the U.S. to biofuel production could eliminate 10 percent of all U.S. road-related GHG emissions. Individual G8 efforts need not be harmonized, but could focus on specific crops of national relevance.

- *Helping hybrids*. Another option for reducing transport-related emissions lies in dramatic improvements in fuel efficiency. One attractive technology is the hybrid gasoline/electric car – which can reduce fuel use by as much as 50 percent. Promoting the penetration of such vehicles (or other low emissions vehicles) into the market can be accomplished through efficiency standards, subsidies or through government purchasing programs. Such programs would primarily serve to “prime the pump” of the international market; over the longer term, it is anticipated that market forces would reduce the costs of these technologies, and allow the removal of any price subsidies.

It is clear that technology solutions will not, in isolation, drive adequate change. Some form of market signal is also likely to be required. To date, the most successful of these appears to be efforts to develop emissions trading programs – combining binding emissions targets with the option to trade allowances under the cap. Such a program was embraced in the Kyoto Protocol and subsequent accords, and a number of countries that are party to Kyoto have developed domestic systems. The European GHG market is the most evolved example of this.

While the U.S. and Australia have not ratified Kyoto, there is some prospect that national or sub-national emissions trading programs could be enacted in those countries, which could allow for some degree international interaction. Promoting efforts that lead to harmonized design of these regimes may allow for easier linking of these systems – and more critically, allow for them to be integrated globally once national programs are established.

A Climate Working Group could: (1) call on all its industrialized members to develop and implement national “cap and trade” programs, and (2) promote the development of common standards for measurement and reporting of reductions, as well as clear and compelling domestic compliance mechanisms, so as to facilitate the integration of trading systems. The Climate Working Group could also promote the development of common standards for project-based offsets, providing additional incentives for engaging developing countries.

While formal commitments at the next G8 meeting may be of an exploratory nature only, such agreements, if more fully implemented, could lead to substantial reductions in national – and global – GHG emissions.

Background and introduction

Climate change is one of the most pressing problems facing the world community. A robust body of scientific evidence makes clear that, while there is more to be learned regarding the geographic distribution and magnitude of climate change impacts, human activities, if left unchecked, will dramatically alter the Earth's climate system.

The core agreements setting forth global commitments for mitigating climate change are the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, which came into force in February 2005. Many parties, in particular, those in Europe, expect Kyoto to form the basis for any next step. At the same time, some of the world's largest emitters have not taken on binding reduction commitments, with the U.S., for example, refusing to accept Kyoto's strictures and with large developing countries facing no emissions caps under the Kyoto structure. Thus, on the one hand, the Kyoto architecture seems vitally important, but on the other, there is arguably a need to look for other avenues for concerted action, provided such action is consistent with or complementary to the aims and processes of Kyoto.

With this perspective in mind, this paper suggests that constructive agreements should be explored at the sub-global level that would have the advantage of producing real emission reductions while at the same time paving the way for engagement at the larger global level by countries whose ultimate participation in a global regime is imperative. In particular, this paper concludes that the G8 could play a vital role in pursuing such agreements by establishing a Climate Working Group in tandem with critical developing countries such as China, India and Brazil, among others.

If the world's largest half dozen developed countries (with the European Union counted as a single entity) along with the largest half dozen developing countries were to comprise a negotiating group, over 80 percent of world Gross Domestic Product (GDP), 70 percent of global emissions, and 60 percent of world population would be covered. Such a group might be small enough to effectively negotiate an accord. Further, the group might have other issues in common: they represent most of the world's trade, most of the investment flows and a very large share of the total technological potential for future action.

There are many examples of such limited fora being used for international agreements. The World Trade Organization began with a limited set of participants – as did the successful Montreal Protocol on Ozone Depletion, and the United Nations charter itself was initially drawn up by only four participants: the U.S., the United Kingdom, the Soviet Union and China. While these negotiations began with a limited group, other countries subsequently joined – over the longer term making these agreements global in scope.

This paper proposes focusing on two categories of agreements among a major emitters group comprising the G8 and key developing countries. The first category involves specific policies to promote the development and dissemination of new technologies to promote low- and zero emitting energy sources, carbon-capture and storage, and long-term research and development, along with strategies to market these new technologies. Technology-focused policies address the long-term time-horizons of climate change that near term price signals often do not capture.[1] Rather than concentrating on marginal changes in the next decade, such an approach may help promote solutions for a 20 to 50 year timeframe. It should be stressed that such policies, in isolation, would likely have little effect. Market signals (appropriately pricing greenhouse gases) will be required to ensure technology penetration and must complement any technology focused effort. Thus, a second category of agreement would focus on expanding the current efforts to develop greenhouse gas trading systems. While the Kyoto Protocol set rules and guidelines for Annex I Parties to trade in emissions, it provides insufficient incentives to engage developing countries in the full trading regime – and to date, no developing country has joined.[2] Neither (although for other reasons) has the U.S. However, many countries might consider systems that had lesser commitments than those established under Kyoto, but which still might allow them to engage in a global greenhouse gas market. While an imperfect proxy for a global system, a series of local parallel regimes may confer some of the benefits of a single international regime, be open to participation by a wider group of countries in the medium term, and pave the way for an ultimate global trading system.

This paper examines both the technology option and the emissions trading option.

In considering the first, we look at three specific sample technology agreement options that could be the subject of agreement within a major emitters group: (1) using loan guarantees to promote the uptake of integrated coal gasification plant technology as a necessary precursor to the widespread application of carbon capture and storage; (2) the rapid penetration of biofuels in the transport sector, promoted by switching subsidies from food crops to energy crops; and (3) promoting the rapid penetration of highly efficient vehicles in the automotive and light truck fleet through measures such as vehicle subsidies, guaranteed government fleet purchases, or efficiency standards. We discuss these ideas as examples of what a Climate Working Group could do; they are not intended to represent an exclusive list of proposals. Rather they illustrate technology efforts in three key domains: carbon neutral fossil fuels for electricity, renewable energy for electricity, and transportation. Collectively, emissions from electricity and transportation account for approximately two thirds of global emissions; significant technology advances in these areas would thus make a major contribution to addressing global climate change.

The proposals discussed here are not intended to serve as a replacement for global policies such as the removal of perverse subsidies (which are rife in both OECD countries and the developing world), or market mechanisms such as globally adopted cap-and-trade systems However, the benefits of drawing in countries that are currently on the climate change sidelines seem considerable. Moreover, while the global process edges forward, real-life decisions are being made that can have beneficial or harmful impacts. For example, hundreds of very large (500 megawatt) coal-fired power plants are on the drawing boards of major countries around the world and will run for decades once they are constructed. If those plants are built to use pulverized coal combustion technology, that would have one set of consequences; if they are built to use Integrated Gasification Combined Cycle, to which carbon capture and storage technologies can be applied, that could have a very different, and far more benign set of consequences. Thus, rather than taking the approach that we will either have progress at the global level or none at all, this paper concludes that action at the sub-global level should be explored with vigor and commitment.

In evaluating which policy choices to make, this paper concludes that it is important to consider the extent to which a policy would contribute to development priorities – particularly of developing and least developed countries. Poorer countries make the legitimate argument that demands for health care, clean water and poverty alleviation are immediate and must be addressed before less obviously pressing issues like emissions reductions can be pursued. Examples abound: over a billion people in Asia and more than 500 million in Africa do not even have access to electricity. Calling on them to limit emissions when their poverty is so acute is untenable. A successful strategy would thus seek to simultaneously protect climate and promote economic growth.

Technology policy options

Loan Guarantees for CO_2-capture-ready Integrated Gasification Combined Cycle Plants

Under almost any projected energy scenario, coal is expected to retain a major or even dominant role in the power sector in several important parts of the world during at least the first half of this century. Prominent among these are China, the United States[3] and India. For these economies, addressing climate change is unlikely to be possible without some strategy for dealing with emissions from their coal sector. Since coal is by its nature a carbon-rich fossil fuel, such a strategy must inevitably involve carbon capture and storage (CCS).[4] The problem is that to make CCS feasible, you need to have Integrated Gasification Combined Cycle (IGCC) plants, rather than conventional coal power plants, usually pulverized coal combustion plants (PCC). While it is technically possible to extract CO_2 for storage from PCC plants, it is both difficult and expensive; IGCC plants, with a different combustion technology, make the separation process easier – and significantly less costly.[5]

The problem is that IGCC plants are currently a good deal more expensive than conventional PCC plants. While their advantages for carbon capture may one day make them more cost-effective in a carbon-constrained world, they are not cost-competitive with PCC plants yet. The commercial scale IGCC plants that are in operation are all subsidized pilot projects; no fully commercial IGCC plant yet exists. This presents both an opportunity and a challenge. There is expected to be considerable room to bring down the cost of IGCC plants, since they are not yet in widespread commercial use, yet some kind of incentive or subsidy is needed at the outset to spur the construction of IGCC plants now rather than cheaper, PCC plants.

The policy option proposed here is to use loan guarantees to offset the initially higher costs of installing such plants, as compared to conventional coal plants.

In addition to the potential advantages of IGCC technology in making CCS possible, it offers important near-term advantages due to its far lower emissions of conventional pollutants such as sulfur, particulates and mercury than is the case with conventional coal power. Indeed, once power plants are required to control these pollutants, (which require expensive end-of-pipe technology in PCC plants) the cost disadvantage of IGCC largely disappears. With developing countries increasingly concerned about the health and economic impacts of pollution, IGCC investment avoids major future costs as well as immediate human impacts.

How could the G8 play a role?

Much energy-sector investment in developing countries is supported in part by developed country government intervention. Most commonly this takes the form of guarantees issued through agencies such as the U.S. Export-Import Bank, or the Export Credit Agencies (ECAs) of many European countries.[6] These underwrite projects in countries seen by investors as risky, and thus enhance the confidence of private sector investors and allow finance to be raised on more favorable terms. Given that a principle obstacle to the use of IGCC is investor perception of technology risk, these mechanisms are well suited to supporting such investments. This might be achieved by reducing the investor risk for deploying new technologies through loan guarantees. Such guarantees are widely used by G8 countries to facilitate investment in countries that suffer a risk premium, particularly in the developing world. Although these bodies support investment in developing countries, there is no reason why a similar form of guarantee should not be used to support IGCC investment in OECD countries. In addition to the countries mentioned above, Australia, Japan and South Africa are major coal consumers. Australia and South Africa are also major producers.

ECAs have come under attack in recent years for supporting projects that are perceived as environmentally or socially harmful, and energy projects are among the most problematic. The support of IGCC, by contrast, would allow the use of ECA funding to support important energy infrastructure projects that would enhance the environment relative to the status quo (PCC) alternative.

Under this proposal, the governments of the G8 would commit to supporting IGCC through loan guarantees under their ECAs. Funds to underwrite such guarantees could come in part from diverting existing ECA support to coal projects in the energy sector and in part from additional money.[7] State guarantees will help investors to overcome the actual and perceived risks that arise both from the relatively new technology and from the political and economic conditions of the project host countries. This model is one familiar to the ECAs and should not be complex to implement.

The advantage in undertaking this action at the G8 level is threefold. First, since the aim is to reduce IGCC project costs through increasing investor familiarity and confidence in the technology, a coordinated approach among investor countries is likely to be productive more quickly than separate initiatives. Secondly, applying environmental standards to ECAs has been the source of disagreement between G8 members in recent years and this kind of collaboration is an opportunity to further environmental goals while avoiding the "race to the bottom" that has characterized competition between ECAs in the past. Finally, a public commitment at the G8 level will be a strong signal both that IGCC technology has an important future and that the G8 countries are prepared to put genuine support behind the improvement of environmental standards in developing countries.

The learning potential for IGCC is the focus here. However, support of this type could also be made available for other technologies, notably renewable energy technologies. Many of these suffer from similar problems of perceived technology risk and some offer significantly greater environmental advantages than IGCC. However, given that in the near term, renewable energy is not expected to be on the scale needed to displace coal use in countries such as China and India, policy alternatives that focus specifically on offsetting the damages from installed and new coal capacity will be critical too.

Expected benefits and costs

The first order benefits of encouraging IGCC implementation are likely to be limited in terms of greenhouse gas (GHG) savings: without an infrastructure for CCS, there is no net carbon benefit. However, promotion of this cleaner technology will bring a major improvement in air and water quality as sulfur, particulate and mercury emissions are drastically cut. Particularly in developing countries this will save many thousands of lives per year.

The total cost of implementing this measure will depend on the degree to which the initial projects increase investor confidence in IGCC technology and increase host country enthusiasm for the advantages of IGCC. If there is a rapid improvement in the technology as a consequence of new investment, and prices come down, total loan guarantees may be limited to several billion dollars over the next several decades (although costs could be a good deal higher if technology does not improve and prices do not come down).

The second order benefits will come when and if it is decided that the risks of climate change warrant the capture and long-term storage of CO_2. The total potential for emission reductions is significant. Taking the U.S., China and India together, if all new coal fired power by 2030 is IGCC with CCS, nearly 900 million tons of CO_2 could be saved annually (or approximately 10 percent of their annual CO_2 emissions from power generation).

Perhaps the most significant uncertainty in this system centers on the cost of this capture and storage. While demonstration scale projects in capture of CO_2 from coal fired generation are now being started and are based on well-understood processes, the science and technology of the CCS approach is still relatively undeveloped. Applying CCS to IGCC plants is far more cost-effective than doing so to conventional power stations, but the cost will still be significant. Current cost estimates range widely – from as low as $10 to more than $60 per ton of CO_2. This implies annual expenditures of between $10 and $50 billion. While a share of the cost may be recouped in slightly higher electricity prices, the initial capital required to establish and operate CCS programs may need to be paid on an ongoing basis by donor countries until such time as developing countries such as China and India are able to participate actively in financing GHG abatement.

One final note concerns the risk of accusations of "tied aid." ECA funding is of course used to support suppliers and industry from the donor country. However, in the case of development assistance such "tied aid" is regarded as highly undesirable, and OECD guidelines generally oppose such linking. As long as the support described above is clearly a part or an expansion of ECA support, it should not be problematic. However, this kind of initiative will have to remain visibly distinct from and independent of development assistance to avoid accusations of tying aid to technologies supplied by donor-country companies.

Promoting biofuels through the diversion of agricultural subsidies

This policy option proposes to speed the introduction of biofuels into the transport fuels market. One way of doing this would be to reallocate subsidies currently used for food crop production to the growing of biofuel crops.

Why promote biofuels?

Addressing transport emissions is one of the most challenging aspects of climate policy. At the global level, the transport sector accounts for approximately one third of total CO_2 emissions.

One solution with significant potential is the wider use of biofuels. These are liquid fuels derived from plants, including ethanol and biodiesel, both of which are already used on a significant scale. Indeed, in Brazil ethanol from sugar cane accounts for a third of all transport fuel used. In addition to potential climate benefits, the use of biofuels can significantly reduce oil demand and thus holds obvious attractions for governments concerned about import dependence and security of supply. At present, biofuels are only minor components of fuel consumption in OECD countries. The most important reason for this is their relatively high cost compared to oil-derived fuels.

How could the G8 play a role?

Most G8 countries heavily subsidize their agriculture sectors. This reflects political priorities in those countries but has a number of serious negative effects, among which are:

- Maintenance of artificially high food prices in rich countries;
- Destruction of developing country agriculture through distorting world market prices for food products;
- Impeding of developing country growth by restricting their access to rich country markets for goods that they produce with a comparative advantage; and
- Related to the above, a critical role in obstructing progress on liberalization of world trade in other goods and services.

At the same time, OECD countries import a large and increasing fraction of their energy supply – with serious consequences for international relations – and use large quantities of fossil fuels, which contribute to serious environmental problems including global climate change.

A policy that could reduce the distortionary effects of agricultural subsidies while providing an alternative to fossil fuel use is therefore well worth exploring.

There are a number of ways in which biofuels can be produced, and some of the most promising involve cellulosic crops. (These are wood and cellulose-based crops such as willow, sorghum and forestry wastes, which can be treated to produce liquid fuels. These crops have the advantage that they can be grown on more marginal land than agricultural crops.) However, some crops that are currently grown for food can also be used to produce biofuels. The main biofuels in question are:

- ethanol, which can be produced from sugar-rich crops, such as sugar cane and sugar beet, or from starchy crops such as grains;
- biodiesel, which is produced from oil-rich crops such as soy and rape seed.

Since these crops are heavily subsidized in most G8 countries under existing programs, the application of these subsidies to production of biofuels should be fairly straightforward. Biofuel subsidies would, in principle, provide the same revenue to farmers and agribusiness that they currently receive for food products. At the same time it will reduce food overproduction and thus lead to less distortion of international food markets. Importantly from the climate perspective, it can bring biofuels close to being price-competitive with (untaxed) gasoline in some circumstances.

If the price were to be reduced – either through the development of new technologies or through the provision of price supports to ethanol or biodiesel production, these fuels could penetrate into the market. The discussion in Appendix 2 briefly analyses the potential for diverting agricultural subsidies to reduce the cost of biofuels and make them a competitive part of the energy mix. It focuses in particular on the U.S. and the European Union (EU) as both are large markets and have heavily-subsidized agriculture sectors that are the subject of criticism in international trade negotiations.[8]

More study will be needed to estimate the effects of this price support on market volumes for biofuels, but the potential is significant. The use of biofuels can be introduced in tandem with both conventional vehicle technology and new approaches. For instance, former CIA Director James Woolsey has pointed out that using an 85 percent ethanol blend in a fleet of hybrids could yield the equivalent of 300 mpg of gasoline mileage.[9] And the potential volumes are significant: if for instance some 50 percent of the subsidized crops were used for fuel production rather than food, this could displace almost 10 percent of current U.S. gasoline consumption and 85 percent of its diesel. In total, the ethanol produced under this scenario would displace over 65 billion liters (17 billion gallons) of gasoline per year. Burning one liter of gasoline leads to CO_2 emissions of about 2.31 kg. Thus the avoided CO_2 emissions would be 151 million metric tons per year. Similarly, the biodiesel produced would displace 17 billion liters (4.5 billion gallons) of diesel fuel per year. Burning one liter of diesel releases about 2.63 kg of CO_2, so this scenario would see avoided CO_2 emissions of 45 million metric tons per year. The combined reduction in CO_2 would be approximately 200 million tons per year. This is equivalent to almost 10 percent of the road transport CO_2 emissions of the U.S. and the EU combined.[10]

The G8 could adopt a commitment to develop proposals for shifting subsidies for suitable crops from food production to production of the same crops for biofuels.[11] Individual G8 country actions need not be harmonized; each country might focus on different crops, or different subsidy reforms. The benefit of common action would primarily be to focus attention – and make a strong statement of international political will – in regard to a biofuels program.

Stimulating the market penetration of highly efficient vehicles

While technology options such as fuel cells and hydrogen have long-term potential, they are not expected to play a significant role for several decades. However, some technologies are already emerging in the marketplace that enable dramatic improvements in vehicle efficiency and consequently significant cuts in fuel consumption.

One very promising technology is that of hybrid-electric vehicles, which combine a battery and an internal combustion engine to significantly decrease fuel consumption. Depending on the type of vehicle, this can lead to as much as a 50 percent cut in fuel use per miles driven.[12] However, other mature technologies are being used to achieve high levels of efficiency improvement, notably advanced diesel technologies. These technologies are referred to collectively below as High Efficiency Vehicles (HEV). It is possible that different countries will have different preferences regarding different technology options. For instance, diesel cars are widespread in Europe and have been promoted in part because of their fuel efficiency, while in the U.S. concerns over the health impacts of ultra-fine particulate emissions have kept diesel use in passenger vehicles low. Additionally, policies may be promoted as part of a longer term strategy: most analysts believe that hydrogen based vehicles will only emerge if advanced hybrid technology penetrates widely.

HEVs offer attractive near-term options for making significant reductions in fuel consumption and thus in GHG emissions. However, at present they cost significantly more than comparable conventional vehicles. While this cost is in part offset by savings from reduced fuel consumption, it remains a significant barrier to wider take-up of the technology generally. The good news is that this cost differential is expected to fall significantly with economies of scale once HEVs are more widespread. Given this potential for cost reduction, and the magnitude of the potential fuel savings, HEVs are a highly attractive target for focused policy support.

This support can take a number of forms. Most economically efficient and "technology neutral" are mechanisms to increase the price of fuel. However, prices would have to rise dramatically to make hybrids immediately attractive purely on a cost basis, and this is not politically tenable at present.

Another option that remains relatively technology neutral is the imposition of efficiency or CO_2 emission standards. Examples of these include the corporate average fuel economy (CAFE) standards in the USA, the voluntary European Automobile Manufacturers Association (ACEA) fuel-efficiency agreement in the EU and the Californian mandate for controlling CO_2 emissions from cars. Such standards have proven difficult to implement, particularly in the U.S. Attempts to update the CAFE standards have repeatedly failed to find support in recent years. The ACEA agreement to limit CO_2 emissions per kilometer for cars sold in Europe is voluntary but it is expected to be met. And the Californian regulation faces legal challenges and does not take effect until 2009, making it too early to tell its impact. Still, increased efficiency standards are an effective policy tool and deserve energetic support.

This section proposes two new programs that would explicitly promote the penetration – and indirectly, reduce costs – of high efficiency vehicles in the market: subsidies for the purchase of HEVs and government fleet purchases of HEVs.

As noted above, different governments may well favor different technologies for this support. This brings the advantage of having several competing technologies with consequently greater choice for the consumer and less risk of globally backing a single technology that fails to live up to its promise. However, since much of the cost reduction being aimed for will come with growing market volume, spreading support over several technology options will reduce the rate at which costs can be reduced.

Price Incentives

Because of its social goods value (in terms of reduced gasoline demand and lower local air pollution), governments have added HEVs to their list of vehicles for which tax breaks, rebates and other price subsidies have been offered. For example, at the federal level, the U.S. consumers purchasing a new Toyota Prius by the end of 2003 were eligible for a "Clean-Fuel" vehicle tax deduction of up to $2,000. State and local municipalities have also provided similar (additional) incentives.

However, such incentives do not fully make up the difference between the price of an HEV and that of lower cost vehicles with comparable amenity values. Furthermore, most of these incentives have sunset clauses – often lasting only two to three years. According to an analysis by Rubin and Leiby,[13] the effectiveness of an incentive is directly related to its duration. They suggest that a subsidy lasting indefinitely can yield a market share of 70 percent, while a subsidy declining to zero after 10 years might generate only a market share of 40 percent (assuming a degree of “learning” by the producers during the period of the subsidy).

The cost and the effectiveness of a price incentive program also depend on the subsidy. Again using results from Rubin and Leiby, a $1600 permanent subsidy in the U.S. could lead to a long term HEV market share of about 45 percent. From this, we can compute a rough carbon saving value from hybrid vehicle penetration: if we assume that the fleet is fully replaced in ten years,[14] the subsidy impact could generate around 168 million tons of CO_2 a year in the U.S. alone, at a cost of between $7 billion per year.

As subsidies are reduced, CO_2 savings decline. However, other policies that promote vehicle penetration into the market might complement a subsidy policy. For example, preferential use of “High Occupancy Vehicle (HOV)” travel lanes, or special dispensation to drive in limited traffic zones (e.g., central London) could provide significant additional non-monetized benefits.

Government Purchases

While price incentives or traffic policies will help drive market penetration through consumer purchases, another option is to modify government purchasing to require that all new light duty vehicles are HEVs. This would have the effect of increasing the volume of HEV production, which will in turn lead to a “learning effect” in the production process, and hence, a decrease in costs. A number of studies have indicated that increasing the volume of a specific product or technology in the market is highly correlated with a lower cost of production. In a study evaluating the learning rates for hybrid vehicles, Rubin and Leiby suggest that vehicle manufacturing prices could decline by 20 to 50 percent if production rates increased from current levels (about 10-20,000 vehicles a year) to 100,000 vehicles a year.

Such volumes are well within the total numbers of vehicle purchased by G8 governments. In the U.S. alone, the government vehicle fleet numbers some 500,000 vehicles. Assuming a 10-year government replacement cycle, the U.S. could purchase approximately 50,000 vehicles annually, enough to generate savings in costs per vehicle of several thousand dollars. Adding other G8 government purchasing could yield additional cost-savings.

Depending on manufacturing costs, this would be a form of direct payment subsidy to the automobile manufacturers; its scale and total benefit would depend in part on the relative manufacturing prices of HEVs compared to conventional vehicles they replace. However, assuming that the additional cost is approximately $3000 per vehicle, the replacement of 50,000 vehicles would require an annual expenditure of $150 million.

A simple analysis provides fuel and CO_2 savings information: According to data on the U.S. government fleet, 277 million gallons are consumed annually. Assuming a 40 percent efficiency improvement, this would yield savings of approximately 111 million gallons.[15] With present prices of approximately $2/gallon, this is equivalent to $220 million – a sum which would help offset the subsidy being paid to the manufacturer.

The CO_2 saved would be relatively small: with annual savings of 111 million gallons, the benefits are only about 0.3 million metric tons of CO_2 a year. The point of the government purchase program, however, would be to help bring down vehicle production costs and prime the market for widespread adoption of HEVs rather than to generate direct greenhouse gas reductions.

The G8 Role

In 2000, the G8 economies emissions from road transport amounted to 2400 million metric tons of CO_2, or nearly 60 percent of the world total from transport. Thus, policies that actively promote vehicle efficiency and lead to significant changes in the sector from these countries will have an enormous global consequence. The key is for the G8 to acknowledge the importance of efforts in the transport sector, to stimulate concerted action, and to commit to taking steps toward such reductions, using the ideas sketched out above as possible examples. A G8 effort might explicitly seek to engage not only governments, but also key auto manufacturers in both G8 countries as well as in China, India and Korea. Such an inclusive effort could significantly offset concerns about unfair competition in the international vehicle market.

Parallel emissions trading regimes

Market-based approaches to addressing environmental problems have become much more prominent in recent years. From the trading of sulfur dioxide emissions among Chinese power plants, to the trading of nitrogen oxide emissions in Los Angeles, to the trading of lead credits in the phase out of lead in U.S. gasoline, harnessing markets to improve the environment has yielded greater environmental benefits at lower costs than traditional regulatory approaches. Designing such markets requires setting an aggregate emissions quota, allocating this quota through permits to firms, allowing these firms to trade among themselves, and then ensuring that all firms in this market submit permits to cover their emissions to the regulating authority at the end of each compliance period. Firms with low compliance costs will sell unused emissions permits to those with higher costs, and this trading ensures the lowest possible cost for achieving the aggregate emissions quota.

This emissions trading approach has drawn substantial attention in the effort to address global climate change. In the multilateral context, international emissions trading was explicitly embraced by the Kyoto Protocol and the subsequent accords detailing implementation. In addition, a number of countries have developed domestic programs that implement their greenhouse gas emissions targets through emissions trading, including the United Kingdom and Denmark, and others are planning such tradable permit programs, including Canada and possibly Japan. The largest greenhouse gas emissions trading program will come online in January 2005 as the European Union initiates trading among its member states for large industrial and utility emissions sources.

While the United States and Australia supported emissions trading in the Kyoto Protocol negotiations, without their ratification of the agreement they obviously would not have an emissions commitment and thus neither a need – nor a right – to engage in international emissions trading under that treaty. However, despite the U.S. rejection of the Kyoto Protocol, several proposals to limit aggregate greenhouse gas emissions, either by sector or by region, have been gaining attention. In the U.S. Senate, the McCain-Lieberman legislation (S. 342) would aim to regulate most sources of greenhouse gas emissions in the U.S. economy by limiting them to their 2000 levels by the year 2010. All regulated sources would receive emissions permits based on their historic emissions, and they could trade these permits to ensure their compliance.[16]

In the absence of action at the Federal level, the states have also begun moving forward on the climate change issue. The Regional Greenhouse Gas Initiative (RGGI), which includes eleven Northeastern and Mid-Atlantic states, will focus on reducing carbon dioxide emissions from the utility sector by setting a region-wide cap and allowing permit trading among the utilities covered by the program.[17] In contrast to the proposed bills in Congress, which currently lack the Administration's support, these states have already decided to move forward and implement the RGGI. Similar State level efforts are underway in Australia, where both Victoria and New South Wales are adopting emissions trading programs.

These proposals for domestic emissions trading programs suggest an enormous potential for international cooperation. With relatively little modification, these domestic trading programs could be tailored to allow for their integration into a common international emissions trading regime. The design of a domestic program could allow for regulated sources to buy emissions permits from any country (or entity therein) following commonly agreed rules. For example, the RGGI would require all regulated utilities to submit emissions permits equal to their emissions for a given year. These utilities could turn in RGGI-issued permits as well as permits from an EU country, or Japan, or any other country within the trading system to demonstrate their compliance.

A limited level of integration could already be achieved if all countries not part of the Kyoto system allowed permits from the Kyoto Parties to be used to offset internal commitments. However, while politically problematic, a more economically efficient approach would allow for any firm to buy and sell in the international emissions market. Thus, for example, integrating the regional Australian and U.S. markets with the EU trading program (assuming comparable levels of stringency in each) could strengthen all of the programs.

First, by enlarging the market, such integration would increase the volume of trading and the deeper, unified market would likely experience less price volatility than the three, smaller separated markets. Second, multinational firms operating under both markets would benefit by playing under the same set of rules. This would lower their costs of complying with greenhouse gas emissions policies in Australia, the EU and the U.S., which would translate into lower costs for consumers. Third, by designing a system in which all firms have a vested interest in climate change policy and the multilateral climate policy agenda more broadly, this approach would further engage them in the development of a post-2012 climate change regime. Active participation by the private sector, especially those who would then have an interest in maintaining the value of their new assets (the emissions permit), would be a welcome change from the indifferent or antagonistic approach taken by many energy-intensive firms to climate change policy. Fourth, it would create an avenue by which the U.S. and Australia could more meaningfully participate with the rest of the developed world on climate change issues, and could serve as a stepping stone to full reintegration in the multilateral climate change regime.

In addition to integrating the domestic program into international emissions trading, the Australian and U.S. programs could be designed to promote investment in climate-friendly projects in developing countries – an analog to the Clean Development Mechanism. Thus, the U.S. and Australia could design programs that simply employ the same procedures for the development and certification of offset projects as in formal CDM projects under the Kyoto Protocol. Alternatively, these countries could choose to take a different route in their developing country offsets programs. This policy variation would provide the benefit of experimentation that could inform the international community as it considers the means of implementing future greenhouse gas emissions commitments. This option would allow for the private sector in the United States and Australia to begin developing investment and strategic ties in climate-related projects in China, India, and other developing countries. Just as in the case with international emissions trading, once these firms have made an investment in a climate-friendly project in a developing country, they have likewise made an investment in the policy regime that governs that investment.

While the domestic tradable permit programs envisioned for the United States in the various proposals described above would likely result in less emissions abatement than would have occurred under the Kyoto Protocol, the effort would not be inconsequential. For example, Senator Carper's legislation (S. 843 in the 108th Congress), which would only regulate carbon dioxide emissions in the utility sector, would still deliver approximately 125 million tons of carbon in emissions abatement from business as usual in 2013 (or approximately 3 percent of 1990 levels). The Northeast states in the RGGI are proposing to limit emissions from the electric generating sector; if a five percent reduction is agreed, it could amount to more than the emissions reductions to be achieved by the UK under its allocation for the EU emissions trading system for the first phase of the plan between 2005 and 2007.[18]

More important than the quantitative emissions abatement, promoting the integration of a U.S. and Australian domestic trading program with the EU trading program or the broader Kyoto Protocol international emissions trading regime would develop the private sector connections and interests in climate change policy that could stimulate more active involvement by the U.S. and Australia in future multilateral negotiations.

G8 Role

Noting that only the European members of the G8 are actively working to implement national emissions trading programs, the first step would be to have the G8 recommend that all members develop and implement national trading programs. While initially these may have different levels of stringency, they should use common standards for measurement and reporting of reductions, and establish clear and compelling domestic compliance mechanisms. The G8 should also actively promote the development of common standards in their national systems for project-based offsets (referred to under Kyoto Protocol as Clean Development Mechanism or Joint Implementation projects), allowing some fungibility between programs, as well as providing additional incentives to engage developing countries.

APPENDIX 1

Potential greenhouse gas emission savings from the promotion of Integrated Gasification Combined Cycle plants

Addressing CO_2 emissions from coal by taking policy steps to make Integrated Gasification Combined Cycle (IGCC) plants the technology of choice for new and replacement coal-fired generation yields two potential advantages from a climate perspective:

1. First order emission reductions due to the higher conversion efficiency of IGCC relative to existing coal power technologies.
2. 2. The potential to capture and store CO_2 from the flue gases. This is far more feasible with IGCC than with other coal-fired generation due to the much higher concentration of CO_2 in the flue gases.

Scale of application

According to projections from the International Energy Agency (IEA), new installations of coal-fired generation capacity through 2030 will be very substantial.

Country	Installed cpacity in 2000 (GW)	CO_2 from coal power 2000 (Mt)	Capacity by 2030 (GW)	CO_2 from coal power 2030 (Mt)
U.S. + Canada	332	2563	422	3561
China	199	1282	696	3462
India	64	420	197	1089

While the increase in total capacity in U.S. and Canada seems relatively modest, the IEA projects a total of 225 GW of new capacity due to the replacement of older plant. In China and India the investment in new plant is almost all for an increase in capacity, due to the surging electricity demands in those countries.

First order efficiency gains

The displacement of older, less efficient coal plant with more efficient modern models will of course reduce fuel consumption and thus emissions. This analysis does not seek to estimate the extent to which an IGCC support system would accelerate closure of older plants. In the case of China and India, both of which are facing chronic shortage of electricity supply, it seems unlikely that investment would be diverted away from new additional capacity towards merely replacing existing capacity. In the US and Canada significant replacement is expected. However, since decisions regarding plant closure are affected more by non-financial issues such as the enforcement of environmental standards, it is not clear that they can be influenced significantly by a loan guarantee tool like the one considered here.

The effect of the guarantees will be principally to encourage the building of IGCC plant in place of more conventional coal power technologies. Current favored technology for new build coal power is Pulverized Coal Combustion (PCC). Although typical conversion efficiencies for existing plants are around 35-36% (significantly lower in developing countries), new PCC plants can have overall thermal efficiencies in the range of 43-45%.

Efficiencies for IGCC plant over the period 2000-2030 are a little more difficult to generalize, as the technology is still emerging. At present, efficiencies are lower than for new PCC plants (around 40%), which means that favoring IGCC will lead to higher emissions at first. However, future technology developments are expected to bring efficiency improvements (up to 49.7% according to the U.S. Department of Energy); these technologies are not currently commercial and the timetable for deployment is unclear. At present, it would seem that favoring IGCC over PCC would lead to an efficiency penalty of 2-5% in the near term, gradually moving to a 4-5 percentage point efficiency gain in the medium to long term.

In the absence of clearer timelines for the introduction of newer and more efficient technologies, it seems plausible that the first-order impacts on emissions from coal power generation will be approximately zero.

The potential for carbon capture and storage

The primary reason for accelerating the deployment of IGCC plant in coal-rich countries is to allow the capture and storage of the CO_2 from the combustion process. IGCC plants are well-suited to this application, as the exhaust gases from such plants are CO_2-rich (lowering separation costs) and at high pressure (lowering compression costs, which are a significant financial and energy cost in CO_2 capture).

It should be borne in mind that installing IGCC does not in itself constitute a climate protection measure, as the capture and storage infrastructure will still need to be added later. However, it does leave this important option open. In stark contrast to PCC plants, where retrofits would be prohibitively costly, CCS can be relatively easily retrofitted to IGCC plants.

So if future coal power investment could be restricted to IGCC technology, what is the potential carbon emission abatement that could be made by retrofitting CCS technology? The annual emission reduction from a loan guarantee system favoring IGCC combined with CCS can be represented as follows:

Emission saving = (N+R) * F1 * F2 * F2

Where:

N = Emissions from new capacity built 2000-2030
R = Emissions from replacement capacity built 2000-2030
F1 = Proportion of emissions that come from plants that are IGCC as a result of the loan guarantees
F2 = Proportion of emissions from IGCC plants for which carbon capture is later technically and economically feasible
F3 = Proportion of captured emissions that can be stored in geological formations.

A number of these factors entail considerable uncertainty. We will consider each in turn.

N (emissions from new capacity) is the best understood. IEA projections in Table 1 project an increase from 2000 to 2030 of CO_2 emissions from coal-fired power generation.

R (emissions for replacement capacity) is estimated here as zero for lack of data, but this is unlikely to be correct. Nevertheless, it will be relatively unimportant in China and India due to the rapid rise in electricity demand which will make capacity closure increasingly difficult. In North America it will be more significant.

F1 (the proportion of IGCC plants driven by loans) is hard to estimate, as it will depend to a large degree on the form and extent of the guarantees offered. However, we can provide some bounds on the range of sums needed. The total new additional installed coal power capacity in the countries considered here is expected to be approximately 1000 GW. Even if we assume a steadily declining cost of IGCC technology, average investment cost over the period is unlikely to be lower than $1000 per MW. At present, IGCC technology is considerably more expensive than competing coal technologies due to its relative immaturity and low volumes. A large-scale program to roll out IGCC would certainly enable economies of scale and experience of application to lower its costs significantly. This may therefore ultimately be expected to lead to IGCC technologies being competitive without government support and thus a much wider application.

The total investment needed will be approximately $1 trillion. While only a fraction of the $16 trillion the IEA estimates will be required in the energy sector over the period, this sum would still stretch Export Credit Agencies (ECA) spending, though not exorbitantly. In 2002, ECAs from OECD countries financed some $56 billion of projects, of which roughly half were in the power sector or related projects. Thus we assume that this level remains broadly constant over 30 years.

Conversely, if the loan is only required to cover the cost differential between PCC and IGCC (today, approximately $300-$500/MW, and likely to decline with time), a sum as little as one third this amount would be needed. Furthermore, it is not clear that the loans would be required for the entire newly installed capacity. If the loans are made to reduce the risk inherent in a new and untested technology, they may be phased out once the volume of new builds reaches ten to twenty percent of the new market, at which point commercial risks should decline. In combination, applying these factors would reduce the total loan obligation amount to approximately $30 billion.

However, this assumes that loan guarantees alone will be sufficient to cover the incremental cost of switching from PCC to IGCC, and that the operating efficiencies improve rapidly enough that power generation provides a payback schedule that is competitive. Another potential limit on F1 is timing: Almost one third of the incremental capacity in China is expected to be installed (or at least well under construction) before 2010. Given the long lead-times in such investments, most of this will be too far advanced to influence with new G-8 guarantees, even if these are implemented swiftly.

Taking into account the above caveats, this analysis uses a value of 50% for F1.

F2 (the proportion of retrofits that is technically and economically feasible) is hard to estimate with precision, but is expected to be high - indeed the relative ease with which IGCC plants can be fitted for carbon capture is the point of this exercise. Here it is assumed that 90% of IGCC plants can be fitted for CO_2 capture. It should be noted that this factor may start at significantly lower initial levels, and the percent suggested here is likely overly optimistic.

F3 (the proportion of CO_2 that can be stored geologically) is difficult to estimate. While the collective potential for carbon storage abandoned coal mines, for enhanced oil recovery, and in saline aquifers is tens of times greater than the total GHG emissions worldwide, disposal sites are not uniformly distributed around the world. As can be seen from Fig 1, in North America the major emission points are situated over or near high prospect areas for CO_2 storage. Conversely, in China the match between emission sites and potential storage areas is much less good. In particular, the coastal regions where both population density and economic growth are concentrated are in many cases 1000 km from sedimentary basins considered "high prospects". In India the situation is more mixed, with high prospect areas to the East and West of the country but with central areas, including the populous state of Uttar Pradesh some hundreds of kilometers from such potential storage.

According to statistics from U.S. DOE and the IEA Greenhouse Gas R&D Program, variability such as this contributes to the wide range in storage costs: from $10 to $50/ton CO_2. In addition, there have been some questions raised about leakage in the transport and injection and long-term storage itself. Combining these factors, it is suggested that about 50% of the capturable CO_2 will be stored within the time span considered here. Even more than with the other factors, the uncertainties here must be stressed.

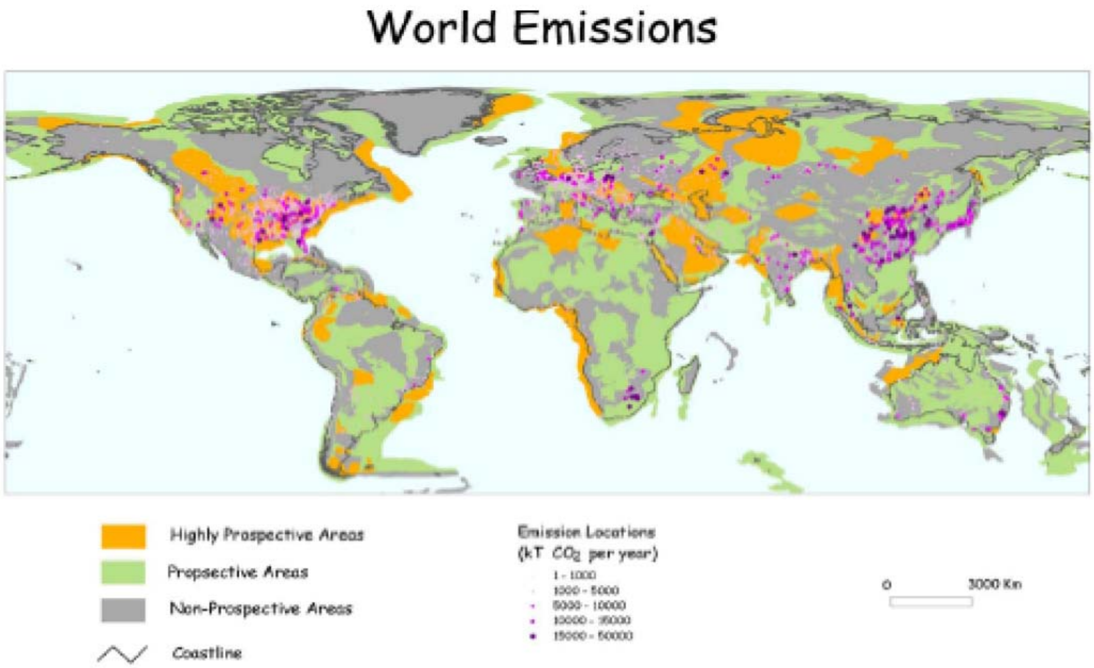


Figure 1: Geographical relationship between CO2 emission sources and sedimentary basins with geological CO2 storage potential

Potential for reductions from CO_2 capture and storage from IGCC

From the above considerations,

$$\text{Emission saving} = (3847 + 0) * 0.5 * 0.9 * 0.5$$
$$= 866 \text{ Mt per year.}$$

This is equivalent to just under 5% of the total CO_2 emissions from these countries in 2030, or just over 10% of the emissions from their power sectors.

It may be noted, however, that perhaps the most significant factor constraining the magnitude of emissions reductions from this effort is the long lifetimes of existing capital stock. If existing plants are retired early (either abetted by additional loans for more efficient new plants, or if required by regulation), the numbers of new IGCC plants – and capturable CO_2 – would likewise increase.

APPENDIX 2

Supporting biofuels though subsidy switching

Biofuels present a number of complexities. First, they are not a “pure” energy source, in that energy inputs are required to produce them. The so-called energy balance – how much net useful energy is produced – depends on a range of factors including the agricultural methods used, the production processes and the difficulties of transporting the fuel to its point of sale. The analysis below does not attempt to address these issues but takes the view that the processes involved can, for instance by using the non-seed parts of the crops to provide energy input into the processes be made very significantly energy-positive. In making comparisons, it is also important to bear in mind that gasoline and diesel themselves require production processes such as refining that are intensive in both energy use and GHG emissions.

The second complication arises due to the varied treatment of biofuels in existing subsidy regimes in G8 countries. This would be a study to itself. Here we simply assume that current biofuels prices reflect these subsidies and that the transferred subsidies considered here can be applied in addition to existing support.

What are the present subsidy levels for crops that could be used for biofuels?

Agricultural subsidies in OECD countries are complex and take a variety of forms. The OECD regularly publishes an overview of these and divides them into two main categories: Producer Support and Consumer Support.[19]

Producer support is generally relatively straightforward and takes the form of direct payment per farm, per unit area cultivated or per unit of production. For simplicity, this analysis reduces Producer Support to a single figure per unit output based on the OECD’s Producer Support Estimate (PSE) for 2003 divided by the production of the relevant crop in that year. Clearly this is crude, as the effective PSE per unit output will vary from year to year depending on yields. However, it provides a useful order-of-magnitude estimate for this purpose.

Consumer Support is more complex. In essence, consumer support comes through measures that cause consumers to pay higher prices for food than they would under free market conditions. It includes tariffs and barriers to trade aimed at maintaining higher prices. These are hard to estimate, as the impact of OECD subsidies on world food markets is so great that there is no undisturbed “real price” for agricultural commodities. In addition to this complexity, it is not at all clear that such support could be transferred to biofuel crops. Thus for the purposes of our calculations Consumer Support has been ignored.

In the EU portion of this analysis, the focus is on the EU community-wide support. While individual member states also give support to their agricultural sectors (notably with support for research and development), the sums involved are very small compared to community-level support and are therefore not included here.

Table 1: Summary of the PSE used in this analysis[20]

	Total PSE (2003, million US$)	**Total Production (million tons)**	**PSE/Ton output (US$/ton)**
EU			
Wheat	11479	92.02	124.74
Barley	6186	46.61	132.72
Rapeseed	1417	8.95	158.32
Sunflower	491	2.67	183.82
U.S.			
Corn (Maize)	4316	261.08	16.53
Soy	4095	66.73	61.37

Notes: EU figures converted to US$ at 1 Euro = $1.2 US$

The crops above cover most of those used for the production of biofuels in the EU and U.S. The only major omission is sugar beet, which is used in France for ethanol production. This is not because sugar beet is unimportant, but the subsidies for sugar are extremely complex and thus have been avoided in this brief paper. A more detailed analysis would have to include them.

The main biofuel crops for biodiesel and ethanol vary between the EU and the U.S.; they are listed in table 2 below.

Table 2: Principal crops for ethanol and biodiesel production in the EU and US

	Ethanol	**Biodiesel**
EU	Wheat, Barley, Sugar Beet	Rapeseed, Sunflower
U.S.	Corn	Soya

What would be the impact of maintaining these subsidy levels for the same crops used for biofuel production?

The efficiency of conversion of crops into biofuel varies according to process and feedstock quality (moisture content, etc.). Studies have therefore produced a range of efficiency values. The IEA has produced a good summary of these results.[21] In order to avoid complexity, here we simply take the median point of the range for ethanol from grain and for the production of biofuel from oil-seed crops.

Table 3: Biofuel production per ton of crop (grains for ethanol, oil-seeds for biodiesel)

	Range of estimates (liters/ton)	**Median (liters/ton)**
Ethanol from grains (wheat, barley, corn)	346.5-470.0	408.25
Biodiesel from oil-seed crops (soya, rapeseed, sunflower)	463	463

Combining data from Table 1 and Table 3, the subsidy per liter of biofuel can be calculated; the results are shown in Table 4.

Table 4: Potential subsidy levels per liter of biofuel

	PSE/Ton output (US$/ton)	Liters per ton (approximate)	Subsidy per liter (approximate US$)
EU			
Wheat	124.74	408	0.31
Barley	132.72	408	0.33
Rapeseed	158.32	463	0.34
Sunflower	183.82	463	0.40
U.S.			
Corn (Maize)	16.53	408	0.05
Soy	61.37	463	0.13

The IEA gives the typical cost for ethanol from a new large-scale plant in the U.S. as $0.29 per liter. This figure includes $0.11 per liter “credit” for the sale of co-products such as animal feed. If ethanol were to be produced on a scale that would satisfy a significant proportion of transport fuel demand in the U.S. then it is unlikely such a special credit would be continued; it has thus been removed from the calculation.

Table 5: Ethanol production costs versus the hypothesized subsidy in EU and U.S.[22]

Costs in US$ per liter	EU	U.S.
Feedstock costs	0.22 – 0.34	0.23
Total Production cost	0.35 – 0.62	0.29
Total per gasoline-equivalent l.	0.53 – 0.93	0.43
Subsidy	0.31 – 0.33	0.05
Subsidized total cost per gasoline-equivalent liter	0.20 – 0.62	0.38
Refinery “gate price” per liter	0.18 – 0.25	0.18 – 0.25

Thus in the EU the transfer of subsidies would be enough to move the price of ethanol to within the range of that of gasoline. This does not take into account policies which favor low-carbon fuels, which would tilt the market further in the favor of ethanol. In the U.S., the smaller scale of subsidies to grain means that ethanol is still not fully competitive with gasoline under these conditions.

The scale of potential emission reductions

Estimating the effects of price changes on the uptake of these alternative fuels will require further analysis. However, to gain an idea of the scale of the potential savings we will assume here that biofuel crop production levels are 50% of the total current yields of the relevant food crops. To keep the calculations simple we have used the median where studies show a range of values for the yield of biofuel per ton of feedstock. The calculations are shown in Table 6 below.

Table 6: Displacement of conventional fuels under hypothetical scenario

	Total Production (million tons)	**50% diverted to fuels (million tons)**	**Biofuel production (million liters)**	**Gasoline or diesel displaced (liters)**
EU				
Wheat	92.02	46.01	18772	15017
Barley	46.61	23.31	9508	7606
Rapeseed	8.95	4.48	2073	1949
Sunflower	2.67	1.33	616	579
U.S.				
Corn	261.08	130.54	53260	42608
Soy	66.73	33.37	15444	14517

In total, the ethanol produced under this scenario would displace 65.23 billion liters (17.23 billion gallons) of gasoline per year. Burning one liter of gasoline leads to CO_2 emissions of about 2.31 kg. Thus the avoided CO_2 emissions from this would be 151 million metric tons per year. Similarly, the biodiesel produced would displace 17 billion liters (4.5 billion gallons) of diesel fuel per year. Burning one liter of diesel releases about 2.63 kg of CO_2, so this scenario would see avoided CO_2 emissions of 45 million metric tons per year. The combined reduction in CO_2 would be approximately 200 million tons per year.

If the figures were applied by region, there would be a significant benefit in terms of oil security. In the U.S. case, for example, the ethanol/gasoline displacement in the U.S. is 42.61 billion liters (11.26 billion gallons), and the biodiesel/diesel displacement is 14.52 billion liters (3.84 billion gallons). This is equivalent to around 9% of U.S. gasoline consumption in 2003,[23] and approximately 85% of US diesel consumption in 2003.[24]

It should be noted that the figures discussed above are analyzed simplistically. For example, they assume that only negligible energy inputs are required in producing the biofuels. This may be true over the longer term -- at least from a CO_2 perspective. If all parts of each plant are used (i.e., including stems, husks and other wastage), the consequent biomass energy could satisfy the additional energy inputs. However, at present, this is not the case – and fossil fuels are used in the biofuel production cycle.

It should also be noted that while this analysis has considered issues relate to the costs of biofuels, a number of other concerns become important if such crop switching is undertaken at a large scale. We are already faced with the environmental impacts of large scale fertilization of crop-lands – which would not diminish with this switch. In addition, there would be clear political and economic impacts from diverting arable land away from food production. These would need considerable additional analysis.

APPENDIX 3

Promoting Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle. Combined, these technologies, result in twice the fuel economy (and concomitant global warming and local pollution benefits) of conventional vehicles, while preserving the range and rapid refueling provided in conventional vehicle technologies.

Table 1 compares the efficiency, fuel consumption (and operating costs) as well as CO_2 emissions of the Toyota Prius (the most advanced and commercially widespread hybrid vehicle) with the Toyota Corolla and Toyota Camry – which are its approximate internal combustion engine (ICE) competitors.

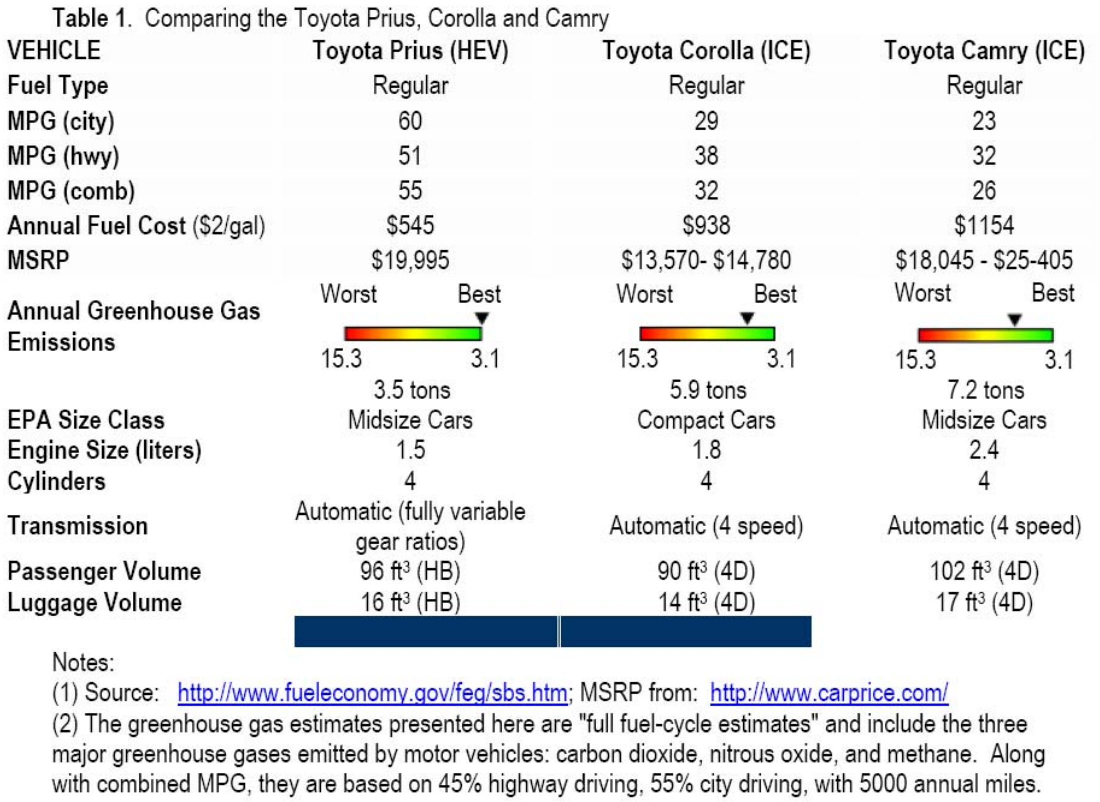


Table 1. Comparing the Toyota Prius, Corolla and Camry

VEHICLE	**Toyota Prius (HEV)**	**Toyota Corolla (ICE)**	**Toyota Camry (ICE)**
Fuel Type	Regular	Regular	Regular
MPG (city)	60	29	23
MPG (hwy)	51	38	32
MPG (comb)	55	32	26
Annual Fuel Cost ($2/gal)	$545	$938	$1154
MSRP	$19,995	$13,570- $14,780	$18,045 - $25-405
Annual Greenhouse Gas Emissions	Worst Best 15.3 3.1 3.5 tons	Worst Best 15.3 3.1 5.9 tons	Worst Best 15.3 3.1 7.2 tons
EPA Size Class	Midsize Cars	Compact Cars	Midsize Cars
Engine Size (liters)	1.5	1.8	2.4
Cylinders	4	4	4
Transmission	Automatic (fully variable gear ratios)	Automatic (4 speed)	Automatic (4 speed)
Passenger Volume	96 ft^3 (HB)	90 ft^3 (4D)	102 ft^3 (4D)
Luggage Volume	16 ft^3 (HB)	14 ft^3 (4D)	17 ft^3 (4D)

Notes:

(1) Source: http://www.fueleconomy.gov/feg/sbs.htm; MSRP from: http://www.carprice.com/

(2) The greenhouse gas estimates presented here are "full fuel-cycle estimates" and include the three major greenhouse gases emitted by motor vehicles: carbon dioxide, nitrous oxide, and methane. Along with combined MPG, they are based on 45% highway driving, 55% city driving, with 5000 annual miles.

According to the Manufacturer's Suggested Retail Price (MSRP), the Prius price is competitive with the Camry (for which it has comparable passenger amenities), although it is substantially above that of the Corolla. In addition, many analysts have suggested that the Prius is still subsidized by Toyota (see Motor Trends, 2003). According to these analysts, Toyota will only recoup its development costs once the technology is much more widely applied to its fleet – including, in particular, its SUV fleet. However, it should be noted that Toyota's own statements indicate the vehicle is "profitable".

For a new vehicle (with completely new technology), the Prius has seen a rapid penetration into the market. Since its redesign in 2003, it has become popular. While Toyota has regularly raised the share of manufactured vehicles offered in the U.S. market, waiting lists are still fairly long. However, in spite of this success fewer than 10,000 vehicles were sold in the U.S. in 2003, and only about 25,000 vehicles were sold from January through June of 2004. However, Toyota has increased production levels to about 10,000 units per month.[25]

Other manufacturers are well behind the penetration (and technical development) of Toyota. The closest competitor is Honda, whose Civic hybrid sold 21,000 units in 2003.[26] Ford Motor Company introduced a hybrid Escape for the 2005 model year, and other manufacturers have promised hybrid models soon.

Because the technology requires no shift in transport infrastructure (unlike hydrogen or natural gas, it does not require new fueling stations, and unlike electric vehicles, it does not limit vehicle travel ranges), this technology may be amenable to more rapid market penetration through price signals and efforts to reduce production costs via guaranteed purchases.

Price Incentives

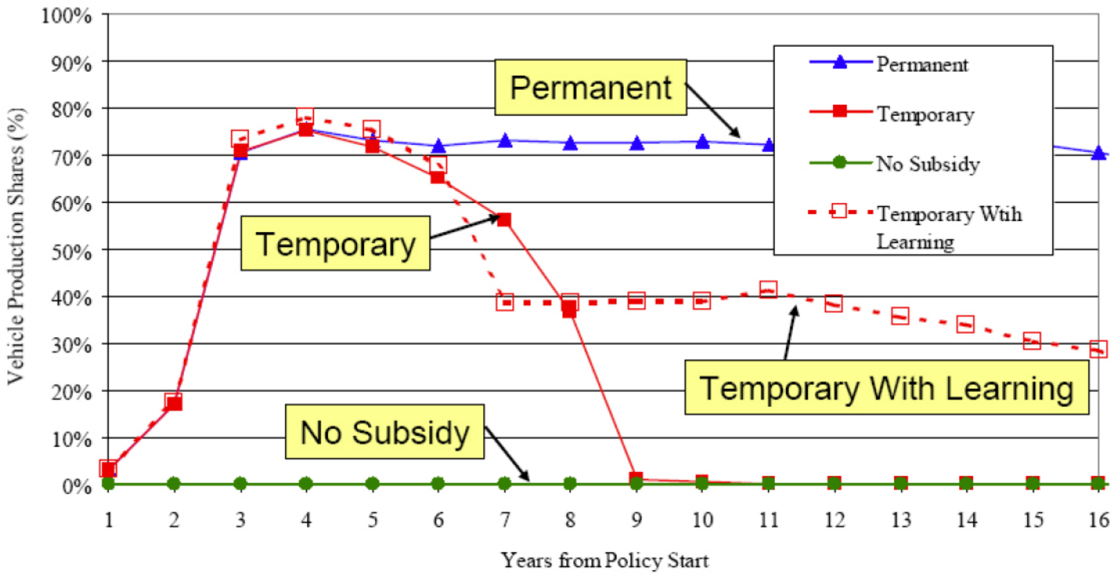
Because of its social goods value (in terms of reduced gasoline demand, and lower local air pollution), governments have added HEVs to their list of vehicles for which tax breaks, rebates and other price subsidies have been offered. For example, at the federal level, the US consumers purchasing a new Toyota Prius by the end of 2003 were eligible for a "Clean-Fuel" vehicle tax deduction of up to $2,000. Although the current incentive is scheduled to phase out over the next two years, vehicles purchased in 2004 will be eligible for a deduction of up to $1,500, vehicles purchased in 2005 will be eligible for up to $1,000, and vehicles purchased in 2006 will be eligible for up to $500.[27]

State and local municipalities have also provided similar, additional incentives. For example, in 2002, a new provision was added to New York's tax incentive program that provides a tax credit of up to $2,000 for the purchase of qualified hybrid-electric vehicles. To qualify, the vehicle must draw propulsion energy from both an internal combustion engine (or heat engine that uses combustible fuel) and an energy storage device; and must employ a regenerative braking system that recovers waste energy to charge such energy storage device. Current production models such as the Toyota Prius and Honda Insight qualify. This provision is retroactive for purchases of qualified hybrid-electric vehicles beginning with the 2000 model year.[28]

However, such incentives do not fully make up the difference between the price of an HEV and that of the lower cost, essentially comparable vehicles. Furthermore, most of these incentives have sunset clauses – often in the next two to three years. According to an analysis by Rubin and Leiby,[29] the effectiveness of an incentive is directly related to its duration. This conclusion can be seen in Figure 1 below. In the

"No Subsidy" case, the market share remains extremely small and does not change much over time. In a "Full Subsidy" case, the market share can rapidly climb to more than 70%. One of the consequences of such subsidies is a degree of "learning" in which the manufacturer improves the process – largely due to economies of scale. Even if the subsidy is then withdrawn, a substantially larger market share is maintained (in the model developed by Rubin and Leiby, approximately 40% (declining to 30% after 15 years)

Figure 1. Market Subsidies and Vehicle Production Shares



Notes:

(1) Source: Jonathan Rubin and Paul Leiby (University of Maine and ORNL), 2002. Transition Modeling: A Comparison of Alternative Fuel and Hybrid Vehicles.

(2) This model assumes a subsidy of $2400, provided in year 1, and either (1) continuing permanently, or (2) ramping down beginning in year 4 and phasing out in year 9.

The cost and the effectiveness of such a program depend on the level of the subsidy. According to Rubin and Leiby, a $1600, permanent subsidy in the U.S. could lead to a long term HEV market share of about 45%, while a $4000 subsidy could generate and HEV share of 90%. Table 2 sets out the potential costs and CO_2 savings using this data. (Note that this information may not correlate exactly with similar subsidy rates in the EU, where vehicle prices reflect a higher proportion of taxes, and the existing fleet is considerably more efficient.)

Table 2: HEV Subsidies – Costs and CO_2 Savings

# new ICE vehicles/year (cars + light trucks)	12,016,660	12,016,660
Share of vehicles upgrading (%)	40%	90%
Subsidy price per vehicle ($/car)	$1600	$4000
Total annual subsidy ($)	$7,690,662,440	$43,259,976,000
Annual carbon saved per vehicle* (tons CO_2/year)	3.5	3.5
Total CO_2 savings in first year	16,823,324	37,852,479
Total CO_2 savings over 10 years	168,233,240	378,524,790

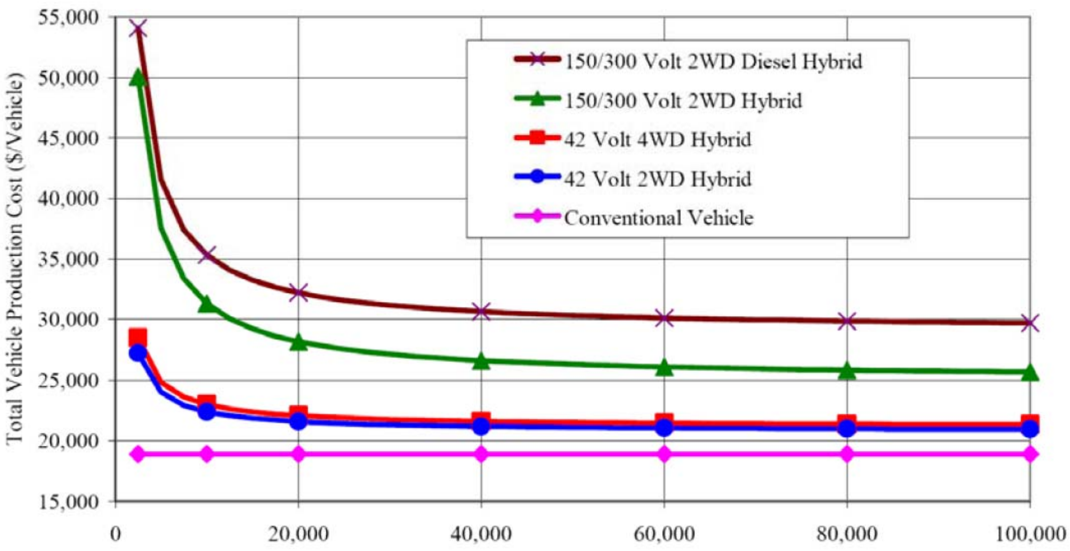
*From Toyota data comparing the Prius and the Camry

If we assume that the fleet is fully replaced in ten years, the subsidy impact could save between 168 and 378 million tons of CO_2 a year in the U.S. alone, at a cost of approximately $7 to $43 billion per year.

Government Purchases

While price incentives will help drive market penetration through consumer purchases, other levers are also available to help promote penetration of HEVs. One option is to modify government purchasing to require that all new light duty vehicles are HEVs. This will have the effect of increasing the volume of HEV production, which will in turn lead to a "learning effect" in the production process, and hence, a decrease in costs. According the work of Rubin and Leiby (see Figure 2 below), this could yield a considerable benefit:

Figure 2. Vehicle cost vs plant size



According to the Federal Fleet report,[30] the U.S. currently maintains a fleet of approximately half a million vehicles. These are distributed among agencies as follows:

Table 3: Federal Agency Fleet

Agency	**# of Vehicles**	
	FY01	**FY02**
Corps of Engineers Civil	4,904	4,635
Defense Agencies	2,154	2,027
Defense Logistics Agency	0	3,106
Department of Agriculture	40,969	37,862
Department of Air Force	53,655	44,733
Department of Army	73,209	67,197
Department of Energy	15,659	14,368
Department of Health and Human Services	3,818	2,678
Department of Justice	42,533	41,910
Department of Labor	4,572	5,491
Department of Navy	40,005	38,463
Department of State	6,521	6,847
Department of the Interior	34,197	36,770
Department of Transportation	10,486	9,087
Department of Treasury	19,706	19,023
Department of Veterans Affairs	8,403	9,328
General Services Administration	2,344	2,214
National Aeronautics and Space Administration	2,261	3,994
Tennessee Valley Authority	2,764	2,977
U.S. Postal Service	210,124	208,395
United States Marine Corp	11,141	11,068
Total Large Fleets	**589,425**	**572,173**

About the authors

Dr. Jonathan Pershing is the Program Director for Climate and Energy at the World Resources Institute (WRI). His focus is on both U.S. and international climate change policy; he is active in work on emissions trading, energy technology and the evolving architecture of international climate agreements. Prior to joining WRI, Dr. Pershing was head of the Energy and Environment Division of the International Energy Agency (IEA) in Paris. From 1990-98, Dr. Pershing served in the Office of Global Change, U.S. Department of State, first as science advisor, then Deputy Director. He was a key U.S. negotiator for the United Nations Framework Convention on Climate Change and the Kyoto Protocol and also supported negotiations on the Montreal Protocol on the Depletion of the Stratospheric Ozone Layer. Dr. Pershing has lectured worldwide and taught at American University and the University of Minnesota. He is the author of dozens papers and several books on climate change, energy, and environmental policy. Dr. Pershing holds a Ph.D in geology and geophysics from the University of Minnesota.

Robert Bradley is an Associate II in the Climate and Energy program at the World Resources Institute (WRI). His areas of expertise include climate change, energy and transportation, and he is currently involved the Sustainable Development Policies and Measures project and the Climate Analysis and Indicators project.

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Endnotes

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[1] For example, new technologies often suffer under-investment because of the externalities of the R&D process. Even if we put the "right" price on carbon, there is still the problem that firms cannot fully appropriate all of the benefits of their innovative activities and thus innovate less.

[2] It might be noted that several countries (both during and since the Kyoto negotiations) have proposed participating in a trading system, including Mexico, Argentina and Kazakhstan. However, procedures to amend the Protocol are cumbersome, and there have been strong political barriers to allowing the system to be modified raised by other developing countries opposed to any targets. Furthermore, national systems of accounting and reporting would be necessary to ensure that any emissions trading programs in developing countries would be environmentally legitimate and compatible with those of Annex I countries; such systems have yet to be developed in much of the world. Developing countries are, however, engaged in the international GHG market through the Clean Development Mechanisms, which allows certified project-based offsets to be counted for credit against national caps of Annex I Parties.

[3] Projections to 2030 in this paper are taken from the International Energy Agency (2002 World Energy Outlook). Their projections combine the USA and Canada, due in part to the integration of the electricity systems of these two countries. Therefore the data here are for those two countries combined. However, the USA accounts for the overwhelming majority of this coal use both at present and in 2030. For instance in 2002, the U.S. consumed 1,065.84 million short tons of coal while Canada consumed 72.21 million short tons (EIA, International Energy Annual 2002, http://www.eia.doe.gov/pub/international/iealf/table14.xls).

[4] Carbon storage entails injecting the carbon dioxide from fossil fuel use into geological formations that appear likely to be able to retain it for millennia. It has been proposed that CO_2 storage may also be undertaken in the deep ocean. However, long-term ocean mixing and the unknown effects of enhanced CO_2 concentrations in this environment make this disposal solution much more controversial. While CCS technology is currently successfully employed (albeit at relatively limited scale) in enhanced oil recovery programs, it has yet to be commercially demonstrated at large scale for coal fired power plants. Pilot programs are currently underway in the U.S.; these are expected to provide information on capture, transport and injection of CO_2 derived from electric power. However, the still-experimental nature of these projects lends a degree of uncertainty to the long-term viability of the IGCC approach.

[5] Costs of extraction in PCC plants are high due to the low CO_2 partial pressures (0.012-0.014 MPa) in plant flue gases. However, IGCC offers much lower incremental costs for CO_2 capture. It involves heating the coal (or other fuel) to produce a synthesis gas rich in both CO and CO_2 and at relatively high pressure (20-70 atmospheres). These give a partial pressure of CO_2 one or two orders of magnitude higher (0.16-1.4 MPa) and thus much more efficient CO_2 capture.

[6] These take various forms and names in various OECD countries, but for simplicity they are referred to here collectively as ECAs.

[7] Redirected finances should not come at the expense of renewable energy or energy efficiency projects.

[8] Note that in the U.S. in particular the production of ethanol is already subsidized, and existing cost estimates include those subsidies. This exercise assumes that shifted food subsidies will be additional to existing support for biofuels.

[9] See James Woolsey's 2004 article "Implications of U.S. Dependence on Middle East Oil." http://www.washingtoninstitute.org/watch/Policywatch2004/882.htm . It might be noted that some overlap between biodiesel and HEV technology could reduce the overall CO_2 reduction.

[10] IEA data: In 2001, U.S. CO2 emissions from road transport were 1445.2 Mt; EU 778.1 Mt.

[11] This proposal does not necessary affect existing cropping patterns. However, it might be made more compelling on sustainable development grounds if it was linked to a commitment to put in place environmental safeguards to ensure that increased subsidies for biofuels did not encourage the development of large plantations or monocultures using chemical-intensive methods, and instead encouraged the use of different crops and sustainable methods, while being sensitive to the land-use implications.

[12] According to manufacturer's data, the Toyota Prius uses as little as 50% as much fuel per mile as a comparable conventional vehicle. However, some heavier vehicles such as the Dodge Durango concept vehicle only demonstrate some 20% cut in fuel consumption from converting to hybrid technology. What a "typical" figure should be across the vehicle fleet in open to debate. Here we have used a 40% fuel economy as a rule of thumb, but this must be taken as an approximation only.

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[13] Jonathan Rubin and Paul Leiby (University of Maine and ORNL), 2002. Transition Modeling: A Comparison of Alternative Fuel and Hybrid Vehicles,

[14] It might be noted that in the U.S., the fleet turnover is approximately 14 years. Thus, this estimate is optimistic regarding the rate of change, although scrappage policies or other policies to induce turnover might supplement this one.

[15] Many economists assume that the increase in efficiency of the vehicle (and reduced fuel costs) will lead to an increase in overall driving; this is called the "rebound effect". Debate over the magnitude of this effect rages, but may be as high as 10%, suggesting overall reductions might be reduced by 10 million gallons.

[16] Over the past five years, a number of other bills have been introduced in both houses of Congress that would regulate the four major air pollutants in the utility sector: sulfur dioxide, nitrogen oxides, mercury, and carbon dioxide. These so-called 4P bills vary in the stringency of the carbon dioxide emissions targets. For example, a bill introduced by Senator Carper (S. 843 in the 108th Congress) would cap utility sector carbon dioxide emissions at the 2006 level in 2009 and the target would decline to the 2001 level by 2013. These 4P policies would allocate emissions permits (specific to each pollutant) to utilities and allow them to trade among themselves.

[17] For more information about the RGGI, refer to http://www.rggi.org/index.htm.

[18] See the UK National Allocation Plan: http://www.defra.gov.uk/corporate/consult/euetsnap-stagethree/nap.pdf, section 1.11.

[19] OECD 2004. Producer and Consumer Support Estimates, OECD Database 1986-2003 http://www.oecd.org/document/58/0,2340,en_2649_37401_32264698_1_1_1_37401,00.html

[20] *ibid.*

[21] International Energy Agency 2004. Biofuels for transport: an international perspective. IEA.

[22] *ibid.*

[23] The BP Statistical Review of World Energy 2004 gives US gasoline consumption as 9.27 million barrels per day, equivalent to 462 billion liters per year.

[24] The BP Statistical Review of World Energy 2004 gives US diesel consumption as 762,000 barrels per day, equivalent to 17 billion liters per year.

[25] http://wardsauto.com/ar/auto_toyota_ups_prius/

[26] http://automobile.auto123.com/en/info/autonews/index,view.spy?artid=23653

[27] Source: US Department of Energy: http://www.eere.energy.gov/cleancities/vbg/progs/laws2_nm.cgi?US Note that the incentive is for the incremental cost to purchase or convert qualified clean fuel vehicles. The Federal Tax code provides a deduction for the clean fuel vehicle property portion of a vehicle and certain refueling properties. A tax deduction for the purchase of a new original equipment manufacturer (OEM) qualified clean fuel vehicle, or for the conversion of a vehicle to use a clean-burning fuel, is provided under the Energy Policy Act of 1992 (EPAct), Public Law-102-486, Title XIX-Revenue Provisions, Sec. 179A. The amount of the tax deduction for qualified clean fuel vehicles is based on the gross vehicle weight (gvw), the type of vehicle and the value of the vehicle's clean fuel vehicle property, as defined in IRS Code Section 179A. Maximum allowable deductions are as follows:Truck or van, gvw of 10,000-26,000 lb = $5,000 ; Truck or van, gvw more than 26,000 lb = $50,000 ; Buses, with seating capacity of 20+ adults = $50,000; All other vehicles, off-road vehicles excluded = $2,000.

[28] Source: New York State Energy Research and Development Authority: http://www.nyserda.org/afvtax.html

[29] Jonathan Rubin and Paul Leiby (University of Maine and ORNL), 2002. Transition Modeling: A Comparison of Alternative Fuel and Hybrid Vehicles, However, while new analyses would need to be undertaken to generate comparable numbers, the general principles should apply in both cases.

[30] Source: FY2002 Federal Fleet Report, GSA, 2003

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Center for American Progress
1333 H Street, NW, 10th Floor
Washington, DC 20005
Tel: 202.682.1611 • Fax: 202.682.1867
www.americanprogress.org