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Climate Policy and Energy Security

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Energy policy is faced with at least four crucial challenges. It has to balance climate protection, energy security, socio-economic acceptability, and equity. Balancing energy policy between these four goals is likely to be a challenging puzzle, much like finding a solution to the fabled magical squares. Between the four cornerstones of energy policy, trade-offs have to be made, but at the same time, pursuing the individual goals may yield strong synergies.

To date, the goals of energy policy are focused on the triangle of security, socio-economic acceptability, and climate protection. Equity is completely neglected in most social cost-benefit analyses of global energy policy. Admittedly, we are not in a position to undertake a comprehensive social cost-benefit analysis according to the proposed magical square ourselves. With this paper we want to broaden the scope of the discussion and shed some light on necessary extensions of the present framework. In the first section, we will discuss the relationship between climate protection and economic growth. This discussion derives crucial criteria for sustainability of the energy system and allows an identification of vital energy security issues in section II. In the third section, we discuss policy instruments for improving international risk management.

I Climate protection and economic growth

There is an emerging international consensus about the necessity of climate protection. Preventing the global mean temperature from rising faster than 0.2°C per decade and above 2°C relative to pre-industrial levels is one ambitious formulation of this challenge. Such constraints are 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. The imperative to avoid such impacts has been adopted as a "guardrail" by the German Scientific Advisory Council on Global Change (WBGU), which emphasized its importance again in its latest survey.[1]

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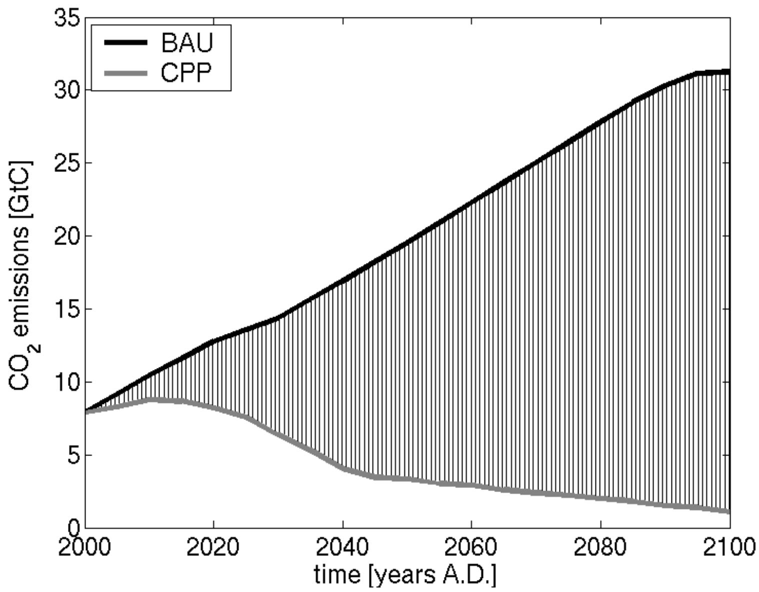
1 German Scientific Advisory Council on Global Change (2003), World in Transition: Towards Sustainable Energy Systems. Earthscan, London and Sterling, 107.

Our calculations show that cost-effective climate protection according to this guardrail 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, economical, and political challenges with which humankind is confronted: a largely emissions-free economy at the end of the 21st century in order to avoid dangerous climate change requires a profound change in the worldwide energy system. 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.

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 cap. This amount of carbon emissions must be mitigated over the next century.



Unfortunately, many economists believe that overcoming this mitigation gap will be quite costly. Figure 2 shows estimated costs from several different studies. Stabilizing CO_2 concentration at a level below 450 ppm leads to increasing mitigation costs. The fact that in virtually all macroeconomic models losses in gross world product (GWP) surge when a target of less than 550 ppm is set demonstrates just how ambitious this goal of climate protection is.[2]

2 For a comparison see Morita et al. (2000) Overview of Mitigation Scenarios for Global Climate Stabilisation based on the New IPCC Emissions Scenarios (SRES). Environmental Economics and Policy Studies 3, 65–88.

Figure 2
The mitigation costs in different macroeconomic models

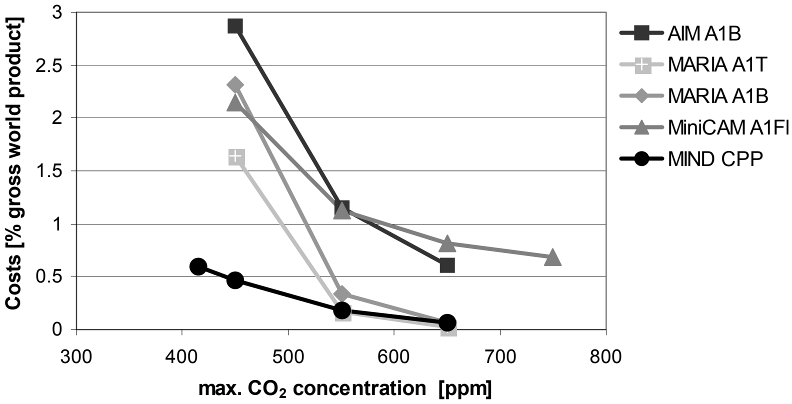


Figure 2 shows that the mitigation costs of scenarios calculated by the MIND model are significantly lower than cost estimates from comparable models used in the Third Assessment Report of the IPCC, in which similar socio-economic scenarios are assumed.[3] The calculations show that 0.6 percent of GWP 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. This is mainly due to the potential of technological change, and therefore the capacity of businesses and investors to react flexibly to the specifications of climate protection, which was included in the MIND model.[4] In the next section we explore whether a path of transformation can be found that exhibits such low costs and in addition has a positive effect on energy security.

II Energy security within the magical square

Within the next century, the energy requirements of humankind will likely 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.

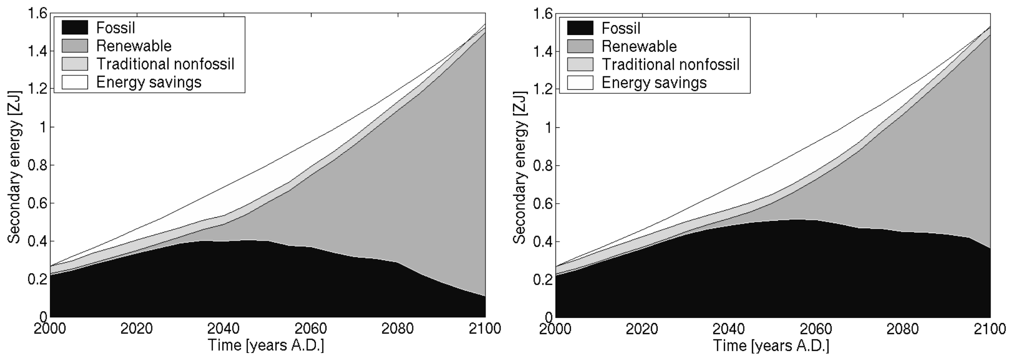
Energy scenarios in accordance with the aforementioned climate guardrails show that the share of renewable energy in the overall energy consumption needs to be increased substantially in the next decades—not only to achieve the ambitious climate targets defined by the WBGU (figure 3a, p. 114) but also for a mere stabilization of CO_2 concentration at 450 ppm (figure 3b, p. 114). Nevertheless, coal, crude oil, and natural gas continue play an important part within the global energy mix: figure 3a shows how a substantial reduction in the use of fossil energy resources is

3 Metz, B., Ogunlade, D., Swart, R., and J. Pan (2001) Climate Change 2001: Mitigation. Intergovernmental Panel on Climate Change. Cambridge University Press, New York.
4 Edenhofer, O., Bauer, N., Kriegler, E. (2005) The Impact of Technological Change on Climate Protection and Welfare: Insights from the MIND Model. Ecological Economics 54: 277–292.

necessary if the climate protection target put forward by the WBGU is implemented. In contrast, figure 3b indicates that fossil fuels can be used to their current extent, even if CO_2 concentration are 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)—currently about 70 USD per ton of CO_2—this option could become economically viable if ambitious emission caps were agreed on and implemented in the next few decades. The reason is the considerable technical progress in exploration and extraction of fossil resources.

Figure 3

Two scenarios for the global energy system with respect to different climate protection goals are shown. On the left-hand side, the climate window of the WBGU is imposed on the economy, on the right-hand side, a stabilization of CO_2 concentration at 450 ppm is to be achieved.



The option of capturing CO_2 from huge coal power plants and storing it in geological formations offers the possibility of using the 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 US and other countries, such as China and India, into climate negotiation, because their income from coal, crude oil, and natural gas would be diminished less than by following climate policy without this option.

Above all, the US is increasingly discussing the possibility of "Industrial Carbon Management," 50 percent of emissions in industrialized countries are produced by point sources, such as power plants and are therefore in principle accessible for CCS. However, the permeability of the geological formations, which critically determines the leakage of CO_2 from the sequestration site, has not been adequately investigated to date. Still, even at high rates of leakage of around 0.5 percent, sequestration of 160 gigatons of carbon (GtC) in geological formations by 2050 would still be of advantageous for the world economy, mainly to "buy some time" by postponing parts of the expensive transformation of the energy system to a later date. Leakage rates can be particularly "critical" in determining the costs of mitigation, as will be demonstrated below.

There is no global shortage of exhaustible resource likely during the 21st century. Reserves of traditional commercial fuels—oil, gas, and coal—will suffice for decades to come. It is assumed that once conventional oil resources are depleted, the huge unconventional oil and gas reserves will be tapped for extraction and clean generating technologies mature. Coal reserves are especially abundant: the resource base is more than twice that of conventional and unconventional oil and gas. The presently known reserves of these resources (coal, crude oil, natural gas) amount to approximately 5000 GtC.[5] Since the beginning of industrialization about 283 GtC have been used up.[6] In our business-as-usual-scenario we calculate that 2200 GtC will be extracted by the economy. If CO_2 concentration was stabilized at 450 ppm only 1200 GtC would be extracted; about 400 GtC would then be captured and sequestered in order to achieve climate protection.

In the scenarios considered, renewable energy resources are needed to provide approximately 20 percent of the worldwide secondary energy in 2050 and 80 percent by the end of the century. But these renewable energy resources are thought to be too costly by some energy economists. Consequently, they often favor a renaissance of nuclear energy in order to fulfill demands 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 percent. The International Energy Agency (IEA) recently estimated that the worldwide electricity production will double by 2030.[7] 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 percent, 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 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 Organisation for Economic Cooperation and Development (OECD) could or should want to

5 Rogner, H.-H. (1997) An Assessment of World Hydrocarbon Resources. Annual Review of Energy and Environment 22, 217–262.

6 Marland, G., Boden, T. A., and Andres, R. J. (2003) Global, Regional, and National CO_2 Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge.

7 International Energy Agency (2004) World Energy Outlook 2004. IEA, Paris. 191–204.

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.

On the other hand, the poor 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 are already observed.[8] 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 depends crucially on this learning rate.

During the transition stage, we observe rising demand for energy related services in our scenario, due to the building up of a regenerative infrastructure. During this time, energy efficiency improvements keep emissions from rising along with energy consumption. Only by means of higher energy efficiency can the share of renewable energy be augmented without defying the climate protection goal. Further results from the energy scenario described above show that efficiency gains alone are not sufficient in the long run. Nevertheless, the short to medium-term potential to save energy is substantial.

Still, the high share of fossil fuels even in the climate protection scenarios implies that the dependence on oil and gas remains an important geopolitical risk for Europe, US and China. In the medium-term this dependence can be reduced by increasing energy efficiency and by diversifying oil and gas imports. However, the increased energy efficiency in industrialized countries will be overcompensated by a rapid growing oil demand in China and India substantially increasing global oil demand and oil prices. Because of this growing energy demand, energy security cannot be further increased for these countries by diversification of their oil and gas imports alone beyond 2020. The issue is amplified by the fact that 70 percent of conventional oil and 40 percent of natural gas resources are concentrated in the so-called Strategic Ellipse comprising countries like Iran, Iraq, Saudi Arabia, and Russia.[9] The countries in the Strategic Ellipse are for the foreseeable future neither politically nor economically low-risk suppliers of oil and gas. Besides the diversification of imports and an increased energy efficiency, the most efficient ways to reduce the dependence on oil and gas further are by promoting renewable energy technologies and by developing new coal strategies. These options do not only comprise low-emission power plants but also the opportunity for providing alternative

8 International Energy Agency (2000) Experience Curve for Energy Technology Policy. IEA, Paris.

9 Rempel, H. (2000) Geht die Kollenstoff-Ära zu Ende? Vortrag auf der DGMK/BGR-Veranstaltung "Geowissenschaften für die Exploration und Produktion: Informationsbörse für Forschung und Industrie," Hannover. Available at <http://www.bgr.de/b123/kw_aera/kw_aera.htm>.

sources for feeding the transport sector with hydrogen, biofuels, or gas-to-liquids. The urgent need for OECD and emerging industrialized countries like China and India for reducing supply side risks will be a powerful driver for the transformation of the energy system.

Beyond 2030, the economic and technical development of renewable energy technologies is the central option not only for climate policy but also for reducing geopolitical risks. This conclusion remains valid if nuclear power becomes a more important option than in our scenarios. Even the most optimistic nuclear power scenarios predict only a 20 percent share on the primary energy consumption in 2030. A reasonable strategy for promoting renewable energy technologies is a not only crucial for climate protection but also a medium-term requirement of energy security.

This transformation for the energy system has also important implications for equity. It is a well-known fact that hydrocarbon-exporting countries suffer from their exports because of the misuse and inequitable distribution of rents from the energy trade. A clear symptom of the "Dutch disease" can be diagnosed if resource abundance in general or resource booms in particular shift resources away from sectors of the economy that have positive externalities on growth. In essence, Dutch disease leads to decreasing growth rates, because countries possessing abundant natural resource tend to have a larger service sectors and smaller manufacturing sectors than resource-poor economies.[10] Therefore, economists believe that a comparative advantage in resource exporting is in many cases not a blessing but a major cause for an economic slow-down.[11]

The transformation of the global energy system requires an increased share of renewable energy technologies, mainly in the developing countries in Africa because the efficiency of wind and solar energy is ten times higher there than in Europe. Now the crucial question emerges, whether Africa benefits from exporting electricity to Europe or not. Exporting electricity does not necessarily imply an infection with Dutch disease because investment in electricity infrastructure has positive externalities on economic growth and even on human capital. Moreover, electricity can be traded on markets and therefore induce revenues from export which can be invested in the domestic economy. It is worthwhile to check to what extent trading electricity could be part of an export-oriented growth strategy for developing countries especially in Africa.

The International Energy Agency predicts an investment for energy-supply infrastructure worldwide of about 16 trillion USD in the period 2001–2030. Almost 10 trillion USD will be spent on power generation, transmission, and distribution alone. Developing countries will require almost half of global investment in the energy sector as a whole. Invest-

10 Sachs, J. D. and Warner, A. M. (1997) The Big Push, Natural Resource Booms and Growth. Unpublished working paper.

11 Sala-i-Martin, X. and Subramanian, A. (2003) Addressing the Natural Resource Curse: An Illustration from Nigeria. IMF Working Paper WP/03/139.

ment needs amount to 1.2 trillion USD in Africa.[12] Financing the required investment in developing countries is a challenge because domestic saving and investment shares in Africa are too small, so that a huge inflow of foreign direct investments is needed for enhancing the capacities for electricity production. Therefore, poorly developed domestic financial markets and high investment risks for foreign investors are the most important reasons for low investment shares and low economic growth rates. But some calculations show that renewable electricity from Africa would be competitive even without further reduction of costs by learning-by-doing. A prerequisite of such an investment strategy are instruments for reducing the risk of foreign direct investment. We will discuss this aspect in the next section.

III How do we deal with risks?

In this last section we conclude that, according to the magic square, promotion of renewable energy technologies is crucial in the long run. Fossil fuels, in particular gas and coal, will be the predominant source for primary energy until the middle of this century. In this section, we will discuss the instruments for implementing such a strategy. These instruments do not represent a comprehensive global energy policy architecture. The discussion of these two pillars should only launch a debate that will hopefully lead to a more complete architecture.

Creating a global market for renewables

It is a common belief in economics that with the introduction of tradeable permits for CO_2 *(black trading)*, subsidies for renewable energy can no longer be justified.[13] This argument would hold if the market for renewables was an example of "perfect competition." Unfortunately, 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 fossil energy system has already written off 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 costs. Hence, in markets showing

12 International Energy Agency (2003) World Energy Investment Outlook, IEA, Paris. 25–29.

13 Wissenschaftlicher Beirat beim Bundesministerium für Wirtschaft. Zur Förderung erneuerbarer Energien. Stellungnahme vom 16. Januar 2004.

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 pronounced 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. However, 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 from 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 percent 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 tradeable *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 power market as well as in the certificates market. 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 quickly in order to increase market share and profit. The share of regenerative energy share 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 instantiate 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 trade in green energy certificates takes place at an international level, giving investors incentives to select the best locations anywhere in the world. The market for renewables suffers from regional fragmentation. International trade for energy certificates could be a first important step to globalize the market for renewable energy.

It is likely that a market for green energy certificates would not attract enough capital for financing a network allowing Africa to export electricity. Therefore, public-private partnerships may be required for building up the required infrastructure for transmitting electricity. In order to finance such a network, a coalition of Annex I countries could issue tradable contracts, securities, or bonds entitling their owners to a fixed income expressed as an interest rate. In exchange for the security, investors on the capital market contribute their capital to the electricity network. After building up the electricity network, the access to the network and the supply of electricity could be auctioned. The profits from this auction are used to pay the contracted fixed income. This scheme will channel foreign direct investments in African countries and will also avoid—as already outlined above—infection with Dutch disease. These securities are tradable and can be sold even before the profits are realized. The purpose of securitization is to attract financing without using the international credit market for African countries itself in which these countries would have to pay relatively high interest rates. Because of this mechanism, the risks of investments in developing countries can substantially be reduced. A European-African electricity network would improve energy security for both regions and allow access to low-emission electricity.

Energy security and CCS–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 at minimum risk.[14]

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

14 German Scientific Advisory Council on Global Change (2003) World in Transition: Towards Sustainable Energy Systems. Earthscan, London and Sterling.

geological formations, tradable permits and the deposit price would provide all the necessary precautions for a 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 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 of foremost important to provide incentives to store CO_2 in formations that are as secure as possible in their 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 predefined amount of bonds from an environmental authority.[15] From the firm's point of view, these 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

15 An analysis of carbon sequestration bonds in two variations (including the one presented here) can be found in Edenhofer, O., Held, H., and Bauer, N. (2005) A Regulatory Framework for Carbon Capturing and Sequestration within the Post-Kyoto Process. Accepted for publication in: Rubin, E. S., Keith, D. W., and Gilboy, C. F., eds., Proceedings of 7th International Conference on Greenhouse Gas Control Technologies. Volume 1: Peer-Reviewed Papers and Plenary Presentations. IEA Greenhouse Gas Programme, Cheltenham. Forthcoming.

obtain high prices only if buyers are convinced of the storage site's security. Hence there are incentives for the whole branch of business not to undermine confidence in the bonds. Because of the threat of devaluation, the security standard for geological formations will emerge to 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 out of reach of the technocrats alone: more democracy concerning its employment and investments is guaranteed.

IV False Dichotomies

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

On the basis of our model 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. We argue that this strategy will also improve energy security for developing and developed countries. 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 the 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. Carbon sequestration bonds could allow for moderate and controlled use of carbon capturing and sequestration. Today, the magical square seems to the majority to be an infeasible challenge. But tomorrow, the magical square could be a synonym for a sustainable, equitable, and efficient market economy. In that way the next energy crisis can be managed by a newly designed energy policy.

Abbreviations

ACEA	European Automobile Manufacturers Association
BP	British Petroleum
BTA	Border Tax Adjustments
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CCS	Carbon Capturing and Sequestration
CEPS	Centre for European Policy Studies
CHT	Combined Heat and Power
CICERO	Center for International Climate and Environmental Research
CO_2	Carbon Dioxide
EFIEA	European Forum on Integrated Environmental Assessment
EIA	Energy Information Administration
ETS	Emission Trading Scheme
EU	European Union
EU-ETS	EU Emissions Trading Scheme
FGD	Flue Gas Desulphurization
G8	Group of Eight
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Gt	Gigatons
GtC	Gigatons of Carbon
GW	Gigawatt
GWP	Gross World Product
HDI	Human Development Index
ICCT	International Climate Change Taskforce
IGCC	Integrated Gasification Combined Cycle
IIASA	International Institute for Applied Systems Analysis
INTACT	International Network To Advance Climate Talks
IPCC	Intergovernmental Panel on Climate Change
KW	Kilowatt
kWh	Kilowatt-hour
NO_x	Nitrous oxides
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
ppm	parts per million
R&D	Research and Development
SRES	Special Report on Emissions Scenarios
TWh	Terrawatt-hours
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USCB	United States Census Bureau
USD	US Dollar
WBGU	Scientific Advisory Council on Global Change to the Federal Government of Germany (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen)
WHO	World Health Organization
WTO	World Trade Organization
yr	Year