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# A Perspective Paper on Forestry Carbon Sequestration as a Response to Climate Change

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The author wants to thank Mykola Gusti and Petr Havlik at IIASA for sharing their latest work on forestry carbon sequestration, Brent Sohngen for the fruitful collaboration on this project and the Copenhagen Consensus Center and particularly Kasper Thede Anderskov for the possibility to participate in and the support during the project. The IIASA research mentioned in this paper has been conducted in the framework of the following projects: Climate Change – Terrestrial Adaptation and Mitigation in Europe (CC-TAME, EC FP7), Full Cost Climate Change (FCCC, EC FP7) and Development of forward-looking REDD scenarios in the Congo Basin (World Bank). The author further acknowledges support by Environmental Defense Fund, which supports work on uncertainty issues revolving around REDD.

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## PREFACE

# ABSTRACT

I find myself in broad agreement with Brent Sohngen's analysis of costs and benefits associated with the climate change mitigation options offered by forest carbon sequestration, which includes afforestation, reductions in deforestation (REDD) and forest management. In this paper, I intend to summarize the assessment paper's approach and conclusions, highlight the most important findings, identify gaps and their implications for the calculations and thus put the results into perspective. The areas dealt with concern competition for land and its potential impact of opportunity costs, the role of various types of uncertainty and their implications for implementing forestry carbon sequestration programs, the effect of accounting for ecosystems services and biodiversity on benefit assessments, and the relevance of option values in considering REDD strategies. The conclusion drawn from the analysis coincides with the findings of Sohngen, who claims that forest carbon will be needed as part of a strategy to mitigate climate change. Solutions can thus not arise exclusively from the technosphere, especially in the face of time and other resource constraints.

# 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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# CONTENTS

# MESSAGES FROM THE ASSESSMENT PAPER

The Assessment Paper explores the climate change mitigation possibilities associated with enhancing forest carbon stocks. It introduces and explains the rationale of forest carbon as a component of the policy mix for combating climate change and then presents the most important options of forestry carbon sequestration: afforestation, reductions in deforestation (REDD) and forest management.[1] The estimates of the costs for these carbon sequestration options are summarized in Sohngen's Figure 1, which depicts the marginal costs of sequestering carbon, where a distinction is also made between regions (temperate/developed versus tropical). Disaggregating the results for a single carbon price of $30 per ton $CO_2$ and calculating the amount of carbon sequestered per activity, the author finds that the largest reduction potential over the next 40 years comes from avoided deforestation (REDD), followed by forest management and finally by afforestation, which has been the focus of policy over the past decade.

Combining these results with an integrated assessment model (DICE), Sohngen produces estimates for two scenarios, where the first is called "optimal" and is the optimal policy scenario adjusted from Nordhaus (2009), while the second scenario is one where policy aims at limiting the temperature increase to 2° Celsius above pre-industrial levels. Benefits include increases consumption and reductions in damages and energy costs. In the optimal scenario, the benefits accrue mainly from a reduction in damages; (carbon prices fall only modestly). Present value benefits roughly equal the costs of the program in this scenario, suggesting a benefit-cost ratio of 1. In the 2° Celsius scenario the ultimate target of limiting the temperature level leads to similar temperature profiles for both the case with and the case without forestry, so there is only a very marginal reduction in damages due to including forestry. Through the reduction in mitigation costs, however, consumption increases substantially, implying a benefit-cost ratio of 1.7. These results are robust across interest rates (5% and 3% are tested).

Table 4 shows that forestry features significantly in terms of cumulative abatement when compared to the energy sector. This is especially true in the near term. However, with a rising carbon price, the forestry proportion continues to play an important role also in the longer run. In the 2°C limiting scenario, the proportion even increases over time.

Following this analysis, Sohngen discusses the policy implications and implementation issues. Furthermore, there are several problem areas that are of importance and have repeatedly been raised in the debate: first, there will be costs associated with measuring, monitoring and verifying (MMV) carbon credits, for the analysis of which the author conducts additional scenario analysis. Even though the results indicate the size of the forestry program will shrink in response to including MMV costs, the importance of forestry as a mitigation option is still vital. Second, there are transactions costs, which might affect negatively the ability to implement large land-use change programs in frontier regions, where property rights are not well-defined; however, the author warns not to overestimate these concerns, especially not for land where the marginal activity is of low-value use. Third, additionality and leakage are mentioned to be problems, where the former is deemed to be less grave, since a baseline for each person entering a carbon contract could readily be determined; the impact of leakage on large-scale policies, however, cannot be determined as there are no estimates of international

1 The sum of these items is often referred to as REDD+.

leakage potential. Fourth, a forestry program might interact with biofuel policy, which in itself might not be efficient, but which does not necessarily raise the costs of mitigation through forestry, especially if biofuel policy aims at equalizing the benefits to the atmosphere from one hectare of biofuel land to those arising from one hectare of forest.

Finally, Sohngen presents an analysis of forestry as a stand alone policy, where the DICE model is run without energy abatement options. In particular, he compares a run without any controls to one where only forestry is possible. The benefit-cost ratio in that case is less than 1 indicating that forestry is not sufficient as a stand-alone strategy to mitigate climate change. As a complement to energy-related abatement it is an indispensable ingredient, however.

# GAP ANALYSIS

Even though I agree with the messages of the Assessment Paper, there are some issues, which are not dealt with in detail. In this section, I am trying to identify these issues and fill the gaps where needed to put the option of forest carbon better into perspective.

## Competition for Land

The Assessment Paper has one very important implication: the forest land will have to be expanded by a substantial area under the proposed programs. The question arises whether there will not be more competition for such a large amount of land in the long run: in fact, growing food demand and other trends reinforcing other land uses could lead to quite some tension in the realization of large-scale forest programs. In the case of food demand, crop yields would need to increase tremendously in order to keep competition for land within its confines.[2] In addition, policies such as the one concerning biofuels mentioned in the Assessment Paper might interfere with goals of expanding forest area for the sake of using it as a carbon sink. As a result, the opportunity costs should be adjusted as larger and larger areas of land need to be reserved for forests. It is clear that this gap needs to be filled by the modelling community in order to offer a full account of the costs involved in REDD (and REDD+).

Actually, some of the current estimates already do account for this effect. A framework combining the Global Forest Model (G4M) and the Global Biomass Optimization Model (GLOBIOM)[3] accounting for the effect of competition over land is currently being used at the International Institute for Applied Systems Analysis (IIASA). The Eliasch Review (2008), for example, already uses the REDD potential estimates of an earlier version of this model cluster (see Gusti et al., 2008). [4]

2 Increases in crop yields would, however, raise land values and therefore also the opportunity costs. Other exogenous factors, which could have such an impact on land value and thus opportunity cost, are e.g. interest rate changes or increases of timber prices.

3 G4M provides spatially explicit estimates of annual aboveground wood increment, development of aboveground forest biomass and costs of forestry options such as forest management, afforestation and deforestation by comparing the income of alternative land use and GLOBIOM is a global partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to give policy advice on global issues concerning land use competition between the major land-based production sectors.

4 This new version of G4M combined with GLOBIOM is planned to be used in the GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model developed at IIASA's Atmospheric Pollution and Economic Development Program (see Bottcher et al., 2008, and information on the latest GAINS workshop at http://gains.iiasa.ac.at/index.php/home-page). In addition, there is OSIRIS, which is an open-source

Currently, a new version of G4M is used for determining optimal $CO_2$ prices for reducing deforestation and raising afforestation. GLOBIOM's predictions for land and forest product price changes are used in G4M to determine afforestation and deforestation patterns in geographic space. First findings show that the leading countries by potential of sequestration of additional carbon and cost competitiveness are Brazil, Zaire, Indonesia, Bolivia and Tanzania. Most importantly, changes in agricultural and forestry markets are found to influence the competition for land. This will have a large impact on economic incentives for carbon sequestration (Gusti et al, 2009).

With respect to interactions with biofuel policy mentioned in the Assessment Paper, an important, new study to mention is by Wise et al. (2009), who employ an integrated assessment model to look at the implications of emissions reductions for land use and land use change. They find that the costs of meeting targets decreases. However, unmanaged ecosystems and forests expand and food crop and live stock prices increase. This result applies when there is a carbon tax on both land use change and energy & industrial emissions. If only the latter are taxed, then energy crops require larger and larger amounts of land and achieving climate goals becomes more expensive. These findings underline the importance of valuing terrestrial carbon.

## Ecosystems Services and Biodiversity

Whereas the previous point suggests that the costs of a forestry program might be larger than estimated by (partially) ignoring issues of competition over land, there is also an underestimation in the benefits of REDD. In fact, avoided deforestation has a wide variety of ancillary benefits - most importantly the preservation of biodiversity, natural habitats and other ecosystems services such the regulation of water balance and flow of the river, the adjustment of regional climate and weather patterns, and the moderation of the spread of infectious diseases (see e.g. Foley et al, 2007). While these benefits are admittedly difficult if not impossible to quantify and monetize, the benefit-cost ratios of the Assessment Paper should be considered in the light of these additional advantages when comparing to other options, as the author also suggests in the conclusion.

## The Role of Uncertainty for REDD

The Assessment Paper does not go into detail about some of the problems relating to implementation and the role that uncertainty plays in there. As can be concluded from the extent and diversity of debates surrounding the implementation of REDD and other forest carbon sequestration programs, these points cannot be neglected in a thorough discussion and when comparing to other options. I will here highlight just a few points in order to put the Assessment Paper's results into perspective.

A key problem featuring among the uncertainties affecting REDD is the definition of the "true" baseline. Most of the proposals to date still suggest using historical baselines, which might not be reliable due to lack of high-quality data. In choosing the right method to determine the business as usual (BAU) baseline, according to which REDD will be measured, it is important

spreadsheet tool, designed to support UNFCCC negotiations on REDD using results from G4M for their simulations (see Busch et al., 2009).

to note that there are significant financial incentives at stake: tropical countries will want to maximize the compensation they receive for reducing deforestation below the baseline by having a higher baseline to begin with. On the other hand, developed countries will have to offer sufficient compensation in order to get forest countries engaged in REDD. This is also linked to the issue of additionality Sohngen discusses on page 25 of the Assessment Paper.

Furthermore, much of the uncertainty surrounding the implementation of a forestry program comes from climate policy uncertainty itself: uncertainty about climate policy emanates from ambiguity about the stabilization target sufficient to achieve an acceptable increase in temperature. More precisely, limited knowledge about climate sensitivity and feedbacks make it difficult to determine the acceptable degree of warming and relate that to a concentration level. Recent findings by Hansen et al (2008), for instance, explain that paleoclimate evidence and ongoing climate change suggest that carbon will need to be reduced to much lower levels than we might have been prepared for. They claim that "the largest uncertainty in the target arises from possible changes of non-CO2 forcing." Whether REDD will be needed to mitigate climate change and to what extent is thus unclear, so a reduction in deforestation rates might be postponed, which will make this option more costly in the long run.

In addition, uncertainty about the future opportunity cost of forest land to supplier countries complicates agreements as well. Those countries might have different expectations and assumptions concerning the development of commodity prices and thus look at a larger range of future opportunity costs. In this respect, more research is needed to determine the value of different future portfolios of land uses that forest nations consider. Related to this, there is uncertainty about the amount of funding that could be raised in order to finance REDD. Voluntary funds might not be sufficient to cover the expenses for implementing REDD, whereas compliance markets promise a bigger potential.5

Uncertainties associated with the need of measuring, monitoring and verifying (MMV) carbon credits on the landscape (see Angelsen et al (2009) for an overview of the issues involved in monitoring) and leakage have already been mentioned by the Assessment Paper and might lead to higher costs in the calculations of the benefit-cost ratios. Again, the estimation of these costs would be very difficult, especially in the case of cross-border leakage. Murray (2008) finds empirical evidence indicating that leakage from avoided deforestation policies could be substantial and claims that this needs to be addressed by policy design (e.g. include discounts to reduce the number of REDD credits issued, broadening of the policy scope). In addition, permanence problems could raise the costs of a REDD program significantly.

It is beyond the scope of this project to precisely estimate the costs associated with MMV, but the Assessment Paper provides a very useful discussion and additional scenario analysis, which points to the impact such costs could have on the benefit-cost ratios. The results actually seem to be robust to shifts in the cost curve, but the forestry program will of course be smaller than without these extra costs.

Finally, it is important to make a distinction between the cost uncertainties that will feature most importantly in the near term compared to those that have more significant implications in the long run. The most important source of uncertainty in the near future is probably the

5 See e.g. Murray et al. (2009) for an overview of currently considered financing structures.

one relating to the estimation of opportunity costs, since good opportunity cost estimates require good estimates of the value of land. However, there are differences in the estimation of agricultural suitability and land values (Ramankutty et al., 2002, van Velthuizen et al., 2007, Naidoo and Iwamura, 2007, FAO, 2000, Benitez et al., 2004). In addition, ignoring the carbon stock of alternative land uses can significantly overestimate the unit costs of actual net emission reductions (Pagiola and Bosquet, 2009).

In the long run, another source of uncertainty gains importance: climate change itself will have an influence on the suitability of land for agriculture and it will also affect forestry. As some regions become drier, for example, land value and therefore opportunity costs might be affected negatively, but forestry will also suffer from the changed conditions. It is thus inherently difficult to determine long run costs. On the other hand, the benefits from avoiding climate change through forestry programs in the near term might be much larger as a result.

## The Option Value Behind Forest Carbon Sequestration

Relating to the point about climate policy uncertainty made in the previous section, if more ambitious goals will need to be achieved than previously assumed, an ***option*** on REDD could potentially serve as a kind of insurance meeting the target. This is an example of a "real" option, where relative irreversibility (the forest can only be regrown at a relatively slow rate) and uncertainty (it is unclear which concentration level will ultimately be needed) imply that there is a value to waiting and keeping the option of using the forest to meet the target open.[6]

From the perspective of the market, the general fear of "market flooding" claiming that cheap offsets might drive the carbon price down and thus deter investment into cleaner technologies and R&D can also be reduced by thinking in an options framework: recent work by Golub et al. (2009) adopts a real options approach to show that this does not necessarily have to be the case, if REDD credits are linked to carbon markets as options and only a limited amount of these options would be available, for instance. Pricing these REDD options as a derivative of the $CO_2$ permit price would ensure that it is high enough, so as not to drive down prices in the carbon market. Firms which have bought REDD options can then exercise them at the initially negotiated strike price, which enables them to avoid spikes in the permit price. The results show that firms do not experience changes in their average profitability. However, they can smooth out some of the variability arising from permit trading by buying REDD options. An option contract on REDD-backed offsets could therefore be an attractive alternative to direct offsets.

Concerning the potential threat to R&D, it is important to realize that technological progress is an inherently uncertain process as well: whether and when a cost- or emission-reducing innovation will be made is largely unknown. Major advances will probably take longer than policymakers want to wait and REDD can offer the possibility of "bridging" the time it takes to transform the energy system. R&D can at the same time be regarded to have an option value by firms: it offers them some flexibility to respond to emission reduction demands with more efficient and less expensive technology if they move early. In particular, in case REDD will be linked to the global carbon market, it could be a powerful risk management tool at the firm level. Investment into new technologies always carries certain risks, but could still be

6 The theory of real options is formalized in the introductory book by Dixit and Pindyck (1994).

encouraged if REDD offsets provide firms with an affordable alternative to fill the gap in their "carbon budget" if deployment of new technologies is delayed for technical or other reasons. Without such flexibility, a firm may be even reluctant to engage in research and development (R&D) targeted at carbon-saving innovations, since in case of a strong policy it would have to invest before having time for the technology to develop. Tavoni et al. (2007), for example, look at the impact of REDD on energy sector innovation and find larger effects than Bosetti et al. (2009). The difference to Bosetti et al (2009) is that they consider a less stringent target and encompass all forestry options, i.e. not only REDD (Murray et al, 2009).

The crucial idea behind such options thinking is the economic value associated with being flexible to respond to the outcomes of uncertain processes. Another way of capturing some of this valuable flexibility that has been suggested in the context of REDD credits is banking (e.g. Dinan and Orszag, 2008). If banking is allowed, then it has been shown that firms – in anticipation of a tightening cap - will buy credits prematurely in order to comply with their reduction obligations at a cheaper price later on. Acceleration in abatement may then lead to an additional benefit of reducing the amount of GHG persisting in the atmosphere (Murray et al., 2009).

# CONCLUSION

While the Assessment Paper gives a good estimate of the costs and benefits involved in a potential forest carbon sequestration program, the multiple uncertainties and unresolved issues outlined in this paper should remind us to be cautious and puts the numbers into perspective for any assessment and comparison across other options.

On the one hand, costs might be larger as future modeling efforts lead to adjustment of opportunity costs under competition for land. Furthermore, problems relating to permanence and leakage will add to total costs of REDD, afforestation and forest management projects. On the other hand, taking into account ancillary benefits in terms of ecosystems services and preservation of biodiversity will lead to an upward adjustment of the benefit numbers, which currently rely on the change in consumption only. In addition, the benefits of avoiding higher degrees of climate change are of great importance as well.

Most importantly, however, one has to make a distinction between the uncertainties relating to opportunity cost estimates relying on inaccurate land values, which matter most significantly in the near term, and the uncertainty concerning the impacts of climate change on agriculture and forestry. The latter will certainly affect both costs in the long run and actually also increase the benefits of mitigation in the near future.

Further to the issue of uncertainty, current research by Gusti et al. (2009) sheds more light on the problems that will be raised as competition for land increases, which will exert further pressure on costs. A new version of the Global Forest Model G4M using results from the land use model GLOBIOM as inputs finds that prices of forestry products and agricultural land could increase substantially, if commodity market effects are taken into account. Future research will have to be expanded to provide even more accurate benefit-cost estimates.

Another issue raised in this paper relates to the option values implicit in forestry carbon sequestration and particularly in REDD: continuing deforestation at the current pace will disable us to use the full forest as a means to meet stabilization targets: forests can only be regrown at a relatively slower rate. Given this irreversibility, there is an option value to holding on to forests and using them as a carbon sink later in the face of uncertainties about the amount of GHG reductions needed for stabilization, for example.

Finally, it is of great importance to emphasize that the Assessment Paper and the Perspective Paper both point into the same direction: it should by now be clear that we can ultimately not rely exclusively on solutions emanating from the technosphere to tackle global warming. The biosphere has large potential to help comply with our targets and can also serve as a bridge, while cleaner technologies are being further developed. Even though it has been the task of the Assessment and Perspective Papers to present and evaluate the option of forestry carbon sequestration, the latter should be understood as a necessary and cost-reducing, but not sufficient component of the overall strategy, which must eventually comprise mitigation, R&D and other options as well.

# REFERENCES

Angelsen, A. et al., "Reducing Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report," Prepared for the Government of Norway, Available at http://www.redd-oar.org/links/REDD-OAR_en.pdf, 2009.

Benitez, P., McCallum, I., Obersteiner, M., Yamagata, Y., "Global Supply for Carbon Sequestration: Identifying Least-Cost Afforestation Sites under Country Risk Consideration," Interim Report IR-04-022, International Institute for Applied System Analysis, 2004.

Bosetti, V., R. Lubowski, A. Golub, and A. Markandya, "Linking reduced deforestation and a global carbon market: impacts on costs, financial flows, and technological innovation," FEEM Nota di Lavoro 56.2009, available at http://www.feem.it/NR/rdonlyres/396DBB3D-C57B-4878-9AE6-E493471DDC89/2930/5609.pdf, 2009.

Bottcher, H. et al., "GHG Mitigation Potentials and Costs from Land-Use, Land-Use Change and Forestry (LULUCF) in Annex I Countries," GAINS Methodology Report; IIASA, Laxenburg, Austria, 2008.

Busch, J. et al., "Open Source Impacts of REDD Incentives Spreadsheet (OSIRIS v2.4). Collaborative Modeling Initiative on REDD Economics," June 2009.

Dixit, A.K., and R.S. Pindyck, "Investment under uncertainty," Princeton University Press: Princeton, 1994.

Eliasch, J., "Climate change: Financing global forests," Office of Climate Change, United Kingdom, 2008.

Food and Agriculture Organization of the United Nations (FAO), "The global outlook for future wood supply from forest plantations," Working Paper GFPOS/WP/03, FAO, Rome, February 2000.

Foley, J.A. et al. (2007) Amazonia revealed: forest degradation and loss of ecosystem goods and services in the Amazon Basin. Frontiers in Ecology 2007; 5(1): 25—32.

Golub, A., S. Fuss, J. Szolgayova and M. Obersteiner, "Effects of low-cost offsets on energy investment: new perspectives on REDD," FEEM Nota di Lavoro 17.2009, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1397144 or http://www.feem.it/NR/rdonlyres/80EAC8FD-07E5-4135-8642-5D959AE95C25/2832/1709.pdf, 2009.

Gusti, M., P. Havlik and M. Obersteiner, "Technical Description of the IIASA Model Cluster," The Eliasch Review; Office of Climate Change, United Kingdom, available at http://www.occ.gov.uk/activities/eliasch/Gusti_IIASA_model_cluster.pdf, 2008.

Gusti, M., P. Havlik and M. Obersteiner, "How much additional carbon can be stored in forests if economic measures are used and how much could it cost?" accepted at Research Reports of the National Agrarian University of Ukraine, 2009.

Hansen, J., Mki. Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagani, M. Raymo, D.L. Royer, and J.C. Zachos, "Target atmospheric $CO_2$: Where should humanity aim?" Open Atmospheric Science Journal, vol. 2, p.p. 217-231, 2008.

Murray, B., R. Lubowski, and B. Sohngen, “Including International Forest Carbon Incentives in a United States Climate Policy: Understanding the Economics,” Working Paper, Nicholas Institute for the Environmental Policy Solutions, Duke University, 2009.

Murray, B., “Leakage from an Avoided Deforestation Compensation Policy: Concepts, Empirical Evidence, and Corrective Policy Options” Working Paper 08-02, Nicholas Institute for the Environmental Policy Solutions, Duke University, Available at: http://www.nicholas.duke.edu/institute/wp-leakage.pdf, 2008.

Naidoo, R. and Iwamura, T., “Global-scale mapping of economic benefits from agricultural lands: Implications for conservation priorities,” Biological Conservation 140: 40-49, 2007.

Nordhaus, W., “A Question of Balance,” New Haven: Yale University Press, 2009.

Pagiola, S., Bosquet, B., “Estimating the Costs of REDD at the Country Level,” Forest Carbon Partnership Facility, 2009, available at: http://www.forestcarbonpartnership.org/fcp/sites/forestcarbonpartnership.org/files/The%20Costs%20of%20REDD%2004-09-09.pdf

Ramankutty, N., Foley, J.A., Norman, J., McSweeney, K. “The global distribution of cultivable lands: current patterns and sensitivity to possible climate change,” Global Ecology & Biogeography, 11(5):377-392, 2002.

Tavoni, M., B. Sohngen, and V. Bosetti, “Forestry and the carbon market response to stabilize climate,” ***Energy Policy*** 35 (11): 5346–5353, 2007.

Van Velthuizen et al., “Mapping biophysical factors that influence agricultural production and rural vulnerability,” Environment and Natural Resources Series 11, Food and Agriculture Organization of the United Nations and International Institute for Applied Systems Analysis, Rome, 2007.

Wise, M., et al., “Implications of Limiting $CO_2$ Concentrations for Land Use and Energy,” Science, 324:1183-1186, May 2009.

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

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