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Climate Protection! – A New Energy Policy?

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Summary: There is an emerging planetary consensus: Climate protection is necessary. Preventing global mean temperature from rising more than 2°C above pre-industrial levels is a common goal of climate protection. In essence, it requires a stabilization of carbon dioxide emissions within the next two decades in order to approach nearly zero emissions at the end of the century. Based on an integrated assessment model, we show that climate protection implies an increasing energy efficiency, a share of 20% of renewable energy at the mid of the century, and the use of carbon capturing and sequestration (CCS) on emissions from point sources. The costs of such a scenario are estimated to be about 1.0% of the gross world product, with a strong dependency on the leakage rate of CCS and the learning rates of the renewables.

In order to implement the cost-effective climate protection path a regulatory framework is presented that comprises tradeable permits for emissions, the promotion of renewable energy via green energy certificates, and carbon sequestration bonds.

Zusammenfassung: Es scheint sich ein planetarischer Konsens zu bilden: Klimaschutz ist notwendig. Es ist allgemein anerkannt, dass die globale Mitteltemperatur das vorindustrielle Niveau um nicht mehr als 2°C steigen sollte, wenn gefährliche Störungen des Klimasystems vermieden werden sollen. Dies setzt im Wesentlichen eine Stabilisierung der CO_2-Emissionen in den nächsten beiden Dekaden voraus; zum Ende des Jahrhunderts sollten sich diese dann der Nulllinie nähern.

Anhand eines Integrated-Assessment-Modells wird gezeigt, dass zur Erreichung dieses Klimaschutzzieles die Energieeffizienz mittelfristig erhöht werden muss, der Anteil erneuerbarer Energien bis zur Mitte des Jahrhunderts auf 20 % steigen sollte und die CO_2-Emissionen an großen Punktquellen eingefangen und schließlich in geologischen Formationen gelagert werden müssen (sog. Carbon Capturing and Sequestration).

Die Kosten der Umsetzung betragen dabei etwa 1 % des weltweiten Bruttosozialprodukts. Die Höhe der Vermeidungskosten hängt entscheidend von der Rate ab, mit der CO_2 aus geologischen Formationen entweicht, sowie von der Lernrate der erneuerbaren Energieträger.

Als hierzu notwendige Instrumente werden handelbare Emissionsrechte, grüne Energiezertifikate und „carbon sequestration bonds" diskutiert.

1 Setting the Scene

There is an emerging planetary consensus – climate protection is necessary. Preventing global mean temperature from increasing more than 0.2°C per decade and 2°C relative to

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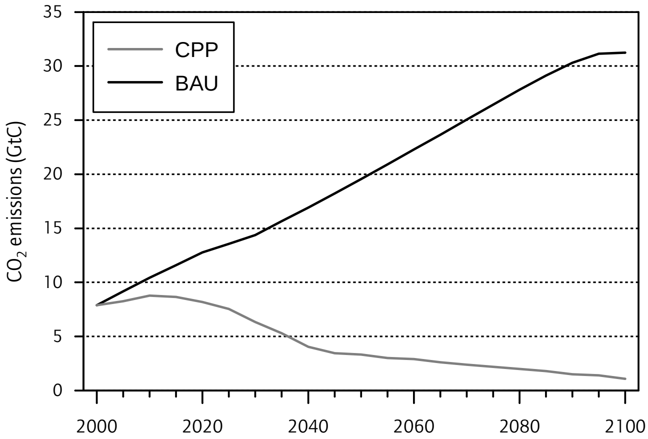
Figure 1

The Mitigation Gap



The area between the climate protection path (CPP) and the business-as-usual path (BAU) is referred to as the mitigation gap. This amount of carbon emissions must be mitigated over the next century.

Source: Own calculation with MIND.

pre-industrial levels is seen as the goal of climate protection. This limitation is necessary if dangerous perturbations of the climate system are to be avoided during the next decades. Otherwise, impacts such as increased probability of extreme weather events, disturbances of the global water circulation, loss of biodiversity, or sudden shifts in monsoon dynamics will likely have to be dealt with. This requirement represents the guard rail of the German Scientific Advisory Council on Global Change (WBGU), which emphasized it once again in its latest survey (German Scientific Advisory Council on Global Change 2003).

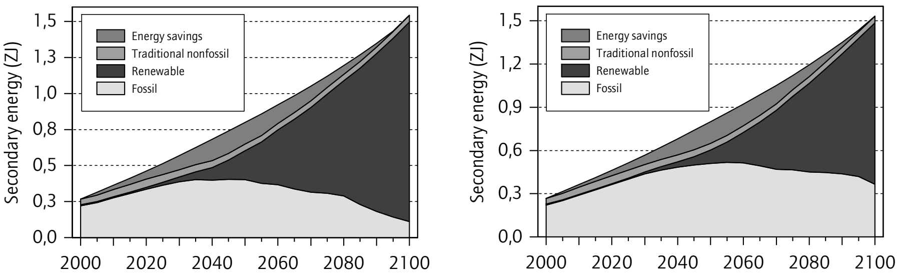
Therefore, efficient climate protection according to this guard rail requires stabilization of greenhouse gas emissions within the next two decades in order to approach zero emissions at the end of the century. The gap between the business-as-usual (BAU) scenario of CO_2 emissions and the climate protection path (CPP) (see Figure 1) shows the technical, economic, and political challenges humankind is confronted with: A largely emissions-free economy at the end of the 21^{st} century in order to avoid dangerous climate change requires a profound change in the worldwide energy system. Therefore, the world economy is about to face a new energy crisis, probably lasting longer and being a greater challenge than both of the oil crises of the 1970s. The reason for this new crisis is the need to overcome the mitigation gap and therefore transform the worldwide energy system.

2 Which Energy System Will be Required for the 21^{st} Century?

Within the next century, the energy requirements of humankind will increase four to five times (relative to current demand), in order to facilitate appropriate economic growth for the less-developed countries as well as for the newly industrialized ones.

Figure 2

Two Scenarios for the Global Energy System with Respect to Different Climate Protection Goals



a) The climate window of the WBGU is imposed on the economy.

b) A stabilization of CO_2 concentration at 450 ppm is to be achieved.

Source: Own calculation with MIND.

The above energy scenarios demonstrate that the share of renewable energy in overall energy consumption needs to be increased substantially in the next decades – not only to achieve the climate targets defined by the WBGU (Figure 2a) but also to stabilize CO_2 concentration at 450 ppm (Figure 2b). Nevertheless, coal, crude oil, and natural gas will also play an important role within the global energy mix: Figure 2a shows how a substantial reduction in the use of fossil energy resources is necessary if the climate protection target put forward by the WBGU is implemented; Figure 2b indicates that fossil fuels can be used to their current extent, even if CO_2 concentration should be stabilized at 450 ppm. In either case, fossil fuels can only be used to the extent shown if parts of the resulting carbon can successfully be captured from large power plants and be sequestered in geological formations. Despite the relatively high costs of carbon capturing and sequestration (CCS) – about $70 per ton of CO_2 – this option could become economically viable if ambitious emissions caps were agreed on and implemented in the next few decades. The reason for that development is the considerable technical progress in exploration and extraction of fossil resources. At present, the reserves of these resources (coal, crude oil, natural gas) amount to approximately 5000 gigatons of carbon (GtC) (Rogner 1997). Since industrialization, about 283 GtC have been used up (Marland et. al. 2003). Due to increasing costs in extraction and exploration of fossil resources, emissions would decrease at the beginning of the next century, if no climate policy were to take place. However, this structural change is carried out way too slowly to avoid dangerous climate change.

The option of capturing CO_2 from huge coal power plants and storing it in geological formations (CCS) offers the possibility of using fossil energy resources without destabilizing the climate system any further. Likewise, this option could be of great importance for international climate negotiations: a climate policy stimulating this possibility would facilitate the entry of the USA and other countries, such as China and India, into climate negotiation, because their income from carbon, crude oil, and natural gas would be diminished less than by following a climate policy without this option.

Above all, the USA increasingly discusses the possibility of 'Industrial Carbon Management' (ICM, also called 'carbon capturing and sequestration' (CCS), where CO_2 is 'captured' from point sources in order to 'sequestrate' it in exploited gas or crude oil fields). This option seems promising because 50% of emissions in industrialized countries are produced by point sources, such as power plants. However, the permeability of the geological formations, which critically determines the leakage of CO_2 from the sequestration site, has not been adequately investigated. But even at high rates of leakage of around 0.5%, sequestration of 160 GtC in geological formations by 2050 would still be advantageous for the world economy. Leakage rates can be particularly 'critical' in determining the costs of mitigation, as will be demonstrated in the following.

Nevertheless, CCS as the sole option will not be sufficient to create efficient climate protection. In the scenarios considered, renewable energy resources need to provide approximately 20% of worldwide secondary energy by 2050, and 80% by the end of the century. But these renewable energy resources are thought to be too costly by some energy economists. Consequently, these people often favor a renaissance of nuclear energy in order to fulfill demand raised by climate protection. However, nuclear energy based on nuclear fission as a global solution is very problematic, if not infeasible. The following estimates outline why.

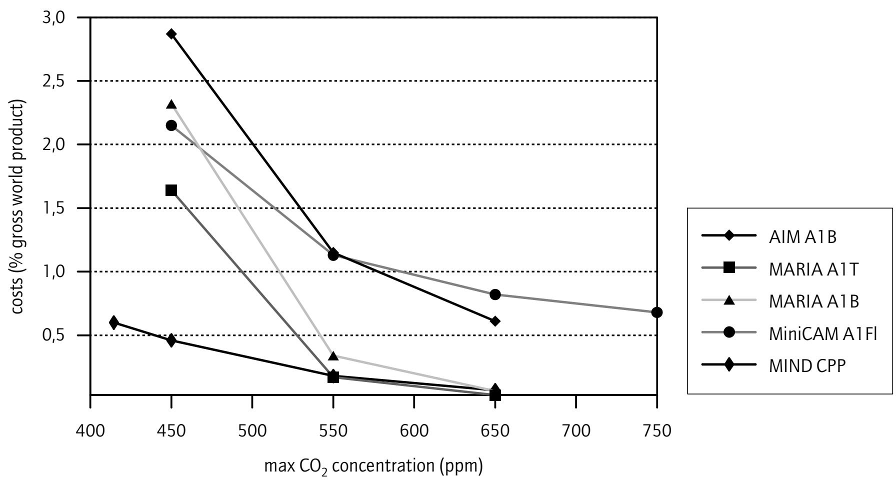
In today's worldwide electricity production, the share of nuclear power is 16%. The International Energy Agency (IEA) recently estimated that worldwide electricity production will double by 2030 (International Energy Agency, 2004). In order to maintain the nuclear energy share at current levels, approximately 500 new pressurized water reactors would have to be built. In order to raise the share to 32%, approximately 1500 new nuclear power plants would be necessary. Not only would this increase the use of uranium and in turn drastically shorten the reach of this resource, but it would also intensify the problem of the ultimate disposal of nuclear waste – not to mention the overall problem of proliferation. The reach of the known resource base for nuclear power may be increased by meaningful improvements in uranium breakdown technology and by deployment of reprocessing facilities. In the light of necessary governmental and technical security standards, however, the chances are that not many states outside the Organization for Economic Cooperation and Development (OECD) could or should want to apply them. Moreover, it is questionable whether nuclear fission will be able to compete with other mitigation options in the long run because of its relatively high investment costs, which until now could not be reduced by accumulated experience ('learning-by-doing').

On the other hand, the bad reputation of allegedly costly renewable energy is not justified: it is commonly recognized that, at present, renewable energy is more expensive than fossil energy, but it is also indisputable that its costs can be reduced through learning-by-doing. In fact, such reductions can already be observed (International Energy Agency, 2000). The potential to reduce costs is expressed by the so-called learning rate, which indicates the percentage cost reduction per unit of power for every doubling of the installed capacity. The higher the installed capacity, the lower the price per kilowatt. The overall costs for the transformation of the energy system depend crucially on this learning rate.

During the transition stage, we observe rising demand for energy-related services in the scenarios shown in Figure 2 due to the building up of a regenerative infrastructure. During

Figure 3

The Mitigation Costs in Different Macroeconomic Models



Sources: MIND: own calculation, AIM: Jiang et al. (2000), MARIA: Mori (2000), MiniCAM: Pitcher (2000).

this time, energy efficiency improvements keep emissions from rising along with energy consumption. Only by means of higher energy efficiency can the infrastructure of renewable energy be augmented without defying the climate protection goal because this infrastructure must be built up in the next decades mainly with fossil fuels. Further results from the energy scenario in Figure 2a and 2b show that efficiency gains alone are not sufficient in the long run. Nevertheless, the short- to medium-term potential to save energy is substantial.

3 Climate Protection Costs

Energy scenarios that are comparable to ours have been presented by other institutions too. One crucial aspect is the economic cost of the energy system's transition. Calculations with the model MIND developed at the Potsdam Institute for Climate Impact Research (PIK) show that an additional 0.6% of gross world product (GWP) is required to reach the WBGU-endorsed climate protection goal of a maximum 2°C temperature rise, for which CO_2 concentration peaks at approximately 420 ppm. The fact that, in virtually all macroeconomic models, losses in GWP surge when a target of less than 550 ppm is set demonstrates just how ambitious this goal of climate protection is (see Figure 3).

Figure 3 shows that the mitigation costs of scenarios calculated by the MIND model are significantly smaller than cost estimates from comparable models used in the Third Assessment Report of the IPCC (Metz et. al. 2003), in which similar socio-economic scenarios are assumed.[1] The reason for this is that the potential for technological change, and therefore the capacity of businesses and investors to react flexibly to the specifications of climate protection, were included in the MIND model (Edenhofer et. al. 2005).

1 For a reference of the quoted models, see Morita et al. (2000).

Although the PIK-based calculations show that climate protection – even with ambitious goals like the WBGU climate window – is relatively inexpensive, one has to concede that the underlying scenarios in Figure 3 cannot guarantee certainty but just plausibility. Hence, the scenarios should be subject to further investigation, especially to point out what would happen in the 'worst case'. Analysis has shown that the costs are highly sensitive to two parameters: the learning rate for renewable energy and the so-called leakage rate (see Figure 4).

As Figure 4 indicates, cost reduction can be particularly efficient if the learning rate for renewable energy is high and the leakage rate of geological formations is low. Even though low learning and high leakage rates do not result in notably high welfare losses, these two parameters are critical in the evaluation of energy strategies.

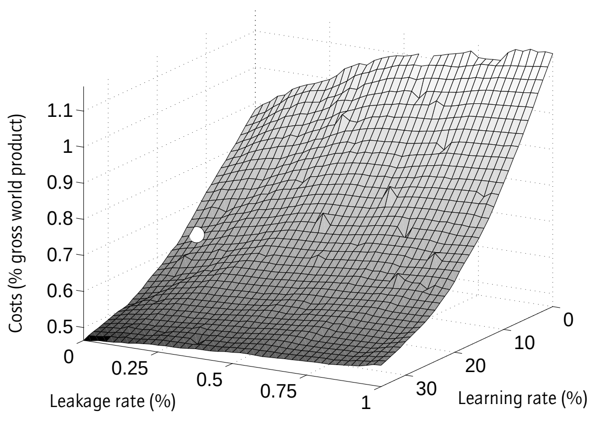
The sensitivity analysis indicates that the realization of high learning rates and sequestration in relatively impermeable sequestration sites play important parts in the cost-effective transformation of the worldwide energy system. A corresponding development path can be induced if a reasonable regulatory framework is implemented. Therefore, in the next section, we will discuss the design of this regulatory framework.

4 A Regulatory Framework for Global Climate and Energy Politics

The regulatory framework comprises at least three different pillars. First, we discuss the need for a tradable permit scheme. Without tradable permits, there will be no investment in carbon-free technologies because the return on investment will be too low. In the second part, we discuss a method for promoting renewable energy technologies. We will ar-

Figure 4

Sensitivity of the Mitigation Costs to the Learning Rate and the Leakage Rate



Source: Own calculation with MIND.

gue that a tradable permit scheme alone does not necessarily guarantee the selection of the most cost-effective technologies, because energy technologies exhibit increasing returns to scale, discriminating against new technologies. Therefore the tradable permit scheme has to be complemented by green energy certificates. In the third part, we discuss carbon sequestration bonds as a management tool for reducing the risk of high leakage of carbon.

Tradable Permits for CO_2

Worldwide trade in CO_2 permits would facilitate the mobilization of climate friendly innovations. Additionally, investors would have an incentive to mitigate CO_2 where it is most cost-effective. However, the existing trading scheme for CO_2 permits is still far from being ideal: neither the USA, China nor India has accepted an emissions cap, and these countries are therefore excluded from the market. It is not likely that Europe on its own will be able to realize ambitious climate protection goals. One way to encourage the USA to take an active part in international climate protection is for the EU to convince China and India to join a Kyoto 2012 framework, e.g. by providing side payments.[2] Once China and India accept an emissions cap and a tradable permit scheme, it will be more difficult for the US government to refuse to participate in international climate protection.

Many stakeholders and economists in the USA as well as in Europe fear an exaggerated increase in permit price. However, from an economic point of view, this fear is not justified. Quite the contrary: temporarily high permit prices are the necessary market signal to mobilize investments that bring about a transformation. For example, investments in renewable energy and in CCS will only become profitable if the permit price increases at least temporarily. With technical progress in the renewable energy technologies and regarding CCS, the permit price may well fall in the future, as our model calculations show. Once high permit prices have induced investments and innovations, and the worldwide energy system has changed into a (nearly) emissions-free economy, the permit price will in turn decline. Therefore, the imposition of a cap on the permit price, as proposed by some experts, presents an impediment to innovation, and innovations are the way to achieve ambitious climate protection targets without damaging economic growth.

Promotion of Renewable Energy Via ‘Green Energy Certificates’

According to the German Advisory Council of the Federal Ministry of Economy, with the introduction of tradable permits for CO_2 (*black trading*), subsidies for renewable energy can no longer be justified (Wissenschaftlicher Beirat beim Bundesministerium für Wirtschaft, 2004). This argument would hold if the market for renewables were an example of ‘perfect competition’. Alas, it is not: for technical reasons, there is a failure of the market for renewable energy. Energy technologies exhibit ‘increasing returns to scale’: the higher the volume of production (or the installed capacity), the lower the cost per kilowatt-hour. As renewable energy resources have so far only taken initial steps in their development, whereas fossil energy resources have long been established in the market, investors will still not invest in renewable energy resources, even though costs below those for energy from fossil fuel are likely to be achieved in the long term. The reason for this is that the

2 For an interesting design for side payments, see von Weizsäcker (2004).

fossil energy system has already depreciated its high initial investment costs, whereas capital costs in the renewable energy sector are relatively high. Innovators, who investigate new techniques in the initial stage, reduce costs through ‘learning-by-doing’. Subsequent imitators benefit from these advances at no additional cost. Hence, in markets showing economies of scale, there is an incentive *not* to be a pioneering firm. But if all firms are waiting to follow a pioneering firm, none can do so. This effect becomes more marked when the entrepreneurs have shorter time horizons. It is economic common sense that internalizing this externality requires policy intervention. Whether renewable energy resources have the potential to compete with fossil energy resources with regard to price is still uncertain. With the introduction of a policy instrument to cure this market failure, renewable energies get a chance to prove their potential.

One needs to be cautious when introducing a subsidy to remedy this market failure: subsidies are known to provoke mismanagement; hence, it is important to design the subsidy system well, in order to prevent it being inefficient.

The Kyoto protocol could be further developed by obliging the engaged countries to create a certain part of their energy production in the regenerative sector. This ‘green energy’ should be traded at an international level, in order to encourage companies to reduce costs by selecting the most appropriate locations. For example, the Annex-I countries could agree to increase the share of renewable energy resources in overall energy production by 10% by 2010. Network operators in the power supply system would be obliged to use a certain quota of the produced renewable energy in their networks. At the same time, a yet-to-be-further-defined department of environment should provide producers/vendors of regenerative power with tradable *green energy certificates*, which would correspond to the amount of regenerative power supplied. The network operators could receive the certificates either through production and supply of regenerative power or by purchasing them on the market. Both are viable ways to fulfill their obligations. Thus, competition takes place in the market for power as well as in the market for certificates. A network operator that produces more than its share of ‘green energy’ could sell certificates. On the other hand, one that provides less than its share will be forced to buy certificates because fulfillment of the obligation is measured by the possession of certificates.

It is likely that the installation of such markets will enable solar thermal plants, biomass, and wind energy to be competitive with fossil energy resources within the next decade. Vendors of regenerative energy will be encouraged to reduce costs fast in order to increase market share and profit. The share of regenerative energy in the overall energy mix could be regulated via national stipulations – prices and selection of the technique will be determined by the market.

Finally, application of the subsidy must cease and renewables must enter unprotected competition alongside fossil energy in order to determine the long-term cost structure of the energy mix. Thus green energy certificates do not distort competition in favor of renewables, but in the first place they initiate competition, through which the most cost-effective alternative will be unveiled. Without this subsidy, there is no guarantee that the best alternative will prevail.

Setting up a market for 'green energy' requires that quotas are valid in the long run and that a 'stop and go' policy is avoided to offer security for long-term investments. Provided these conditions hold, entrepreneurs will invest in technology with high initial costs and late profitability. The crucial point will be that the trade of green energy certificates takes place at an international level, giving investors incentives to select the best locations anywhere in the world. The efficiency of wind and solar energy is ten times higher in Africa than in Europe – given proper locations, solar thermal energy could be competitive today. The market for renewables suffers from regional fragmentation. International trade for energy certificates could be a first important step in globalizing the market for renewable energy.

Carbon Sequestration Bonds

The way to a sustainable energy system must be bridged by fossil energy resources. Hence the use of geological formations is of great importance. The sequestration of 200 Gt of carbon in exploited gas and oil fields, according to the WBGU proposal, is possible with minimum risk (German Scientific Advisory Council on Global Change 2003).

For sustainable use of geological formations, two institutional problems must be solved. First, because of limited storage capacity, one must levy a *deposit price* for using storage capacities such as saline aquifers and exploited gas fields. CO_2 may then be 'emitted' either into geological formations or into the atmosphere. As long as deposit price plus costs for transport and control is lower than the atmosphere's usage price – for instance, expressed in the permit price for CO_2 – storage in geological formations will be used. If it were certain that no CO_2 would leak from geological formations, tradable permits and the deposit price would provide all the necessary precautions for the sensible use of a sparse commodity. But, second, there is the risk of leakage.

Leakage as such is not a catastrophic event from a climate point of view, as long as not all storage sites leak CO_2 to a great extent at the same time. The probabilities of such accidents may not be known yet, but the maximal economic damage cost is easy to calculate: it equals the leaked amount of CO_2 times the permit price for emissions at the time of the leakage. The leaked CO_2 would then use the atmosphere as storage, of course without the permit price being paid. In this case, the sequestration company must purchase the appropriate number of permits. Nevertheless, this strategy alone will not prevent the misuse of sequestration in geological formations. Firms could speculate that CO_2 will start to leak beyond their existence, that the permit price will fall in the long run, or that a later management will be confronted with the consequences. If the time horizon of risk-seeking investors and managers is shorter than the presumed event of leakage, storage in geological formations will pay because the risks can be passed on to later generations. Hence it is foremost important to provide incentives to store CO_2 in formations that are as secure as possible in the firms own interest.

The implementation of carbon sequestration bonds offers the possibility of reasonable risk management: every firm willing to store CO_2 in geological formations must buy a pre-defined amount of bonds from an environmental authority (Edenhofer et. al. 2004). From the firm's point of view, the bonds are an asset as long as the CO_2 remains in the geological formation. If this is the case, indeed, an interest rate will be paid. However, the bonds will be devalued every three years or so by the environmental authority *unless* the firm can prove without doubt that no CO_2 has leaked. Otherwise, the bonds must be partially written off.

The authority can use the money generated by leaked carbon to subsidize renewables not yet ready for the market. This liability should compensate the market penalties of the renewables arising from the fact that, without sequestration, they would have become profitable more quickly. If stored CO_2 leaks from geological formations, precious time required for a cost-effective transition of the energy system will be wasted.

Carbon sequestration bonds must be tradable on markets: a firm can sell its bonds in order to increase its cash flow. But firms will be able to sell their bonds only if they can offer buyers a higher return on investment than a risk-free asset can. The magnitude of this risk surcharge will depend on how buyers assess the risk of a devaluation of the bonds. The firm can obtain high prices only if buyers are convinced of the storage site's security. Hence there are incentives not to undermine confidence in the bonds. Because of the threat of devaluation, the security standard for geological formations will emerge as a market-ready commodity. Namely, firms will face incentives to employ high-performance checks to ensure that the CO_2 remains in the geological formations. The better this can be proved, the higher the value of the bonds. Because carbon sequestration bonds are tradable, investors, analysts, and customers can show their confidence by buying the bonds even at high prices. Accordingly, the public participates in the decision about the extent to which sequestration should be applied. Risk assessment for this technique is thus not in the hands of the technocrats alone; more democracy concerning its employment and investments is guaranteed.

5 False Dichotomies

So far, the discussion about climate policy has been shaped by falsely posed alternatives – growth of energy demand without climate protection or climate protection without economic growth. However, wrong alternatives constantly narrow the set of options. Tragic decisions are induced by a limited set of options. Therefore tragic decisions can also hint at a wrongly posed problem – scientists, politicians, statesmen, and entrepreneurs are always in danger of having their decisions dictated by wrong alternatives.

On the basis of our model's calculation, we have shown that even ambitious climate protection goals can be achieved without substantial losses in economic growth if the share of renewable energy is increased, energy efficiency is enhanced, and CO_2 is captured at point sources and stored in geological formations. Nobody can predict exactly how the energy system will evolve through the 21st century. Hence, what is necessary is a stable political framework that allows entrepreneurs, investors, and consumers to investigate the most efficient techniques by trial and error. At the same time, only techniques that do not cause irreversible damage should be used. Kyoto must come back to its most prominent task: the design and implementation of markets from which optimal solutions will emerge by trial and error. A market for green energy certificates not only increases the efficiency of renewable energy, but also opens up opportunities for development in Africa, which can provide the proper sites for solar power generation. Integrating China and India into the tradable permit scheme could not only convince the USA to join a Kyoto 2012 framework, but will reduce the costs of climate protection, especially for countries that have already ratified Kyoto. Carbon sequestration bonds could allow for moderate and controlled use of carbon capturing and sequestration. Today, Kyoto seems to the majority to be a bureaucratic monster. But tomorrow, Kyoto could be a synonym for a sustainable, equitable, and efficient market economy. In that way, the next energy crisis can be managed by a new designed energy policy.

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