# A Perspective Paper on a Technology-led Climate Policy

## Including an Analysis of Geological Carbon Sequestration as a Response to Climate Change

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# A Perspective Paper on R&D in Green Energy Technologies, Including an Analysis of Geological Carbon Sequestration as a Response to Climate Change

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The perspective paper was written while the author was visiting the Princeton Environmental Institute. The hospitality and excellent working conditions offered there are gratefully acknowledged. The author gratefully acknowledges useful comments from Massimo Tavoni. All usual disclaimers apply.

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**PREFACE**

# ABSTRACT

Three are the basic messages emerging from the present paper:

1. **R&D will be an essential part of any climate policy**, independently of how stringent the optimal climate policy is believed to be;

2. **R&D policy alone will not do the trick**, unless the goal is simply to diversify energy provision rather than significantly reduce emissions;

3. **Combining R&D and climate policies** (as for example through an international fund for breakthrough technologies R&D) **might lead to efficiency gains and help contain climate policy costs**.

In the paper I have been requested to specifically focus on R&D in Carbon storage as a solution to Climate Change. Although uncertainties are very relevant when dealing with R&D investments, a program aiming at decreasing capturing costs or increasing the CO2 capture rate is shown to **pass the cost benefit test, if a climate policy is in place**.

It is however essential to keep in mind that the **rationale of a large R&D investment in CCS technologies** strongly depends over the **likelihood of implementing CCS technologies at large scale**. However in order to assess this likelihood some crucial questions, related to the **long term security of geologic storage** and **social acceptance**, need to be addressed.

Considering the whole R&D portfolio, **R&D aiming at a breakthrough in technologies for the non electricity sector** (transport in particular) is probably the most promising step in order to decrease climate policy cost.

Finally, one should keep in mind that stringent stabilization targets will require large shifts of **investments in the energy sector** and in the economy as a whole, figures which are an order of magnitude larger than R&D investments, a small portion of the overall picture.

# COPENHAGEN CONSENSUS ON CLIMATE

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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# INTRODUCTION

Much has been said on how to reduce current anthropogenic emissions with the aid of a portfolio of existing technologies. However, stabilization of atmospheric concentrations of greenhouse gasses to a safe level requires that over time net emissions fall to very low levels, if not to zero. There is only one way that this can be achieved in a manner that is acceptable to the majority of the world's citizens: through some kind of technological revolution. To bring about such an innovation breakthrough extensive research and development (R&D) investments will be required. This will be specifically important for countries willing to maintain both a leading position in climate negotiations and a first mover advantage in earning the rents on innovation. Indeed, technological breakthroughs will have an essential role in tackling the competitiveness issue that has gained great relevance lately in the policy debate. On top of this, technological transfers to Developing Countries could be the turning key to solve the logjam affecting international negotiations. Innovation and technologies treaties have been analyzed in the context of climate coalition formation, suggesting that they could largely improve the robustness of international agreements to control climate change (Barrett 2003, Hoel and de Zew, 2009, Burniaux et al, 2009).

If it is commonly agreed that we need extensive R&D efforts to reduce emissions in an efficient manner, less consensus characterizes the debate on whether relying on R&D policies alone might be sufficient to achieve the required reduction in emissions.

Many have argued that R&D policies alone will not be sufficient to achieve stringent targets and/or to minimize mitigation costs, because such an approach would provide no direct incentives for the adoption of new technologies and, by focusing on the long term, would miss near-term opportunities for cost-effective emissions reductions (Philibert, 2003; Sandén and Azar, 2005; Fisher and Newell, 2007, Bosetti et al., 2009a).

Nonetheless the argument that innovation and technology policies might be sufficient to solve the climate change problem has a strong appeal on policymakers (see for example the position of the past US Administration on the role of technical change)[1]. Some climate-related scientific and technology agreements have emerged, including the Carbon Sequestration Leadership Forum, the Asia Pacific Partnership on Clean Development and Climate, and the International Partnership for a Hydrogen Economy. Proposals of international technology agreements have been put forward, that would encompass domestic and international policies to foster R&D and knowledge-sharing (Newell 2008).

Recent empirical and numerical studies (see section 2) show that though R&D investments are essential to improve the efficiency of a climate policy, they are typically induced by some carbon price signal while standalone R&D policies would not produce the required halt in emissions. Revenues from the carbon policy (whether a tax or cap and trade system with fully allocated permits) can be also used to finance additional R&D investments, though the largest part of the investments will take place as a response to the higher price of carbon. It might however be the case that international financing of R&D spending and technologies transfers could be used to improve the efficiency of a carbon policy and be a lever at the negotiation table.

1 See for example the "Administration Actions to Advance Technologies for Addressing Global Climate Change", Published August 2005, http://www.climatetechnology.gov/vision2005/

While in many instances the Assessment Paper (AP) on R&D in Energy Technologies claims that an R&D policy is all we need[2], it also argues that R&D policy should be a complement to a carbon price policy. By arguing for a low -though doubling every ten years- carbon tax used to finance energy R&D spending, the authors of the AP are supporting a mild environmental target (something in line with the stabilization of atmospheric CO2 at 550 ppm levels[3]) and a specific climate policy instrument: a carbon tax. On the one hand, depending on the assumptions concerning the discount rate, the magnitude of the damage and the climate sensitivity parameter, one could agree on the optimality of a mild climate policy (although the under-estimation of damages in earlier modeling exercises showed up in recent studies, as for example the revised estimates of sectoral impacts for the US in Hanemann, 2008). On the other hand, though, the whole discussion in the AP against a cap and trade system is potentially misleading and, in the light of the EU Trading System and the Waxman-Markey proposal, basically unrealistic.

Overall, although the basic message of the AP is at times contradictory, it matches that of this Perspective Paper on three basic issues:

1. R&D will be an essential part of any climate policy, independently of how stringent the optimal climate policy is believed to be;
2. R&D policy alone will not do the trick, unless the goal is simply to diversify energy provision rather than significantly reduce emissions;
3. When added to a climate one, an R&D policy (as for example an international fund for breakthrough technologies R&D) might lead to substantial efficiency gains and help containing climate policy costs.

The aim of this Perspective Paper is twofold: firstly, to shed some additional light on the issue of R&D policies in the context of climate change, by discussing both empirical literature and numerical model results, in Section 2; secondly, to provide some specific information on R&D in Carbon storage[4] as a solution to Climate Change, in Section 3.

## THE BENEFITS OF INNOVATION POLICIES

Empirical analysis of the process of innovation is chiefly based on patent counts, employed to measure the output of innovation but also the transfer of inventions across borders. One of the latest extensive studies (Dechezleprêtre, et al., 2008) shows how the Kyoto protocol actually induced innovation. In particular, the increased innovation in carbon free technologies that has taken place in Annex I countries which have ratified the Kyoto Protocol, was not mirrored in Australia and in the USA. The link between environmental policy and induced innovation has been found in a large number of studies. The literature review on empirical

2 "Relying on carbon pricing to cut global emissions substantially is neither likely to be politically acceptable nor economically time consistent. Carbon pricing alone, or as the main policy tool, is not an effective means of inducing long term commitments to undertake and pursue endemically uncertain (of success) basic R&D". (Assessment Paper, page 4)

3 Throughout the paper when discussing stabilization scenarios, I will be referring to ppm CO2 only numbers.

4 When describing CO2 in geological formations and oceans, the term "CO2 storage" is used. It is now commonly accepted that sequestration refers only to the terrestrial storage of CO2.

studies in Vollebergh, 2007, points out to the clear impact, found across many studies, of environmental policy on invention, innovation and diffusion of technologies.

Hence, empirical evidence points towards the need of a climate policy to induce (and not only to finance) the required innovation. However, (Dechezleprêtre, et al., 2008) also find that there is no evidence that the Kyoto protocol has increased the transfers or international spillovers of knowledge. Hence, there is room for improving the design of a climate policy by including some mechanisms to promote spillovers of knowledge (although this might be tricky as free knowledge spillovers lower the rents on innovation and thus might discourage innovators). That technology transfers are a crucial point in negotiations is no big news, as manifested by the institution of an Expert Group on Technology Transfer.[5]

Many analysts have concluded that the current scale of energy R&D is inadequate for the climate challenge and propose more or less arbitrary increases to the level of effort. Both the United States and the European Commission envision large expansions of government energy R&D funding[6]. Nemet and Kammen, 2007, claim that a five- to tenfold increase in American energy R&D spending is both warranted and feasible. Using a rule of thumb, Stern, 2007 recommends doubling all government energy R&D budgets.

Similarly, by using an Integrated Assessment model with a fairly detailed description of endogenous technical change, Bosetti et al., 2009b, find that energy R&D is crucial if we aim at creating a significant dent in carbon emissions. Investments in Public Energy R&D would need to return to at least the peak of the 1980s as a relative share of GDP. Expenditures should thus increase from today's 0.02% to 0.08% of world GDP, or equivalently from 8 to 40 Billions USD. These extra investments should take place in the next 20 years, given the long lags that separate research from market adoption. In the paper, they look at different types of energy R&D, and find that public energy **R&D should be targeted at innovative technologies that can contribute to the decarburization of energy** indispensable for significant emissions cuts. Especially the **non-electric sector** (transport above all) needs breakthrough technologies that are not available today. The power sector needs innovation as well, but to a smaller extent. Only if the use of existing carbon free technologies such as nuclear power, renewables or CCS is limited by socio-political constraints, is the development of alternative technologies necessary to prevent policy costs increase by 40%. Nonetheless, R&D may also help by improving the efficiency and safety of existing technologies (see Section 3).

In order to understand the **potential benefit of R&D** in breakthrough technologies one can measure what would be the additional policy cost of a climate policy **assuming that no R&D program aiming at bringing down the cost of breakthrough technologies in both the electric and non electric sectors is undertaken**. As a result, the new technologies would

5 See for example the Advance report on recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the Convention. Note by the Chair of the Expert Group on Technology Transfer. SUBSIDIARY BODY FOR IMPLEMENTATION. Thirtieth session. Bonn, 1–10 June 2009

6 "National Commission on Energy Policy. 2004. Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges. Washington, D.C.: National Commission on Energy Policy." and "European Commission. 2009. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: Towards a Comprehensive Climate Change Agreement in Copenhagen. Brussels: European Commission. p.10, section 3.3."

become competitive at a later stage and diffusion and learning by doing mechanisms would be delayed as well. Table 1 reports figures relative to the **increase in policy costs**, for two different policies, a mild climate target (550 CO2 ppm) and a more stringent one (450 CO2 ppm). In both cases, and independently of the discount rate, the increase in policy costs that is due to the lack of the induced breakthrough is sizeable.

One should not forget that technological change is an uncertain phenomenon. In its most thriving form, ground-breaking innovation is so unpredictable that any attempt to model the uncertain processes that govern it is close to impossible. Despite the complexities, research dealing with long-term processes, such as climate change, largely benefits from incorporating the uncertainty of technological advance. Adu-Bonnah and Baker (2008), Bosetti and Tavoni (2009) and Blanford (2009), among others, model R&D as an uncertain phenomenon. Two of the main findings of this literature are: i) that the optimal level of energy R&D investments should be higher in order to cope with climate change, if we acknowledge the uncertainty characterizing the innovation process ; ii) that a portfolio of technologies should be considered in order to hedge the risks of R&D program failures.

However essential, **R&D programs will not be sufficient**. As underlined in Bosetti et al (2009a), under fairly optimistic assumptions about the funding available for, and the returns to R&D, innovation policies alone cannot stabilize global concentration and temperature; a strong carbon price signal is indispensable. A very robust finding across a wide range of simulations is that the largest achievable reduction in cumulative emissions with respect to the baseline case is in the order of 13 to 16%. To put this in perspective, the reduction required to be consistent with a mild stabilization target (550 ppm CO2) would be in the order of halving cumulative emissions.

Finally, on top of R&D induced by a climate policy, there might a need for additional R&D policy (as for example an international fund for breakthrough technologies R&D) in order to foster technology diffusion and to overcome the various innovation market failures, such as the underinvestment in R&D in the private sector. As investigate in Bosetti et al. (2009a) an additional R&D policy could lead to visible efficiency gains, reducing policy costs of up to 10-15%.

**Table 1. Increase in climate policy costs without an R&D program aimed at breakthrough in low carbon technologies, for two climate policy targets.**

| | | Discount Rate | |
|---|---|---|---|
| | | 3% | 6% |
| Increase in Climate Policy costs associated with the lack of a breakthrough R&D program. (Discounted Trillions 2005 USD) | 550 ppmv | $ 24 | $ 3 |
| | 450 ppmv | $ 63 | $ 9.5 |

# COST BENEFIT ASSESSMENT OF R&D IN CARBON STORAGE AS A SOLUTION TO CLIMATE CHANGE

We now shift the focus on a specific category of R&D, the one dedicated to the improvement in CO2 capture and storage (CCS) technologies. Among the many technologies available in the climate mitigation portfolio, CCS is considered an important low carbon technology, because it allows the continuation of using fossil fuels while reducing the corresponding CO2 emissions. CCS may therefore play an important role, especially in countries that heavily rely on coal for the generation of electricity, such as China and India. A second important characteristic of CCS is that it has a value only if there is a price on carbon. If a very stringent climate policy, as that in line with a 2°C stabilization target, is enacted then bioenergy coupled with CCS is the only way to obtain negative emissions. On the other hand, unlike other technologies which presents benefits unrelated to climate change (such as increasing energy security, decreasing local pollution and others), CCS is not meaningful outside the context of a climate policy, as it otherwise represents a decrease in plant efficiency and an increase in capital and operating expenses.

CO2 is already being captured in the oil and gas and chemical industries. Indeed several plants capture CO2 from power station flue gases for use in the food industry.[7] However, only a fraction of the CO2 in the flue gas stream is captured - to reduce emissions from a typical power plant by 75% the equipment would need to be 10 times larger. If capture is used to minimize CO2 emissions from a power plant it would add at least 1.5 US cents/kWh to the cost of electricity generation. In addition, the generating efficiency would be reduced by 10 to 15 percentage points based on current technology. It is expected that wide-spread application of this technology would result in developments leading to a considerable improvement in its performance. The cost of avoiding CO2 emissions is 40-60 US$/ton of CO2[8] (depending on the type of plant and where the CO2 is stored), which is comparable to other means of achieving large reductions in emissions.

Having captured the CO2 it would need to be stored securely for hundreds or even thousands of years, in order to avoid it reaching the atmosphere. Major reservoirs, suitable for storage, have been identified under the earth's surface and in the oceans. Work to develop many of these options is in progress.

As underlined in the IEA report on CO2 Capture and Storage, 2008, the next 10 years will be critical for CCS development. By 2020, the implementation of at least 20 full-scale CCS projects in a variety of power and industrial sector settings, including coal-fired power plant retrofits, will considerably reduce the uncertainties related to the cost and reliability of CCS technologies. Given that the market alone will probably lack the required finance to support these demonstration projects, one of the most crucial factors in CCS technologies is the need for government finance to support these decisive early demonstration projects. Also, some additional effort by governments in designing adequate legal and regulatory frameworks is needed, as storage of CO2 raises issue as liability for CO2 leakage and property rights. A

7 For more references on the technical description of CO2 capture and storage and detailed information on current R&D programs the reader is referred to IEA Greenhouse Gas R&D Programme site: http://www.co2captureandstorage.info/

8 It should be noted that the actual figure is uncertain and some source talk about 100 US$/ton of CO2.

similarly important endeavor will be needed to carry out a careful campaign to inform and raise public opinion awareness, as large scale CCS might encounter strong public resistance.

Keeping in mind that the demonstration part is the top priority in preparing the avenue to large scale deployment of CCS technologies, R&D investments, though secondary in this early stage, might play an important role later on. We refer the reader to the IEA report on CO2 Capture and Storage, 2008, for a detailed description of R&D actually undertaken in OECD and fast-growing countries. Research projects currently in place range from the analysis of public acceptance, to the availability of sites and the risks associated with CO2 storage, to the optimal structure of the transport network. One important breakthrough would for example concern the increase of the capture rate at a reasonable cost and with reasonable losses in the plant efficiency.

Baker et al, 2009, focus on understanding how current investment in R&D has the potential to lower CCS costs 40 to 50 years in the future. They perform an expert elicitation, to identify areas where there is potential for significant progress or even breakthroughs and then assess probability of success and failure of R&D programs in these different areas. Crucial areas of investigation are: Pre-combustion carbon capture, alternative combustion, and Post-combustion removal. They find that both post combustion and chemical looping (alternative combustion) targeted R&D programs are characterized by very large disagreement over the probability of success. They also underline that the rationale of a large R&D investment in CCS technologies strongly depends on the likelihood of implementing CCS technologies at large scale. Indeed, "if the likelihood of implementing it is not high, then it reduces the attractiveness of a broad R&D investment in this technology (and increases the importance of pursuing other lines of research)". The National Academy of Science study on Prospective Evaluation of Applied Energy Research and Development[9] made a first attempt to assess this likelihood, but they recognize it is a very complicated question as it involves technical issues about the viability and long-term security of geologic storage; plus a range of non-technical issues and social preferences.

Given the large sources of uncertainties we have discussed so far, both concerning the actual implementation of large CCS technologies and the probability of success of R&D programs, some heroic assumptions have to be made in order to evaluate benefit and costs of R&D in CCS technologies as a solution to Climate Change. The basic idea of the exercise I outline here is the following. By assuming that through R&D investments the capture rate of CCS technologies can be improved, it is possible to provide a rough estimate of the benefits associated with such an improvement in terms of decreased policy costs and compare these with the potential costs of such R&D program.

I use the WITCH model, an Integrated Assessment model first described in Bosetti et al 2006, as it explicitly represents the optimal portfolio in energy technologies in the face of different climate policies. In WITCH, CCS can be applied to integrated coal gasification combined cycle power plant (IGCC-CCS). IGCC-CCS competes with traditional coal, so that it replaces it for a sufficient carbon price signal. CCS transport and storage supply cost curves are region specific and they have been calibrated following Hendriks et al. 2004. Costs increase exponentially

9 National Research Council. Prospective Evaluation of Applied Energy Research and Development at DOE (Phase Two). The National Academies Press, Washington D.C., 2007. http://www.nap.edu/catalog/11806.html.

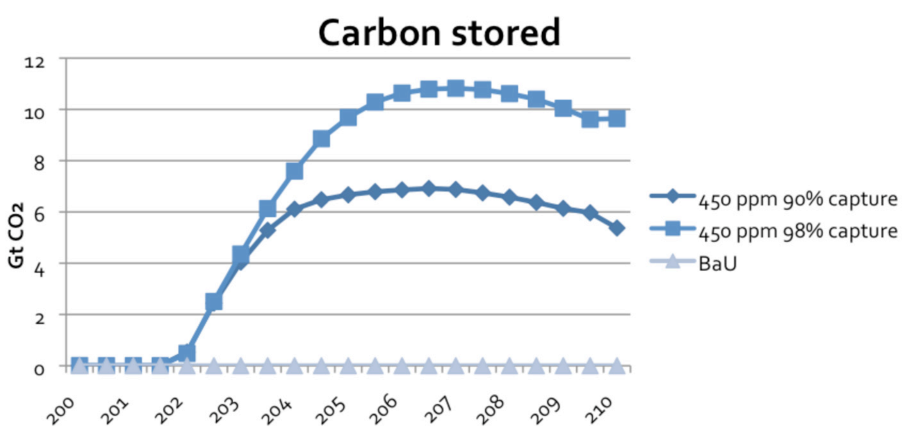
with the capacity accumulated with this technology. The CO2 capture rate is set at 90% and no after-storage leakage is considered. Other technological parameters such as efficiency, load factor, investment and O&M costs are described in Table 2.

As CCS is not competitive in a baseline scenario, I will focus the investigation on two policy scenarios, where the objective is to stabilize CO2 concentration at 450 ppm and 550 ppm levels by the end of the century, respectively. For each of the two policy scenarios I consider two cases: the basic case, where capture rate is 90%, and a second case where, as a result of an R&D program, the capture rate is 98%, without any increase in electricity costs or efficiency loss. The effect of different capture rates on total stored carbon is significant, as shown in Figure 1, for the 450 ppm policy case. During the second half of the century the climate target implies an increasing carbon price. The vented carbon that is not captured represents a cost for IGCC plus CCS plants; hence being able to reduce such a pricy byproduct could decisively increases the potential of CCS technologies.

**Table 2 Technological parameters for traditional coal and IGCC-CCS power plants.**

| | **Investment costs** World average $USD_{2005}$/KW | **O&M** World average $USD_{2005}$/KW | **Fuel Efficiency** % | **Load factor %** | **Plant Lifetime** years | **Depreciation %** |
|---|---|---|---|---|---|---|
| Coal | 1530 | 47 | 45% | 85% | 40 | 5.6% |
| IGCC-CCS | 3170 | 47 | 40% | 85% | 40 | 5.6% |

**Figure 1**



I compute the decrease in policy costs that would be associated with such technological leap and use that as a measure of the benefit of a dedicated R&D program. Table 3 reports benefits, as decreased policy costs, for two discount rates and for two policies. By considering the two policy scenarios we mimic two cases, one where damages from climate change are higher (the 450 ppm stabilization case) and a second where climate change damage is lower (the 550 ppm stabilization case).

In order to provide an estimate of the R&D program costs, I assume that the expenditure on the R&D program on CCS is 10% of overall energy R&D bill (which is endogenously calculated by the model) and that its duration spans between 2010 and 2045. Table 4 summarizes the benefit cost ratios.

*Many are the simplifications required to perform this analysis, hence results should be taken cautiously. In particular, it should be kept in mind that costs estimate are very rough. However, the gap between benefit and costs is wide, even for much less conservative estimates of the R&D program costs.*

**The basic message is that if we place some value on the reduction of the climate change threat, then investing in an R&D program in CCS technologies passes the cost benefit tests.**

### Table 3. Cost Benefit Analysis of a R&D in CCS Technologies Program

| | | Discount Rate | |
|---|---|---|---|
| | | 3% | 6% |
| Benefit as avoided policy costs (Discounted USD Trillions) | 550 ppmv | $ 0.48 | $ 0.09 |
| | 450 ppmv | $ 0.92 | $ 0.20 |
| Cost of R&D Program (Discounted USD Trillions) | | $ 0.03 | $ 0.02 |

### Table 4: Benefit /Cost ratios for a R&D in CCS Technologies Program

| Discount rate | Low (3%) | | High (6%) | |
|---|---|---|---|---|
| Climate change damage | Low (550 PPM) | High (450 PPM) | Low (550 PPM) | High (450 PPM) |
| BCR | 16 | 30.7 | 4.5 | 10 |

One should keep in mind the following caveats:

- Estimates do not take into account the additional benefits that result from these measures, such as the growth in markets, job creation and health benefits of reduced local pollution. On the other hand the extensive use of coal has many external costs, for example associated with mining, that we have not accounted for here.

- Institutional, legal and social barriers can become a major issue in the large scale deployment of CCS technologies. As we have seen, independently of the technological dimension it might be the case that a large deployment of CCS will not take place.

- The analysis performed is deterministic. Baker et al, 2009, discuss extensively of the uncertainties surrounding the effectiveness of such R&D program. In order to diversify such risk, the portfolio of CCS R&D investments should be diversified on the different potential technologies, at least in the early stages.

- Deployment and demonstration projects are the key to bring about some reduction in costs; these are not considered in the present analysis.

- International spillovers of knowledge might speed up the breakthrough in capture technologies, but they are not considered in the present analysis.

# CONCLUSIONS

During their most recent meeting in Italy, G8 countries have reiterated their commitment to take rapid and effective global action to combat climate change. The representatives of the largest developed economies have recognized the need that the increase in global average temperature above preindustrial levels should not to exceed 2°C. They have also supported a target of emissions reductions in developed countries by 80% by 2050, and proposed a global objective of minus 50% by 2050.

Meeting these targets is going to require a monumental change of the energy system and of the whole economy, a change that only a series of technology revolutions can make possible. Then the question rests on whether technology-push or market-pull instruments will do the trick. In this paper I claim that both instruments will be required and that a **hybrid policy will probably prove to be the most effective both in economic and environmental terms**.

Induced and directly financed **R&D investments should be diversified** as only a portfolio of investment can hedge against risks associated with the success of R&D programs.

In particular, **transport** is the sector where **carbon free alternative technologies** are more distant from being competitive, therefore a large part of the portfolio should be dedicated to existing promising technologies in order the bring down the costs and start commercializing some of these technologies.

CCS technologies could play a relevant role in the power sector. If electrification of the transport sector becomes one of the major responses to the quest for the decarbonization of transport, then CCS could play even a larger role. Finally, if CCS technologies are coupled with biomass both to produce fuels and electricity, then CCS could have a crucial role in providing negative emissions as well. Assuming that all non technical barriers to the large scale diffusion of CCS technologies can be overcome, then investing in **R&D in CCS technologies would pass the cost benefit test**.

One should however keep in mind that the **demonstration phase is now the top priority** in preparing the avenue to large scale deployment of CCS technologies; R&D investments finalized at improving the capture rate and capturing costs of CO2, though secondary in this early stage, might play an important role later on.

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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.

## COPENHAGEN CONSENSUS CENTER

The Copenhagen Consensus Center is a global think-tank based in Denmark that publicizes the best ways for governments and philanthropists to spend aid and development money.

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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