A Perspective Paper on a Technology-led Climate Policy as a Response to Climate Change

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A Perspective Paper on R&D in Green Energy Technologies as a Response to Climate Change

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ABSTRACT

The Assessment Paper by Galiana and Green clearly establishes: (1) the inexorable growth in demand for energy services over the current century, (2) the magnitude of the technological revolution required to address climate change, and (3) the inability, for various reasons, of *on the shelf* technologies to adequately fulfill the required technological change. This *Perspective Paper* generally agrees with their conclusion that comparing a *Technology-Led Policy* to *Brute Force Mitigation* produces benefit cost ratios well above one. Several points are central to their calculations, and to consideration of climate R&D in general, and require further elaboration:

1. A carbon price signal is insufficient to induce the technology development investments required to limit global temperature increase for two reasons: first, voters have a low willingness-to-pay to avoid climatic damages and second, knowledge spillovers make the private returns to R&D investments low.
2. The Technology Led Policy will shift the bulk of technological decision-making from the private sector to the public sector; several challenges need to be resolved to achieve the BC ratios described including: reliance on fewer decision-makers, institutional capacity, unstable social priorities, and risk aversion.
3. Full acknowledgment of the inherent stochasticity of the returns to R&D investments makes the Brute Force Mitigation policy alternative best described as a highly risky choice, rather than dismissible as a futile one.
4. Collective action problems associated with international cooperation on R&D would produce unproductive duplication of effort, analogous to a patent race.
5. Mediation of crowding out effects could improve BC rations.
6. Alternative policies that involve low abatement costs and high climate-related damages are more likely in many large emitter countries than is Brute Force Mitigation. Consideration of modest mitigation, modest technology investment policies would clarify the crucial role of technology investment.
7. Incorporation of health related co-benefits associated with changes to the energy system would produce substantially higher benefits values for all options that involve mitigation.

This paper describes these issues and comments on their implications for the benefit-cost ratios estimated in the Assessment Paper.

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The Copenhagen Consensus Center has commissioned 21 papers to examine the costs and benefits of different solutions to global warming. The project's goal is to answer the question:

"If the global community wants to spend up to, say $250 billion per year over the next 10 years to diminish the adverse effects of climate changes, and to do most good for the world, which solutions would yield the greatest net benefits?"

The series of papers is divided into Assessment Papers and Perspective Papers. Each Assessment Paper outlines the costs and benefits of one way to respond to global warming. Each Perspective Paper reviews the assumptions and analyses made within an Assessment Paper.

It is hoped that, as a body of work, this research will provide a foundation for an informed debate about the best way to respond to this threat.

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CONTENTS

1 PRICE SIGNALS ARE INSUFFICIENT FOR INDUCING TECHNOLOGY INVESTMENT

A central argument behind mitigation-oriented approaches to climate change is that policy-driven changes in prices will stimulate development and adoption of improved low-carbon technologies. There are two distinct reasons why a GhG-based price signal is insufficient to induce the required investments in technology development: (1) knowledge spillovers associated with technology development investments are high and (2) the public apparently has a low willingness-to-pay for climate change mitigation. The scope of the changes to the energy system is indeed vast but in itself does not justify the Technology-Led Policy; it is these two reasons that make carbon prices inadequate. There is a wide body of literature on *induced technological change* making the case that changes in input prices, and expectations about future markets direct investments in innovation. It is the weaknesses in that argument that provide the strongest justification for the Technology-Led Policy described in the Assessment Paper.

1.1 Knowledge spillovers make payoffs too low

Knowledge spillovers, arises because firms under-invest relative to the socially optimal level of R&D (Nelson 1959; Arrow 1962; Teece 1986). Firms are unable to capture the full value of their investments in R&D because a portion of the outcomes of R&D efforts "spills over" to other parties as freely available knowledge, e.g. other firms can reverse engineer new products (Griliches 1992). Jones and Williams (1998) found that the social rate of return to R&D is four times larger than the private rate of return. Okubo, Robbins et al. (2006), in an effort to estimate the macro-economic asset value of R&D expenditure, surveyed previous work comparing the social and private rates of return to R&D. In Figure 1, I display the data in the surveyed studies - (Terleckyj 1974; Mansfield, Rapoport et al. 1977; Sveikauskas 1981; Scherer 1982; Bernstein and Nadiri 1988; Goto and Suzuki 1989; Bernstein and Nadiri 1991; Nadiri 1993) - to show that the public rate of return consistently exceeds the private rate of return and to show the dispersion in estimates. The average private return to R&D across these studies is 25% whereas the public return is 66%. While spillovers, per se, are beneficial since they expand access to the outcomes of R&D efforts, inappropriability prevents firms from receiving the full incentive to innovate and thus discourages them from investing as much in R&D as they otherwise would.

The inability of firms to appropriate the returns to their investments in innovation is an even more severe problem for early stage technologies, such as would be necessary to catalyze the energy technology revolution called for in the Assessment Paper. Much of the technical progress in early stages easily becomes shared knowledge, is difficult for inventors to patent or easy for others to patent around, and is less amenable to becoming embodied in physical devices and manufacturing equipment and processes. *Because knowledge spills over, price signals alone, even in combination with strong intellectual property protection, fail to provide sufficient incentives for private sectors to invest in developing technologies needed to transform the energy sector.*

Figure 1: Private and social rates of return to R&D

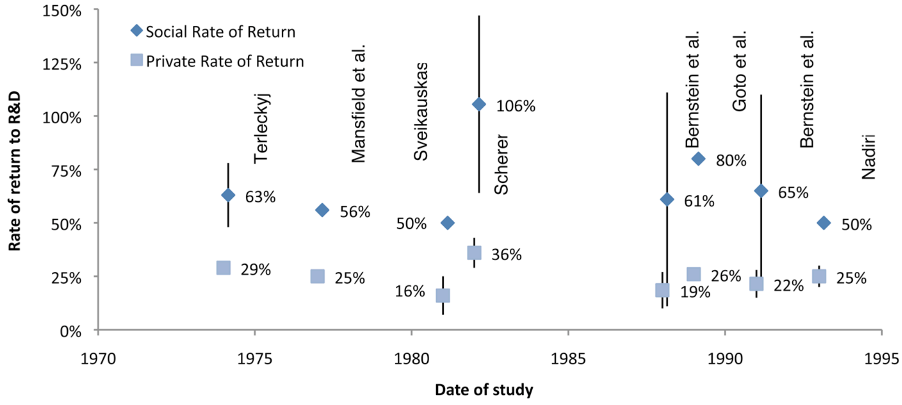
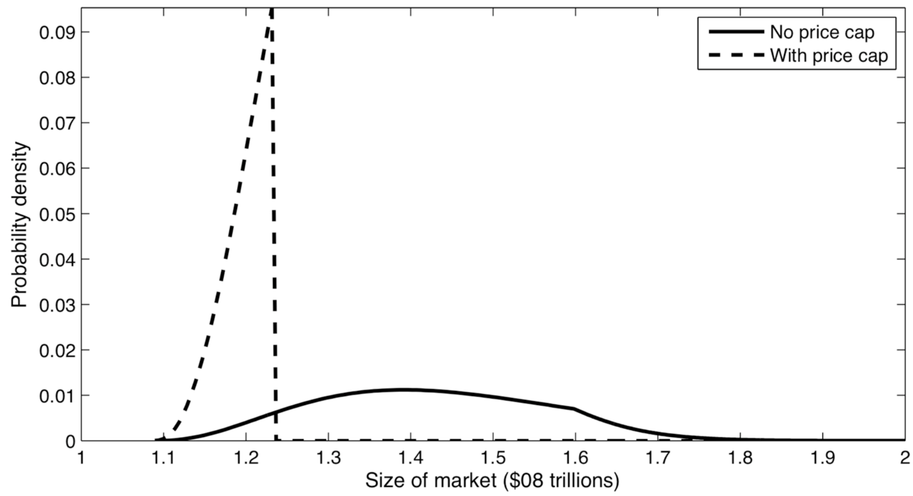


Figure 2: Size of a market for a low-carbon energy technology with and without carbon price caps



1.2 Willingness to pay for avoided climatic damages is too low

A second deficiency of the argument that mitigation policy will induce technological change is the low-likelihood of carbon prices high enough to provide incentives for the required investments. Uncertainty in expectations about future policies increases the risk in investing in low-carbon energy technologies. If expectations about the level - or existence - of mitigation policies several years in the future are uncertain, then firms will discount the payoffs resulting from these future policies and under-invest in innovation.

Firms are rational in discounting proposed policies and resulting prices. A dominant characteristic of public policy related to energy over the past four decades has been volatility; targets are set and are changed; the electoral cycle reshuffles supportive political coalitions. Even for policies that involve "long-term" targets, out-clauses and options for non-compliance undermine longer-term incentives in the name of "flexibility" and "cost containment." For example, "safety valves" included in an array of proposed GhG reduction policies impose price caps on carbon prices, thereby limiting the payoffs to investments in innovation. Figure 2 shows an example of the reduction in payoffs for a hypothetical technology investment imposed by recently proposed legislation in the U.S. Congress (Nemet 2008). It shows a probability density function (PDF) showing the size of the market for a zero-carbon technology (trillions of current dollars) assuming a distribution of possible future carbon prices. The solid line shows the PDF of market size when no price cap is in place and the dashed line shows the PDF of market size with a price cap in place at $29/tCO2.

The low expected likelihood of high carbon prices is often attributed to "political infeasibility." While this assessment is probably accurate, it is perhaps more helpful to the panel assessing the R&D solution to consider the source of this infeasibility. There are two likely candidates, both of which exist for the same reason; the public has a low willingness to pay to avoid climate damages.

One source of "infeasibility" is that the public, while supportive of climate policy in general, is simply not willing to pay more than a small premium on their energy consumption; in the U.S. something in the range of a 10-15% increase appears tolerable. While there is a dearth of work in estimating this parameter, willingness-to-pay is almost certainly far less than the costs that would be imposed under the Brute Force Mitigation strategy discussed in the Assessment Paper. It is also well below the marginal climatic damages of future emissions, recently estimated as somewhere in the range of $10-30/tCO2 (Tol 2009). In a contingent valuation study of willingness of U.S. residents to pay for the Kyoto Protocol (Berrens, Bohara et al. 2004) estimate that households valued the benefits at just under $191 per household per year. With average household CO2 emissions of approximately 50tCO2/household/year, willingness to pay appears to lie in the mid single digits of $/tCO2. $5/ton of CO2 is far below the price level needed to catalyze the technology investments required to achieve climate stabilization; it is however well aligned with the Technology-Led Policy the Assessment Paper authors recommend.

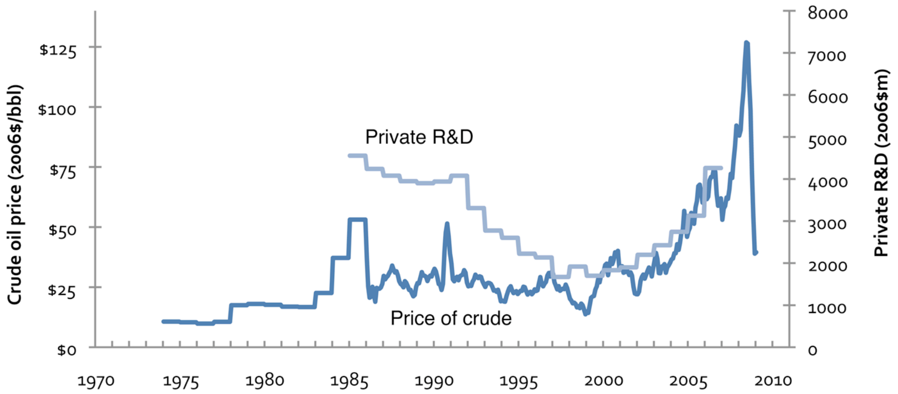
A recent survey-based contingent valuation study in the U.S. found willingness-to-pay for energy R&D of $137/household, which amounts to about $16b/year nationally (Li, Jenkins-Smith et al. 2009). This amount is about one-sixth of the amount the Assessment Paper authors' recommend for worldwide R&D in the Technology-Led strategy. If national R&D contributions in the proposal are prorated based on current national GDP, U.S. willingness to pay for energy R&D of $16b/year is not far from the required proportional contribution of $24b/year. *The Technology-Led Policy fits much closer to the preferences of voters than does Brute Force Mitigation.*

A second source of political infeasibility is that incidence of carbon pricing is likely to be concentrated among a small group industries with such large economies of scale that they consist of a relatively small number of firms that will be especially vulnerable to carbon pricing. As a result, these firms are able to wield influence negotiations over legislation that is disproportionate even to their large size. The best way to accommodate the concerns of these influential firms is simply to compensate them for the cost of making the transition from a world of free emissions to one of costly emissions (Bovenberg, Goulder et al. 2008). However, the WTP described above severely limits the feasibility of shifting abatement costs from carbon-intensive firms to consumers.

Finally, consider the data that show U.S. private energy R&D's responsiveness to price signals (Figure 3)(Nemet and Kammen 2009). Crucially, these are price signals that are *not* associated with political decisions to raise prices to capture externalities; rather they result from transactions in the global oil market. While there appears to be some price elasticity of energy R&D investment, the level of investment ($2-4b/year) is strikingly low compared with the Technology-Led Policy's proposed government funding of $100b/year. For example, the doubling of private sector energy R&D from 2000 to 2006 was associated with a tripling of world oil prices. The CO2 price required to raise the cost of oil from $25/bbl to $75/bbl would be roughly $115/tCO2, which is about 20 times the willingness to pay described above. Inducing private sector R&D sufficient to fund the development of low-cost low-carbon technologies appears an unlikely prospect.

In short price-signals are insufficient because knowledge spillover make the payoffs to investors are too small and because low willingness to pay in the public will keep prices low. This combination makes the technology-led approach essential. The small set of contingent valuation surveys that exist suggest that political feasibility of the technology led approach is far more feasible than the Brute Force Mitigation approach.

Figure 3 U.S. Private Sector Energy R&D and CrUDE Oil prices



2 SHIFTING TECHNOLOGICAL DECISION MAKING TO THE PUBLIC SECTOR

The discussion in Section 1 supports the Assessment Paper's claim that direct government support of technology investment is needed. It must be clear however, that there are important implications of shifting technological decision-making from the private sector to the public sector. These implications need to be addressed in program design. If they are not, BC ratios are likely to overstate the advantages of the technology-led strategy.

2.1 Centralized decision making

An important advantage of a price-induced technology strategy - such as Brute Force Mitigation - is that decision-making about technology development is dispersed among a large set of actors.

The thousands of important decisions related to the funding, continuation, and abandonment of technology development would occur among a large set of actors that presumably should be able to incorporate vast amounts of information obtained from diverse sources. In contrast, direct involvement by governments in supporting technology development necessarily shifts a substantial portion of decision making to the government itself. A much smaller group of individuals will be involved in the vetting of technology decisions. They will be challenged with assimilating large amounts of costly information of varying reliability about the ultimate prospects for promising technologies.

Examples of difficult choices that will be increasingly made by the public sector instead of the private sector include:

- assessing technical viability and market acceptability at early stages,
- determining when to switch from exploring alternatives to focusing resources on individual technologies and initiating demonstration and deployment,
- diversifying technology investments - especially in the early to middle stages of the development process,
- cancelling unpromising development programs before they become expensive,
- assessing of critical scale for research program, to avoid over-diversification by funding too many programs at low levels,
- enabling inter-technology knowledge flows, by supporting collaboration, incorporating new knowledge from outside existing R&D programs and dispersing knowledge to other programs.

All of these decisions will need to be made amidst interest group pressure and inevitable competing social priorities.

The challenge is to preserve some aspect of that decision making in the private sector. Changes to the intellectual property system, such as adjusting patent length and breadth, provide one avenue to incorporate private sector knowledge. Prizes that allow flexibility in deciding means to achieve government-prescribed technological ends are another. Establishing industry consortia, such as Sematech, as well as R&D subsidies for private sector research are another. Since the BC ratios are highly sensitive to assumptions about the outcomes of the proposed technology program, program design that enables governments to manage difficult technical decisions is essential to preserving the high BC values estimated in the Assessment Paper.

2.2 Expertise and institutional capacity

A consequence of the shift in the loci of decision-making is that governments themselves will require substantial increases in their capacities to make decisions about nascent technologies. Government's will need to get smarter. They can draw on private sector knowledge but ultimately, if energy-related R&D is to increase by a factor of 10, the intellectual capacity within governments would have to increase as well. The notion that "governments should not pick winners" is typically used to denigrate the government's ability to participate in technology decisions. And examples of poor picking abounds (Cohen and Noll 1991). But if one accepts the arguments for a Technology-Led Policy made in the Assessment Paper and made in Section 1 of this paper, then the suggestion provides little normative guidance for policy makers. As a result, governments need to improve their ability to "pick" and the option to abdicate responsibility to do so will not be viable.

2.3 Vulnerability to pork, linked issues, and shifting social priorities

Large government R&D programs, especially in the energy sector are notoriously vulnerable to political vagaries that are unrelated to the objective of the programs themselves. The authors make reference to an important concept - that strict emissions limits are unlikely to stimulate low-carbon investment because governments cannot credibly commit future administrations to strict adherence to costly climate policies. But why would this time-consistency problem not also exist for an R&D program that involves hundred of billions of dollars to be invested over 40 years with the same international collective action problems as in mitigation? A large R&D program will need to address these issues - especially in the context of history of volatility in energy R&D spending, lack of successful experience in international technology development cooperation, international knowledge spillover problems, and government budget reviews that typically treat technical failures in R&D programs as evidence of poor resource allocation. Such a program would almost certainly come under budgetary pressures in the face of inevitable competing social priorities over four decades.

2.4 Performance management and risk aversion in governments

Governments are often assumed to have longer time frames and more concern for social welfare than private firms, which in part leads to them employing social discount rates that are typically less than half of the private discount rates used by firms. Yet governments increasingly adopt performance management techniques that reward measurable outcomes over discrete time periods. As a result, governments may actually find it *more* difficult to tolerate the inevitable technical dead-ends that will result from such a large R&D endeavor than would the private sector. Tolerance of many small failures in the effort to produce a few large successes is a hallmark of innovation and has been perhaps most successfully employed by the venture capital industry. Governments will have to change in order to persevere with large investments in technology development in the face of inevitable failures. There will be failures; the Technology-Led Policy depends on the ability of governments to not only tolerate them, but also learn from them.

2.5 The case for a small price signal

Another reason for implementing a low CO2 price - rather than none at all - is the need to create an initial market for these technologies, feedback from the market, and as selection mechanisms for which of the outputs from the R&D program are most promising. It is clear that a positive feedback exists between R&D and deployment. Knowledge is gained through the experiences of produces and users through learning-by-doing and learning-by-using; this feedback informs the direction of the R&D program. Pursuing an R&D strategy and a modest market creation strategy simultaneously allows connection of technical opportunities (from R&D) and market opportunities (from demand). This feature allows some of the decision making to be done by the private sector, especially for later stage technologies.

An important conclusion underlying this proposal is that the sum of the problems arising from shifting a substantial portion of technological decision making from the private sector to the public sector amounts to less of a concern than does dependence on induced technological change in response to carbon price signals. Still the BC ratios presented in the Assessment Paper are sensitive to the outcomes of the proposed R&D programs, which in turn depend on governments resolving the challenges described above. The extent to which the panel considers the BC ratios reliable should depend in part on the ability to mediate the problems associated with the shift in decision making from the private sector to the public sector.

3 RETURNS TO R&D ARE STOCHASTIC

As in nearly every study that compares government R&D spending to other policy options, the attractiveness of R&D ultimately hinges on the expected returns to R&D investment.

The BC ratios presented depend on the investment of $100b/year successfully delivering low-cost low-carbon technologies. The authors arrive at an investment of $100b/year in R&D over 40 years, which amounts to $3 trillion in present value terms. That investment allows the deployment of low-carbon energy technologies sufficient to achieve the 2100 target with no impact on GWP and only a 1% of GWP extra cost for deployment on top of a carbon price of $80/tCO2 by mid-century.

The level of R&D investment seems reasonable given previous work on this issue. Although the deterministic relationship between R&D and deployment costs as well as emissions is concerning; even at $100b/year, the program might not succeed in producing adequate technologies. The case for R&D would be much easier to make if the probability of success were 100% - but even at such large amounts, surely it is not. The sensitivity analysis provided allays some of the concern about assumptions but not entirely. First, the results show that the claim of BC ratios >> 1 are not entirely robust to the three assumptions on the timing of R&D returns and discount rates. Second, there really is not much empirical or theoretical evidence for the assumed acceleration of decarbonization due to the R&D investment. The authors have little choice in developing BC ratios for the R&D option - still reliability of the results is an issue. Third, it's not clear that the sensitivity analysis, which consists of three assumptions of the timing of R&D returns, adequately spans the full range of possible outcomes of the R&D program.

The panel should focus on three assumptions in their evaluation of the reliability of the BC ratios presented:

- *Rate of decarbonization*: One of the most important assertions in this BC analysis is that global 21st century decarbonization needs to be -4.0%/year and that, even in a most favorable case under brute force, will not exceed -3.3%/year. While the authors make a strong case for the latter, the reliability of the second assumption is much more difficult to ascertain. This estimate is crucial since the BC results are dominated by the GWP loss that directly results from the gap between these two figures. I suspect that the review panel will focus on the extent to which this -3.3% decarbonization limit is a lower bound on how much the world economy can decarbonizes under climate policy.

- *Mitigation costs avoided*: It comes across clearly this value dominates the BC analysis ratios reported since it is an order of magnitude larger than the other three. Also, as mentioned above, this value depends directly on the expected rate of decarbonization under Brute Force Mitigation. As suggested above, the size of this value also seems sensitive to the assumption that the decarbonization shortfall gets expressed as a GWP loss rather than an excess of emissions

- *Climate damages*: Since they depend on the value of climate damages (S) and the timing of them, it is not obvious that BC ratios remain well above 1 even at high climate sensitivity.

The inherent stochastic aspect of R&D investments implies that one should at least acknowledge the presumably low, but non-negligible, probability that the Technology Led Strategy may fail to deliver the necessary technologies - not just that they are delayed. Conversely, there must be some probability that the Brute Force Mitigation strategy succeeds in achieving sufficient decarbonization. In short, the Assessment Paper's policy conclusions would be more convincing if it would discuss Brute Force Mitigation as a highly risky strategy than dismissing it as a futile one.

4 INTERNATIONAL COOPERATION ON TECHNOLOGY DEVELOPMENT

The collective action problems that appear to paralyze global cooperation on emissions reductions also exist in the Technology Led Policy. The best case made for the Technology Led Policy in this regard is that the investments at risk of free ridership are smaller. Still, international cooperation on technology development has very little precedent. A likely result is that investment strategy will be competitive rather than cooperative. Competitive R&D development will increase the BC ratio to the extent that national-level decision making is superior to coordinated decision making, and will decrease the BC ratio to the extent that it leads to technology races and duplication of effort.

5 MEDIATION OF CROWDING OUT EFFECTS

The Assessment Paper rightfully acknowledges the issue of crowding out effects. While some previous analyses see this as a central problem for any R&D program (Goolsbee 1998) others find mixed results when surveying empirical work (David, Hall et al. 2000). The authors point out that crowding out is not a serious issue at present - certainly not when less than $12b a year is spent on energy-related R&D worldwide. But at a proposed $100b/year, this program would constitute about 12% of current global R&D across all sectors. At that level there would likely be some economic cost to this redeployment of scientific and engineering talent away from other productive ends. Any crowding out above 0% would have a negative effect on GWP and would decrease the BC ratios.

The authors point to the *supply* of scientific and engineering talent as a reason to expect low crowding out effects. Rapid economic development in East and South Asia provides one avenue for mediation of crowding out. This reason however assumes that opportunities for technical advance in non-energy fields grow slower than does education. A more purposive means with which to remedy crowding is to increase the supply directly - by devoting a portion of the Technology Led Strategy to education or perhaps by enlarging the program. This plan would raise the cost of the R&D program but would reduce the adverse GWP impact described above.

6 CONSIDER MODEST MITIGATION, MODEST TECHNOLOGY INVESTMENT

The Review Panel should consider the BC ratios in light of alternative policies, not discussed in the Assessment Paper, that involve *lower* abatement costs and *higher* climate-related damages. The authors assert strongly, throughout the paper, that Brute Force Mitigation is the most likely policy direction at present, and thus deserves to be the basis for BC comparisons. The BC analysis shows the Technology Led Strategy to be superior to Brute Force Mitigation, a result that is robust to a large range of assumptions.

Brute force is a seriously considered option in a few countries, mainly in Europe. But important emitter countries such as China, the U.S., Canada, Australia, and perhaps even Japan are far more likely to proceed along a path of what the authors at one point mention as "feasible brute force." We might call this path, *modest mitigation, modest technology investment* - small near term emissions reductions combined with a small technology development investment. An example might be the legislation recently passed in the U.S. House of Representatives (H.R. 2454, "The American Clean Energy and Security Act") that includes soft emissions reductions targets and a technology-funding component that amounts to approximately 1% of the level proposed in the Assessment Paper's Technology Led Strategy. H.R. 2454 is a modest policy: modest mitigation, modest technology investment.

If the marginal cost of abatement is greater than marginal climate damage costs then why shouldn't governments just exceed the emissions limits? Is part of the reason that the BC ratios are so high in TLP vs. BF due to the assumption that governments are strictly unwilling to exceed their emissions targets? *In BC ratio terms modest mitigation, modest technology investment - as compared with Brute Force Mitigation - would have lower mitigation costs, higher climate damages, lower R&D costs, and lower deployment costs.*

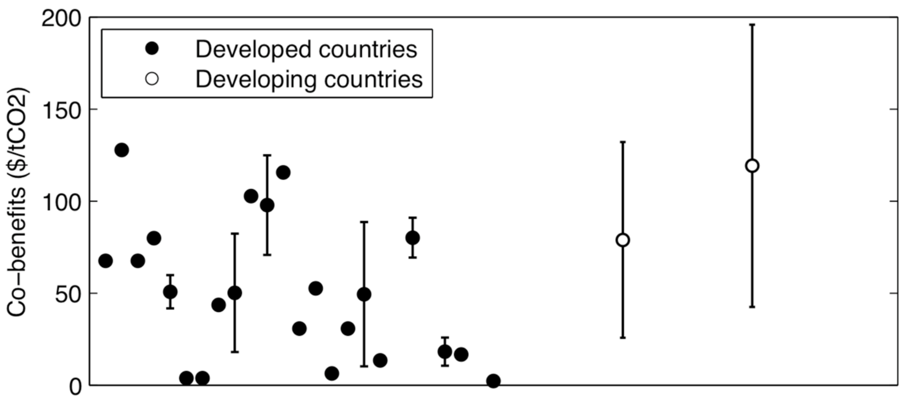
Given the appealing BC characteristics of the Technology Led Strategy, the most relevant concern is not that governments will impoverish their constituencies by making Draconian emissions reductions. Rather, it is that governments will choose to pursue a combination of modest abatement and inadequate technology investment. It is important that the analyses of the energy R&D solution area are used not only to reject Brute Force Mitigation but to inform choices between a Technology Led Strategy and a policy strategy that is modest both in near term abatement and in funding for technology development.

7 CO-BENEFITS

The panel should also consider the non-climate benefits associated with transformation of energy production and use. The deep uncertainty associated with the damages from climate change has shaped climate policy making so that it involves selecting emissions targets, rather than valuing the benefits of emissions abatement. One consequence of this emphasis on cost minimization, rather than benefit-cost analysis, is that it discourages full consideration of the ancillary benefits that accrue to human health through air quality improvement - even though these *co-benefits* are substantial, nearer term, and less uncertain. These co-benefits however are not easily compared to those of climate change mitigation. Differences in the characteristics of associated risks, valuation issues, epistemic communities, and institutional arrangements reinforce the barriers to consideration of the two benefits simultaneously. As a result, air quality co-benefits of climate change abatement, while generally acknowledged, are treated as a windfall or serendipitous result of climate change activities. The contentiousness of climate change policy - heightened by the combination of distant and diffuse benefits with concentrated and immediate costs - implies that policy makers are unlikely to fully value air quality co-benefits unless they can be compared on an equivalent basis. While they have been asserted as providing a hedge against uncertainty in benefits of climate change abatement, AQ co-benefit may actually be dependent on better valuation of climate damages in order to positively affect decisions regarding policy stringency and international cooperation.

The magnitudes of the air quality co-benefits of mitigation are non-trivial and relatively certain. Positive co-benefits have been estimated across a large set of studies and across varied geographies, time periods, and sectors. A forthcoming study surveyed 34 studies that provided 45 estimates of the economic value of air quality benefits of climate change mitigation (Nemet, Holloway et al. 2009). In Figure 4 studies of developed countries are shown on left and those of developing countries on right. Within each category, data are reported from left to right by date of study (1991-2006). The values for developed countries are in black and those for developing countries in white. For the 56 values in the 26 developed country studies the range was $2-128/tCO2, the median was 31/tCO2 and the mean 44/tCO2. For the 6 values in the 19 developing country studies the range was $26-196/tCO2, the median and mean were $99/tCO2. Inclusion of the value of co-benefits would increase benefits in both the TLS and in the BFM scenarios.

Figure 4 Estimates of the value of Air Quality co-benefits



8 SUMMARY

This Perspective Paper supports the Assessment Papers primary claim that the Technology Led Strategy is highly preferable to Brute Force Mitigation. This perspective has attempted to clarify the arguments in favor of technology investment, particularly the reasons why relying on price signals to induce technological change appears unlikely and risky. Just as in mitigation-oriented policies, the implementation details of a technology investment strategy are crucial to the ultimate outcomes. Realizing the benefits that drive the high calculated BC ratios depends on these details and will require some impotent changes to how governments interact with the technology innovation system.

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COPENHAGEN CONSENSUS ON CLIMATE

The science is clear. Human-caused global warming is a problem that we must confront.

But which response to global warming will be best for the planet? The Copenhagen Consensus Center believes that it is vital to hold a global discussion on this topic.

The world turned to scientists to tell us about the problem of global warming. Now, we need to ensure that we have a solid scientific foundation when we choose global warming's solution. That is why the Copenhagen Consensus Center has commissioned research papers from specialist climate economists, outlining the costs and benefits of each way to respond to global warming.

It is the Copenhagen Consensus Center's view that the best solution to global warming will be the one that achieves the most 'good' for the lowest cost. To identify this solution and to further advance debate, the Copenhagen Consensus Center has assembled an Expert Panel of five world-class economists – including three recipients of the Nobel Prize –to deliberate on which solution to climate change would be most effective.

It is the Copenhagen Consensus Center's hope that this research will help provide a foundation for an informed debate about the best way to respond to this threat.

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The Center commissions and conducts new research and analysis into competing spending priorities. In particular it focuses on the international community's efforts to solve the world's biggest challenges.

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