World in Transition

German Advisory Council on Global Change (WBGU)

Future Bioenergy and Sustainable Land Use

Summary for Policy-Makers

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(as on 31. October 2008)

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Summary for policy-makers

Global bioenergy policy for sustainable development: WBGU's guiding vision

The incipient global bioenergy boom is giving rise to vigorous and strongly polarized debate. Different underlying aims, such as reducing dependence on imported oil and gas or using biofuels to reduce the CO_2 emissions of road traffic, predominate in different quarters and shape the political agenda. Supporters of bioenergy argue that, at a time of sharply increasing demand for energy, bioenergy can help to secure energy supply and to mitigate climate change as well as create development opportunities, particularly in the rural areas of industrialized and developing countries. Critics, on the other hand, maintain that growing energy crops will heighten land-use conflicts as food cultivation, nature conservation and bioenergy production compete for land, and that bioenergy is likely to impact negatively on the climate. Because of the dynamics and huge complexity of the issue, as well as the considerable scientific uncertainty and the multiplicity of interests involved, it has not as yet been possible to carry out an integrated assessment of the contribution bioenergy can make to sustainable development. WBGU aims to show that the sustainable use of bioenergy is possible and to outline how to exploit opportunities while at the same time minimizing risks.

To that end, WBGU presents an integrated vision that will provide policy-makers clear guidance for the deployment of bioenergy. The principle behind the change of direction that is required must in WBGU's view be the strategic role of bioenergy as a component of the global transformation of energy systems towards sustainability. The guiding vision is inspired by two objectives:

- *Firstly* the use of bioenergy should contribute to mitigating climate change by replacing fossil fuels and thus helping to reduce greenhouse gas emissions in the world energy system. The fact that bioenergy carriers can be stored and used to provide control energy in power grids can make a strategically important contribution to stabilizing electricity supplies when there is a high proportion of wind and solar energy in the energy systems of industrialized, newly industrializing and developing countries. In the long term, bioenergy in combination with carbon dioxide capture and secure storage can even help to remove some of the emitted CO_2 from the atmosphere.
- *Secondly* the use of bioenergy can help to overcome energy poverty. In the first place this involves substituting the traditional forms of bioenergy use in developing countries that are harmful to people's health. The modernization of traditional bioenergy use can reduce poverty, prevent damage to health and diminish pressures placed on natural ecosystems by human uses. Some 2.5 billion people currently have no access to affordable and safe forms of energy (such as electricity and gas) to meet their basic needs. Modern yet simple and cost-effective forms of bioenergy can play an important part in significantly reducing energy poverty in developing and newly industrializing countries.

WBGU's central message is that use should be made of the global sustainable potential of bioenergy, provided that risks to sustainability can be excluded. In particular, the use of bioenergy must not endanger food security or the goals of nature conservation and climate protection.

If this ambitious guiding vision is to be realized, politicians must play their part in shaping the processes involved. It is essential to avoid undesirable developments that could prevent proper use being made of the available opportunities. Some of the political measures that are currently in place – such as inappropriate incentives under the Framework Convention on Climate Change or the European Union's quota specifications for biofuels – actually promote bioenergy pathways that exacerbate climate change. It is also important that bioenergy does not trigger competition for land use in a way that puts food security at risk or leads to the destruction of rainforests or of other natural and semi-natural ecosystems. When assessing the use of energy crops it is important to take account of both direct and indirect land-use changes, since these changes have a cru-

cial impact on the greenhouse gas balance and on the risks to biological diversity. By contrast, the use of biogenic wastes and residues entails far fewer risks for land use.

On account of the many possible bioenergy pathways, their different characteristics, and the global linkages among their effects, it is not possible to arrive at a single sweeping assessment of bioenergy. The analysis must be more specific, and in its report WBGU therefore considers bioenergy from an interdisciplinary, systemic and global perspective. WBGU has created an analysis matrix; this involves defining ecological and socio-economic sustainability criteria for the use of bioenergy, conducting an innovative global analysis of the potential of bioenergy on the basis of these criteria, and finally evaluating specific bioenergy pathways in terms of their greenhouse gas balance and environmental impacts over the entire life cycle, taking account of objectives and costs in the process.

Building on that analysis, WBGU develops strategies showing how bioenergy can be deployed as part of sustainable energy systems in industrialized, newly industrializing and developing countries. In the process it becomes evident that the modern forms of bioenergy that are currently in use are insufficiently geared towards the goals of sustainability and climate change mitigation. This applies in particular to the use of annual energy crops grown on agricultural land in order to produce liquid fuels for transport purposes. It would be better to give priority to bioenergy pathways that generate electricity and heat from residues or from perennial crops. WBGU therefore calls for a rapid end to the promotion of biofuels in the transport sector by means of a progressive reduction in the blending quotas for fossil fuels and for the scheme to be replaced by an expansion of electromobility.

With an appropriate regulatory framework, the sustainable use of fuels derived from energy crops can be an important component in the transformation towards sustainable energy systems, with the potential to function as a bridging technology until around the middle of the century. By then the growth in wind and solar energy production is likely to be so far advanced that sufficient energy will be available from these sources. At the same time the pressures on global land use will have increased significantly, principally as a result of three factors: the growth in a world population whose food consumption patterns are increasingly land-intensive, the increasing demand for land to cultivate biomass as an industrial feedstock, and, not least, the impacts of climate change. As a result, the cultivation of energy crops will probably have to be reduced in the second half of the century, while the use of biogenic wastes and residues will be able to continue. In view of these escalating trends, the problem of competing land use is a potential source of future conflict with implications ranging far beyond the field of bioenergy. Global land-use management is therefore a key task of future international policy-making and an essential requirement for a sustainable bioenergy policy.

For steering the use of bioenergy, WBGU proposes a global regulatory framework for a sustainable bioenergy policy. The key elements of such a framework are a revised UN climate regime with corrected incentives, the setting of sustainability standards, and accompanying measures to safeguard sustainability by strengthening and developing international environmental and development regimes (such as the biodiversity and desertification conventions). Within this framework WBGU formulates promotion strategies with the aim of furthering efficient, innovative technologies and increasing investment in necessary infrastructure – thus contributing to attainment of the guiding vision's two objectives.

By supporting country-specific sustainable bioenergy strategies, development cooperation can help to mobilize sustainable bioenergy potential in developing and newly industrializing countries, to significantly reduce poverty and to build climate-friendly energy systems. An important condition for developing countries, if they are to start using modern forms of bioenergy, is the strengthening of their capacities to take action (such as governance capacities in relation to developing and implementing a sustainable bioenergy policy; monitoring capacities in relation to land-use conflicts; application-oriented research into bioenergy). In addition, for such countries it is essential that bioenergy strategies are linked with food security strategies. This applies in particular to the low-income developing countries who are net importers of food.

In view of the major opportunities and risks associated with it, and the complexity of the subject, bioenergy policy has in a short time become a challenging political task for regulators and planners – a task which can only be accomplished through worldwide cooperation and the creation of an international regulatory framework. In this flagship report WBGU provides decision-makers with guidance to help them in this process of crafting a differentiated and coherent global bioenergy policy.

1 Present use and future potential of bioenergy

To acquire a comprehensive perspective on bioenergy it is necessary to look beyond the narrow focus on the cultivation of energy crops for the production

of liquid fuels for transport purposes and to consider the full potential. For this purpose it is in WBGU's view useful to divide bioenergy use analytically into the following areas: (1) traditional bioenergy use, (2) use of biogenic wastes and residues, (3) cultivation of energy crops.

Most present bioenergy use is traditional biomass use

Modern bioenergy plays only a small part in present global bioenergy use, representing about 10 % of the total. Biofuels for transport purposes, while much discussed, account for a mere 2.2 % of all bioenergy. The lion's share of global bioenergy use – almost 90 % of the total, or around 47 EJ per year – is accounted for by traditional bioenergy: this represents around one-tenth of current global primary energy use. This traditional usage involves burning wood, charcoal, biogenic residues or dung, mainly on inefficient three-stone hearths. Around 38 % of the world's population, mostly in developing countries, depend on this form of energy, which is harmful to health. More than 1.5 million people a year die from the pollution caused by these open fires. Simple technical improvements to stoves can to a large extent prevent the health risks posed by biomass use while at the same time doubling or even quadrupling its efficiency. The process of modernizing traditional bioenergy use or replacing it with other – preferably renewable – forms of energy can therefore provide important leverage for poverty reduction worldwide, a fact that has been often neglected in the debate on bioenergy and development policy.

The sustainable potential of biogenic wastes and residues

WBGU estimates the technical potential of biogenic wastes and residues worldwide to be around 80 EJ per year. However – for soil protection and other reasons – the sustainably usable potential can be set at only about 50 EJ per year, of which around a half may be economically viable. The scientific basis for estimates of the sustainable global potential of wastes and residues is very slim; WBGU recommends that further studies be carried out so that more precise estimates can be made.

A new modelling of the global sustainable potential of energy crops

Since the available estimates of potential are based on different methods and deliver widely varying results, WBGU has undertaken a new analysis of the global sustainable potential of energy crops. This estimate is based on a dynamic global vegetation model. Scenarios of the potentially available areas of land incorporated those sustainability requirements that must in WBGU's view be met if a globally integrated perspective is adopted. Future land requirements for food security and nature conservation were estimated and excluded from energy crop cultivation. Areas of land were also excluded if the greenhouse gas emissions arising from the conversion to agricultural land would take more than ten years to be compensated for by the carbon removed from the atmosphere by the cultivation of energy crops; these areas were primarily forests and wetlands. Different scenarios relating to climate, emissions and irrigation were also examined, although set against food security and nature conservation the influence of these three factors is relatively small. These different scenarios result in figures for the global sustainable technical potential from energy crops of between 30 EJ and 120 EJ per year.

Figure 1 shows a scenario that represents an average estimate of potential. It describes the technical potential that can be produced in a sustainable manner. However, considerations of economic viability and political conditions in the different parts of the world impose further restrictions on this technical potential. WBGU therefore conducted a further analysis of the regions in which the modelling identifies significant sustainable bioenergy potentials. The preconditions for rapid realization of these potentials include a minimum level of security and political stability in the countries and regions concerned: significant investment activity cannot be expected in fragile states or those embroiled in civil war. Infrastructure-related and logistical capacities are also required, together with a basic level of regulatory competence, if sustainability requirements are to be formulated and implemented.

In the light of these factors five regions were considered in more detail; in the other regions it was either the case that the estimated bioenergy potentials are relatively low (e.g. the Middle East and North Africa), or that economic and government capacity can be regarded as given in the foreseeable future (e.g. North America, Europe). As the results of the modelling show, there are considerable potentials for the sustainable cultivation of energy crops in tropical and subtropical latitudes. Central and South America alone account for 8–25 EJ per year. The political and economic conditions there are also particularly favourable for realizing the sustainable bioenergy potential compared to the other regions. In addition, good prospects for harnessing the sustainable potential to the extent of 4–15 EJ per year exist in China and its neighbouring countries; there, too, it would be possible to secure the necessary investment and develop the required capacities. There is also considerable potential on the Indian subcontinent (2–4 EJ per year) and in South-East Asia (1–11 EJ per year).

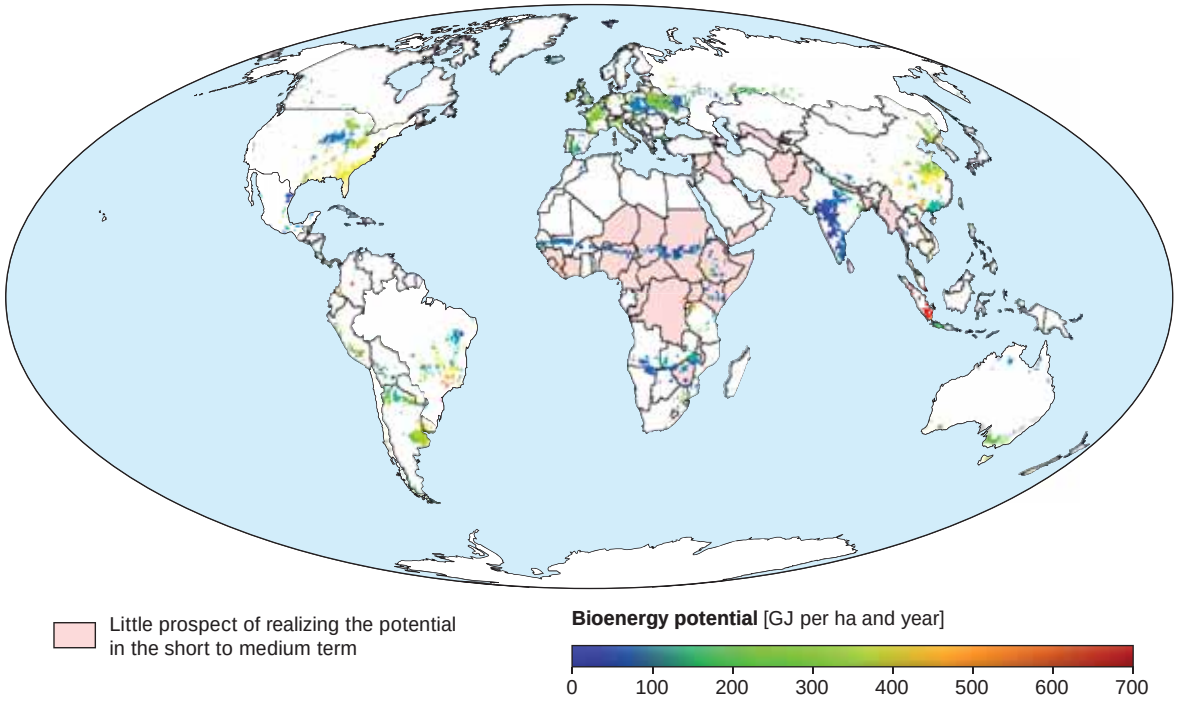

Figure 1
Regions with potential for sustainable bioenergy from crops and countries that are affected by state fragility or collapse of the state. The map shows the distribution of possible areas for the cultivation of energy crops and the potential production in the year 2050 for a WBGU scenario involving a low level of need for agricultural land, high level of biodiversity conservation and non-irrigated cultivation. One pixel corresponds to 0.5° x 0.5°. In order to assess whether the identified sustainable bioenergy potentials are likely to be realizable, the quality of governance in individual countries was rated using the Failed States Index (FSI). The countries coloured light red have an FSI > 90, indicating that in the short to medium term the prospect for realizing bioenergy potentials can be regarded as poor.
Source: WBGU, drawing on data from Beringer and Lucht, 2008 and from Foreign Policy, 2008

These regions, however, face particular challenges in the form of high land-use density, risks to food security, deforestation and the need to conserve biological diversity. On account of state fragility or the collapse of government, in many African countries it is unrealistic to expect that the full potential of around 5–14 EJ per year in sub-Saharan Africa will be realized. In African countries where the economic and political situation is more favourable the options for tapping the potential should be explored in more detail.

The sustainable potential of bioenergy is significant!
Including the potential from wastes and residues (ca. 50 EJ per year), WBGU estimates the total sustainable technical potential of bioenergy in the year 2050 to be 80–170 EJ per year. This represents around a quarter of current global energy use and less than one-tenth of the expected level of global energy use in 2050. However, this range represents the upper limit; some of this technical sustainable potential will not be viable, for example for economic reasons or because the area in question is one of political conflict. The economically mobilizable potential may amount to around a half of the sustainable technical potential. In view of these figures the importance of bioenergy should not be overestimated, but the expected scale is nonetheless significant. Considering the strategic merits of bioenergy, it should not be neglected in the future development of energy systems. The challenge for policy-makers is to make full use of the sustainable bioenergy potential that is economically mobilizable while at the same time ensuring through suitable regulation that undesirable developments are avoided and sustainability limits observed.

2
Risks and undesirable developments arising from unregulated bioenergy expansion

Against the potentials and opportunities must be set the risks of unregulated bioenergy development. The increased cultivation of energy crops couples the rapidly growing worldwide demand for energy to global land use. This increases the demand for agricul-

tural land, which is already becoming scarcer, and increases the likelihood of land-use conflicts in the future. Some ecosystem services and products are inextricably linked to land use and the production of biomass and cannot be substituted by other means. These include, for example, the conservation of biodiversity, biogeochemical cycles, biomass as food and feed and to some extent the use of biomass as feedstock in industrial production processes. In contrast, renewable energy can also be produced in ways that are unlikely to trigger land-use conflicts, such as through the generation of wind power or solar energy. Risks arise when the cultivation of energy crops triggers direct or indirect competition for land, with the result that non-substitutable uses of biomass are displaced and hence jeopardized. These risks were taken into account in WBGU's analysis of potential, but in the practical mobilization of this potential it is a major challenge for a sustainable bioenergy policy to avoid them.

Risks to food security

If the food requirements of the world's growing population are to be met, global food production will need to increase by around 50 % by 2030. The amount of land needed for future food production is also influenced by the land-intensive food consumption patterns of the industrialized countries, which are spreading to the growth regions of emerging economies such as China. This demand can only partly be met by increasing productivity per unit of land; in consequence the FAO estimates that the amount of land used for agriculture will need to be increased by 13 % by 2030. It is therefore likely that there will be a significant increase in competition for the use of agricultural land and, consequently, a trend towards rising food prices. Furthermore, a significant increase in the cultivation of energy crops implies a close coupling of the markets for energy and food. As a result, food prices will in future be linked to the dynamics of the energy markets. Political crises that impact on the energy markets would thus affect food prices. For around one billion people in the world who live in absolute poverty, this situation poses additional risks to food security, and these risks must be taken into account by policy-makers.

Risks to biological diversity

The increased demand for agricultural products that arises from the expansion of bioenergy use can be met by intensifying existing production systems, at the expense of the biological diversity of the land thus farmed. The other option is to claim new agricultural land at the expense of natural ecosystems; this process is at present regarded as the most important driver of the current global crisis of biological diversity. This impact on biodiversity may occur directly, such as when tropical forests are cleared and the land used for energy crops. Indirectly triggered land-use changes are more difficult to assess: when agricultural land is given over to the cultivation of energy plants, the production that previously took place on this land must now take place elsewhere. Through the world market for agricultural goods these indirect displacement effects often acquire an international dimension. Thus, an uncontrolled expansion of energy crop cultivation would further exacerbate the loss of biological diversity.

Risks to climate change mitigation

The conversion of natural ecosystems into new agricultural land releases greenhouse gases. Whether and to what extent greenhouse gas emissions can be reduced by using bioenergy from energy crops depends to a large extent on the land-use changes involved. Emissions created by the conversion of ecosystems that contain a high proportion of carbon (such as forests and wetlands, as well as some natural grasslands) generally negate the climate change mitigation effects that bioenergy use might have. In such cases the use of energy crops may even exacerbate climate change. Both direct and indirect land-use changes must therefore be taken into account in evaluating the greenhouse gas balance of bioenergy use.

Risks to soil and water

Forms of bioenergy that focus on the use of annual energy crops on agricultural land are insufficiently compatible with the goals of soil protection. Perennial cultivation systems, on the other hand, may actually help to restore degraded land. Whether the cultivation of energy crops is acceptable in terms of soil protection also depends on agro-ecological conditions in the region. In addition, the removal of residues from agriculture- or forestry-based ecosystems must be restricted, as the soil may otherwise be depleted of organic substances and mineral nutrients. Uncontrolled expansion of energy crop cultivation and inappropriate cultivation systems may also greatly increase the pressure of use on the available water resources. Energy crops are a new driving force in the land-use sector; the major effects that they may have on future water use have as yet barely been explored.

3 Sustainable bioenergy pathways: WBGU's findings

On the basis of the two objectives of its guiding vision, WBGU explores a number of important bioenergy

pathways. The use of bioenergy only has a climate change mitigation effect if the greenhouse gas emissions arising from the land-use changes and from the cultivation and use of the biomass are lower than the emissions that would arise if fossil fuels were used. Bioenergy can best contribute to overcoming energy poverty when its advantages are exploited by locally adapted technology: biomass can decentrally store and provide energy without the need for major financial or technical investment.

Production of biomass for use as energy: What are the key issues?

In producing biomass for use as energy a fundamental distinction needs to be made between wastes and residues on the one hand and energy crops on the other.

Priority for the use of wastes and residues

The use of biogenic wastes and residues has the advantage of causing very little competition with existing land uses. It involves no greenhouse gas emissions from land-use changes and cultivation, so that the contribution to climate change mitigation is determined primarily by the conversion into bioenergy carriers and their application in energy systems. When using residues, care must be taken to meet soil protection standards – and hence ensure climate change mitigation – and that pollutant emissions are avoided. Overall, WBGU attaches higher priority to the recycling of biogenic waste for energy (including cascade use) and to the use of residues than to the use of energy crops.

Land for energy crop cultivation

Where specially cultivated energy crops are used, it is essential to take account of land-use changes. While emissions from direct land-use changes can be quantified using standard values, much greater uncertainty attaches to indirect land-use changes. WBGU uses a provisional method for calculating these indirect effects, enabling an initial rough estimate to be made.

WBGU is strictly opposed to the direct or indirect conversion of woodland, forests and wetlands into agricultural land for energy crops; such conversion is usually accompanied by non-compensatable greenhouse gas emissions and its impacts on biological diversity and soil carbon storage are invariably negative. The cultivation of energy crops should preferably be restricted to land for which the change of use to bioenergy production does not involve indirect land-use changes. The total greenhouse gas emissions initially caused in the context of cultivation should not exceed the quantity of CO_2 that can be resequestered by the cultivation of energy crops on the land in question within ten years.

The cultivation of biomass on marginal land (that is, land with a limited productive or regulatory function) has the significant advantage that land-use competition, for example with food security, is unlikely; in consequence, indirect land-use changes will probably not be induced. WBGU therefore concludes that marginal land should be preferred for the cultivation of energy crops and this type of land use should be encouraged, provided that the interests of local population groups are taken into account and the implications for nature conservation are assessed before cultivation commences.

Cultivation systems for energy crops

The principal criteria used by WBGU to assess the sustainability of cultivation systems are the effects on biological diversity and soil carbon storage. Bioenergy can only be classed as sustainable energy if the land on which it is grown continues in the long term to produce as much biomass as is used for energy – in other words, if long-term soil fertility is ensured. Only in this situation can it justifiably be assumed that the carbon that is removed from the atmosphere and stored by the energy crops and that is rereleased in the form of CO_2 when the crops are used for energy does not lead to an increase in the concentration of CO_2 in the atmosphere and therefore does not need to be regarded as an emission. In addition, differing yields per unit of land must be taken into account. From this point of view perennial crops such as *Jatropha*, oil palms, short-rotation plantations (fast-growing timber) and energy grasses score better than annual crops such as rape, cereals or maize; the former group should therefore always be preferred. If suitable cultivation systems are chosen, additional organic carbon can be incorporated into the soil; this improves both the greenhouse gas balance and soil fertility.

Conversion, end-use application and system integration: What are the best ways of using bioenergy?

Once the biomass has been made available, the climate change mitigation effect is mainly determined by two factors: the way in which biomass is converted into usable products such as gas, plant oils, biofuels or wood pellets, and the way in which it is used and integrated into the energy system – for example, into transport or into the generation of heat or electricity. On the whole, however, these influences carry less weight than the effect of direct or indirect land-use

changes in connection with the cultivation of energy crops. Much depends on what energy carrier the biomass replaces and on the magnitude of the energy losses in the conversion pathway. In industrialized countries, in the rapidly developing urban and industrialized regions of newly industrializing countries and in some cases also in developing countries the way in which bioenergy is used should be geared towards its climate change mitigation effect. In relation to overcoming energy poverty the primary tasks are modernization of traditional bioenergy use and provision of access to modern forms of energy such as electricity and gas. Both are challenges that are of particular importance in the rural regions of developing countries. Here, too, the use of bioenergy can have a positive effect on climate change mitigation.

Mitigating climate change

From the point of view of climate change mitigation the most attractive application areas for bioenergy are, firstly, those in which bioenergy can replace fossil fuels with high CO_2 emissions, predominantly coal.

Roughly similar reductions in greenhouse gases can be achieved by various conversion pathways producing electricity, such as co-combustion in coal-fired or cogeneration plants, the use of biogas from fermentation or crude gas from gasification in cogeneration (combined heat and power, CHP) plants, or the use of biomethane in small-scale CHP plants or combined-cycle power plants. Where biomethane is used, however, a greater climate change mitigation effect can be achieved if the CO_2 which must in any case be captured during the production process can be securely stored. The conversion of biomass into electricity has the additional advantage that, unlike liquid fuels for transport, it eases the shift towards electric mobility. The current greenhouse gas (GHG) abatement costs of these pathways vary widely: while the simple co-combustion of solid biomass and the use of biogas or biomethane from fermentation already represent cost-efficient climate change mitigation options, this is not yet the case for gasification technologies (although significant reductions in costs can be expected). The use of biomethane is also particularly attractive for technological and system-related reasons, since it can be collected and distributed over natural-gas grids and converted very efficiently into electricity in small-scale CHP units or combined-cycle power plants near where it is needed. The biomethane route can already be recommended for industrialized countries; for industrialized regions in newly industrializing and developing countries it is a promising option for the future.

On account of its high energy efficiency combined heat and power production is to be preferred to the generation of electricity alone, provided that demand for the heat exists. In regions where this is appropriate CHP can also be used to generate cooling, a factor which is of interest for many developing and newly industrializing countries. Where bioenergy is used exclusively for the production of heat (e.g. pellet stoves) GHG abatement costs are relatively high and the potential for reducing greenhouse gas emissions is only about half that which can be achieved in the electricity sector; such use is therefore only worthwhile as a transition measure where alternative renewable energy sources are not available. With direct generation from renewables (wind, solar) constituting an ever-larger proportion of production, there will in future be a significant increase in the overall energy efficiency of electric heat pumps, so that in the medium term they will represent a viable alternative for heat generation. Overall CHP pathways are to be preferred both to pure electricity and pure heat use pathways.

From the point of view of climate change mitigation the first-generation biofuels (such as biodiesel from rape or bioethanol from maize), which involve the cultivation of temperate, annual crops on agricultural land, score very badly. When emissions from indirect land-use changes are taken into account, they frequently result in higher emissions than would arise from the use of fossil fuels. Where residues are used (e.g. timber waste, liquid manure, straw) the impact on the greenhouse gas balance is indeed positive, but the reduction in greenhouse gases is only about half that of applications in the electricity sector. Second-generation biofuels are not on the whole any better.

A different picture emerges for the use of perennial tropical plants such as *Jatropha*, sugar cane or oil palms that are grown on degraded land and result in carbon being stored in the soil there. In this situation a major climate change mitigation effect can be achieved at low cost. However, if these crops are grown on freshly cleared land or on agricultural land and thus are associated with direct or indirect land-use changes, the greenhouse gas balance becomes negative; in some cases emissions will be substantially larger than would be the case using fossil fuels. Ensuring sustainability in the cultivation of energy crops is therefore the deciding factor in evaluating the climate change mitigation effect of these pathways.

Since there are as yet no established sustainability standards for biofuels, their import and use pose problems. Once relevant minimum standards have been introduced, it may be appropriate to import plant oils and bioethanol – perhaps produced in tropical regions – for power and heat applications. During the transition period, however, care should be taken to avoid any promotion of biofuels that fail to meet the envisaged minimum standards.

For the future of mobility on the roads, WBGU considers the most appropriate solution to be the generation of electricity from renewables in combination with the use of electric vehicles. This means of utilizing bioenergy achieves a significantly higher climate change mitigation effect than blended biofuels. If electric vehicles were to be introduced on a large scale, it is likely that the costs could be drastically reduced within 15–20 years, enabling the GHG abatement costs – which at present remain very high – to also be reduced. Through the use of smart grids, electromobility can also contribute as control energy to the stabilization of power grids. WBGU recommends a swift phase-out of the promotion of biofuels for transport purposes. The quotas for blending biofuels with fossil fuels should be frozen and should then be completely removed within the next three to four years.

Overall, the substitution of bioenergy for fossil fuels, making use of the sustainable bioenergy potential estimated by WBGU, can achieve a global reduction in greenhouse gas emissions of 2–5 Gt CO_2eq per year. However, this would require all the biomass to be used in such a way that the greenhouse gas reduction amounts to 60 t CO_2eq per TJ of raw biomass used. This corresponds to roughly a doubling of the mitigation efforts currently under discussion in the EU as a standard for biofuels in the transport sector. WBGU proposes this level as a necessary precondition for promotion of bioenergy use. From a very optimistic viewpoint it might be possible to achieve a reduction in greenhouse gases of up to 4–9 Gt CO_2eq per year. By way of comparison: global anthropogenic greenhouse gas emissions currently amount to around 50 Gt CO_2eq per year, and a hypothetical stop to global deforestation would reduce these emissions by up to 8 Gt CO_2eq.

Leaving aside bioenergy pathways that involve the use of marginal land in the tropics or are based on established technologies such as co-combustion in coal-fired power plants or the production of biogas through fermentation, the GHG abatement costs of many bioenergy pathways in 2005 were significantly more than 60 € per t CO_2eq; in WBGU's view they cannot therefore be currently considered to be cost-efficient climate change mitigation options.

The cultivation of energy crops must therefore be carefully weighed against other climate change mitigation options, such as afforestation or the avoidance of deforestation. It is particularly important that energy crop cultivation does not undermine the politically very complex endeavours to reduce emissions from deforestation.

If exploitation of the sustainable bioenergy potential is combined with the capture and secure storage of CO_2, it is possible for "negative" CO_2 emissions to be produced. By this means around 0.2 ppm CO_2 could be removed from the atmosphere per year. This corresponds to around one-tenth of the current annual increase in the concentration of CO_2 – hence even over quite lengthy periods of time this technology can counteract only a relatively small proportion of the human-induced increase in the concentration of CO_2.

Until a global system of mandatory limits to greenhouse gas emissions is put in place that encompasses all relevant sources, WBGU recommends emissions standards for bioenergy.

Overcoming energy poverty

In the rural regions of developing countries, and to some extent also in their urban areas, overcoming energy poverty is an important precondition for tackling poverty in general. As a first step WBGU recommends as an international objective the complete phase-out of traditional forms of bioenergy use that are harmful to health by the year 2030.

To achieve this, some technologies can even now be implemented rapidly and at low cost. The use of improved cooking stoves can cut fuel consumption by between one-half and three-quarters while at the same time drastically reducing the risks to health. Greater emphasis should also be placed on the promotion of small, decentralized biogas plants for residues and wastes, and on the use of plant oil – produced from oil plants grown locally on marginal land – for lighting, electricity generation and mechanical energy use. These technologies also help to reduce the pressure of use on natural ecosystems and to tackle poverty, because the time and money required to procure the fuel is significantly reduced. They provide an important lever for significantly improving the quality of life of many hundred millions of people in a short time and at low cost. It is important, though, to ensure at all stages of development cooperation in this field that the technologies are accepted and that they can be maintained by the individuals who use them.

Further down the track to reducing energy poverty, access to modern forms of energy, particularly electricity and gas, is a priority. In developing countries medium-scale use of modern bioenergy to generate electricity in CHP or gasification plants can be an important means to this end, particularly if biomass such as that from residues or from timber plantations on marginal land is used. The use of liquid fuels for stationary applications (e.g. electricity generation, water pumps, cooking) may be appropriate in rural regions of developing countries, if these regions are at a disadvantage in terms of infrastructure on account of their remoteness.

The larger-scale production and use of modern bioenergy, which can likewise contribute to the tackling of energy poverty in developing countries, should always also be considered from the point of view of its climate change mitigation effect. For those bioenergy pathways that are associated with low GHG abatement costs, new sources of funding can be accessed through international climate protection instruments.

Energy crops as bridging technology

The sustainable use of bioenergy from energy crops can be an important bridging technology during the transformation from existing fossil energy systems to future systems based predominantly on wind and solar energy. It can fulfil this function only until approximately the middle of the century, for two reasons:

Firstly, demands on global land use will increase markedly in the coming decades as a result of dynamic trends such as a growing world population with increasingly land-intensive patterns of food consumption, increased soil degradation and water scarcity. In addition, for reasons of climate change mitigation, among others, there will be a growing tendency for petrochemical products to be produced from biomass. The non-substitutable land use for the manufacture of textiles, chemical products, plastics etc. is likely to require around 10 % of world agricultural land. After use some of the biomass-based products will be able to be recycled as biogenic waste for purposes of energy recovery ("cascade use"). These increasing pressures on land use take place against a backdrop of increasingly manifest anthropogenic climate change. Because of all this, the cultivation of energy crops will probably have to be cut back in the second half of the century.

Secondly, in forthcoming decades there will be a growing trend for renewable energy in the form of electricity to be produced directly by wind and water power, as well as by solar energy on a large scale from the middle of the century; by this time, therefore, energy crops will largely have fulfilled their function of bridging the way to sustainable energy provision. This will not affect the part of bioenergy use that centres on the use of wastes and residues which, together with the remaining use of fossil fuels, will increasingly take on the task – as control energy in power grids – of balancing fluctuations in the output of directly generated electricity from renewables. In combination with smart electricity grids, electromobility can also make an important contribution to control energy.

4 Research recommendations for sustainable bioenergy use

While WBGU highlights in this report viable corridors for sustainable bioenergy use in some areas, gaps in knowledge remain that need to be filled through further research. WBGU identifies a particular need for research in six fields:

1. *Broadening the knowledge base on global land use:* In order to create the scientific basis for setting up a global land register supported by a Geographical Information System (GIS), the state of global land use and land cover as well as the dynamics of global land-use changes must be studied and evaluated in more detail than has so far been the case. This needs to include the collection of high-resolution data on vegetation cover, hydrology and soil condition, agricultural usage and surface sealing in the different regions of the world.
2. *Determining more precise greenhouse gas balances for different bioenergy pathways:* The greenhouse gas balance is the crucial indicator of the climate benefit (or in some cases harm) of a particular use of bioenergy. It has to date only been possible to calculate it imprecisely, for example with regard to indirect effects such as the displacement of previous land use onto other land.
3. *Determining the potential, the greenhouse gas balances and the economic deployment pathways of residue use:* Biogenic residues, such as those from agriculture and forestry, represent a still virtually untapped potential for energy generation. The opportunities for making use of them in future should be researched.
4. *Analysing the role of bioenergy in a future energy system at national, regional, and global levels:* The strategic importance of bioenergy and its integration in particular energy systems (e.g. as control energy in power grids) should be explored in more detail. These factors play an important part in the selection of preferred bioenergy pathways.
5. *Clarifying the links between food security and bioenergy:* The complex local, national and global cause-effect chains that link bioenergy use and food security urgently need to be examined from a socio-economic perspective. This research needs to take geopolitical factors into account: could the "primacy of securing energy supply" of the western world and other powerful political players in a world energy system of which bioenergy is an important component result in increased food-security problems in poor and politically less influential countries? How could such scenarios be avoided through international cooperation?

6. *Analysing international land-use competition and developing the components of a global land-use management system:* As a result of various driving forces, land will in the forthcoming decades become a scarce resource worldwide. Land use will in consequence become a matter of global governance. Research should explore interest structures relating to global land use and help to develop an effective global regime for managing land resources and preventing land-use conflicts.

5
Recommendations for action: Components of a sustainable bioenergy policy

The competition between farming biomass as a resource for energy production and growing food on increasingly scarce agricultural land links two fundamentals of human societies: energy and food. Adoption of a systemic perspective further reveals that the emerging bioenergy policy involves complex issues that are not restricted to matters of energy, agriculture and climate policy; transport policy and foreign trade policy as well as environmental, development and security policy all play an important role. Because non-sustainable bioenergy strategies can harm the climate, exacerbate food-security problems and drive land-use conflicts, policy-making must establish a framework that addresses all the matters mentioned above. Furthermore, bioenergy policy cannot be formulated solely within the national context; it requires collective, transboundary action and effective multi-level governance. To render bioenergy use sustainable, complex regulatory measures need to be taken; this represents a major challenge for a policy-making system that is structured mainly along "departmental" lines. Competing goals need to be reconciled at both national and international level.

In the light of these considerations and in view of the urgency to redirect global policy, WBGU has developed a differentiated mix of policy instruments for a sustainable global bioenergy policy. The considerable risks attached to energy crop cultivation – risks for climate change mitigation and from land-use competition – must be countered by institutional regulation. The first task is to ensure that the expansion of bioenergy use contributes to climate change mitigation. The accounting rules under the UN climate protection regime must be adjusted to remove any incentives to engage in a bioenergy energy policy that is counterproductive for climate change mitigation. Since this will not be accomplished in the short term and cannot guarantee that other sustainability criteria (food security, conservation of biological diversity etc.) will be met, work on drawing up and applying bioenergy standards must be undertaken simultaneously. WBGU proposes a demanding minimum standard in combination with additional criteria to be met as a pre-condition for any kind of bioenergy promotion (promotion criteria). Accompanying measures to secure global food production and biological diversity and to protect soil and water resources are also necessary. Existing UN institutions such as the Food and Agricultural Organization (FAO), the Biodiversity Convention (CBD) and the Convention to Combat Desertification (UNCCD) can contribute to these processes. In conclusion WBGU assesses which forms of bioenergy use should be explicitly promoted through national policies and international development cooperation.

5.1
Making bioenergy a consistent part of international climate policy

Reform accounting procedures for CO_2 emissions from bioenergy

The existing provisions in the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol create false incentives in relation to bioenergy production and use; they distort the picture of the contribution made by bioenergy to climate change mitigation and may even promote bioenergy use that is harmful to the climate. In WBGU's view the modalities for determining contributions to commitments under the Kyoto Protocol and its successor regime must therefore be corrected. The correction needs to involve the following elements: firstly, the use of bioenergy must no longer be counted en bloc as free of CO_2 emissions ("zero emissions") in the energy sector. However, WBGU is not advocating replacement of the presumed zero emissions by cumulated emissions from a life-cycle analysis of the bioenergy, since this would not be compatible with the other allocation modalities within the UNFCCC and would lead to double counting. Instead, within the energy sector the actual CO_2 emissions arising from the combustion of the biomass should be counted and included. In return, the uptake of CO_2 from the atmosphere by energy crops in the land-use sector should also be counted. This correction would align the way in which bioenergy is treated with the principle used elsewhere of always allocating emissions to the place and time of their creation. Secondly, the existing rules, under which only selected CO_2 emissions and absorptions from land use and land-use change are or can be set against the commitments made by states, should be replaced by full accounting of all emissions from these sectors. Ideally this accounting would form part of a wider agree-

ment on the conservation of the carbon stocks of terrestrial ecosystems within the UNFCCC. Thirdly, there need to be supplementary regulations regarding trade between countries that have and countries that have no binding commitments to limit emissions. In addition, for those emissions from the life cycle of bioenergy use for which there is already an appropriate allocation to the inventories (e.g. non-CO_2 emissions from agriculture), the countries that have committed to limit emissions should systematically introduce incentives for limiting emissions at stakeholder level (e.g. for farmers and foresters).

Consider bioenergy in the CDM in more specific detail

The Clean Development Mechanism (CDM) involves only a small number of bioenergy projects and these have as yet had only a limited influence on overall bioenergy use in newly industrializing and developing countries. Any expansion of CDM projects that include the cultivation of energy crops should be viewed with scepticism unless it can be ensured that the use of land for this purpose will not give rise to the well-known displacement effects and result in terrestrially stored carbon being released elsewhere. The scope for CDM projects to improve or replace inefficient traditional biomass use should be utilized without damaging the integrity of the CDM. As a matter of principle, CDM projects in the area of bioenergy should be certain of meeting the minimum standard called for by WBGU.

Limit emissions caused by land-use changes in developing countries

Since the present expansion of the cultivation of energy crops can contribute to an increase in tropical deforestation, an effective regime for reducing the emissions from deforestation and forest degradation in developing countries (REDD) under the UNFCCC is extremely important. An appropriate REDD regime should provide effective incentives for rapidly generating real emissions reductions by reducing deforestation, and it should mobilize international funding transfers at a sufficient level. The regime should consist of a combination of national targets to limit emissions and project-based procedures in order (i) to prevent leakage effects and (ii) to permanently protect the natural carbon reservoirs such as tropical primary forests from deforestation and degradation as well as limit emissions from grassland conversion. The REDD regime would ideally form part of a comprehensive agreement on the conservation of the carbon stocks of terrestrial ecosystems within the UNFCCC.

Move towards a comprehensive agreement on the conservation of terrestrial carbon reservoirs

CO_2 emissions arising from land use, land-use change and forestry (LULUCF) should be fully and systematically included in the post-2012 regime in order to ensure that the incentive given to bioenergy use by the UNFCCC is based on the actual contribution to climate change mitigation made by this use. However, the absorption and release of CO_2 by the biosphere differs from the emissions of fossil energy sources in a number of fundamental respects, including measurability, reversibility, long-term controllability and interannual fluctuations. Since the different sectors also have very different characteristics in terms of time-related dynamics and amenability to planning, it would seem more appropriate – from the point of view of remaining within the 2°C guard rail – to define separate reduction targets rather than one overarching target. WBGU therefore recommends that a comprehensive separate agreement on the conservation of the carbon stocks of terrestrial ecosystems be negotiated. This agreement should (i) take up the debate on REDD, (ii) replace the existing rules on offsetting reduction commitments in the sectors listed in Annex A to the Kyoto Protocol against sinks (including through CDM activities) and (iii) fully include all CO_2 emissions from LULUCF. Despite separate target agreements, WBGU considers it appropriate from the point of view of economic efficiency to aim for a certain level of fungibility; however, on account of measurement problems and other uncertainties attaching to LULUCF emissions, this fungibility should be clearly demarcated and associated with deductions.

5.2 Introducing standards and certification for bioenergy and sustainable land use

In order to ensure sustainable production of bioenergy carriers within WBGU's guard rails for sustainable land use, it is necessary to introduce sustainability standards for bioenergy. A minimum standard for bioenergy carriers should be met before bioenergy products are allowed onto the market.

Gradually introduce a minimum standard for bioenergy and sustainable land use

As a first step, a statutory minimum standard for all types of bioenergy should be introduced promptly at EU level. The sustainability criteria for liquid biofuels for transport contained in the planned EU directive on the promotion of renewable energies should be further developed and applied as a mini-

mum standard for all types of bioenergy in the EU. In addition to provisions relating to soil, water and biodiversity conservation, the standard should include impacts of indirect land-use changes and criteria for restricting the use of genetically modified organisms (GMOs). Certain core labour standards of the International Labour Organization (ILO) should also be made mandatory. With regard to greenhouse gas emissions, WBGU recommends to request a specific absolute emissions reduction in relation to the quantity of raw biomass used, rather than a relative emissions reduction based on the final energy or useful energy. The use of bioenergy carriers should reduce life-cycle greenhouse gas emissions by at least 30 t CO_2eq per TJ of raw biomass used in comparison with fossil fuels.

The cultivation of energy crops and the supply of biomass resources should only be promoted if this gives rise to a demonstrable reduction of energy poverty or to demonstrable advantages for climate change mitigation, as well as soil, water and biodiversity conservation, and if such cultivation also rates positively with regard to social criteria. Another precondition for promotion should be that the use of bioenergy carriers can achieve a reduction in life-cycle greenhouse gas emissions of at least 60 t CO_2eq per TJ of raw biomass used in comparison with fossil fuels. Bioenergy pathways considered particularly worthy of promotion are the use of biogenic wastes and residues and the cultivation of energy crops on marginal land, if the above-mentioned promotion criteria are met.

In order to attain the goal of globally sustainable land use there is a need in the medium term for a global land-use standard to regulate the production of all types of biomass for a wide range of uses (food and feed, use for energy and use as an industrial feedstock, etc.) across national borders and cross-sectorally. The EU member states should therefore prepare suitable provisions for extending the bioenergy standards to all types of biomass.

Until a globally agreed land-use standard is created, the anchoring of bioenergy standards in bilateral agreements remains an effective instrument for increasing sustainability. WBGU recommends that the European states include binding sustainability criteria in future agreements with countries that are important producers and consumers of bioenergy. Existing bilateral agreements should be amended to this end. In return, trading partners who adhere to the minimum standard should be accorded free market access for bioenergy carriers.

With a view to WTO rules and in order to limit recourse to alternative markets for bioenergy products that fail to meet the minimum standard, the German government should also endeavour to ensure that international consensus on a minimum standard for sustainable bioenergy and on a comprehensive international bioenergy strategy is achieved as quickly as possible. During the transition period efforts must be made to rapidly dismantle all promotion of non-sustainable bioenergy use.

Establish certification schemes for sustainable bioenergy carriers

To enable adherence to the minimum standard to be demonstrated, corresponding certification systems must be created promptly. WBGU recommends the development of an internationally applicable certification scheme for all types of biomass. This makes it easier for the bioenergy standards to be extended at a later stage to other uses of biomass. The International Sustainability and Carbon Certification system drawn up on behalf of the German Ministry of Food, Agriculture and Consumer Protection (BMELV) or a comparable certification system should be put in place at an early stage.

The duty to furnish proof that the standards have been adhered to could lie in the first instance with the entity marketing the end product. This would remove the need for a duty to certify the origin of bioenergy feedstocks that could also be used for non-energy purposes. While the certification should be carried out by private companies, institutions capable of imposing sanctions must be created by the state to monitor actual implementation of the standards. Developing countries, and in particular the least developed countries, should be offered technical and financial assistance in setting up certification systems and monitoring bodies, and in implementing the certification.

Ensure WTO conformity of environmental and social standards

The World Trade Organization (WTO) conformity of a unilateral European standard can be justified in law, particularly with regard to criteria for the reduction of greenhouse gas emissions and the protection of global biodiversity, because the necessity of protecting climate and biodiversity is laid down in multilateral environmental agreements in international law. In general the acceptance of environmental and social standards in the WTO regime needs to be further improved. In addition, the intended liberalization of trade in relation to what are known as “environmental goods and services” (EGS) must not run counter to the goal of sustainable production and use of such goods and services. In the context of the relevant negotiations the German government should therefore work to ensure that goods are not classified as EGS unless they are guaranteed to meet the minimum standard called for by WBGU and/or result from sustainable bioenergy pathways.

5.3 Sustainably regulating competition among uses

Ensure priority for food security

Unless action is taken, the degree of scope for food production will in future come under increasing pressure, partly as a result of the emerging bioenergy boom. In order to prevent a crisis situation developing, there is a need for action in the following areas:

- *Develop an integrated bioenergy and food security strategy:* Over and above the measures specified by the departmental working party on world food affairs in its report to the German Federal Cabinet, WBGU recommends including the cultivation of energy crops in an integrated bioenergy and food security strategy in which food security has priority. This is particularly important for those low-income developing countries that are net importers of food (Low-Income Food-Deficit Countries, LIFDCs). Any controlled expansion of bioenergy must be accompanied by global efforts to strengthen farming. For this to happen, the food situation in affected regions must first be improved, for example by distributing free seed for the next growing season. At the same time the conditions for food security and food production must be improved over the long term and consistently incorporated into other policy areas such as climate protection and nature conservation. Cultivation of energy crops should be promoted primarily on marginal, in particular degraded land.
- *Take greater account of increasing pressure on land use as a result of changing food consumption patterns:* The sharply increasing pressure on land use as a result of land-intensive food consumption patterns in industrialized countries, and the replication of these patterns in large and dynamically growing newly industrializing countries, is exacerbating global competition for land use. This is a major challenge and one that remains largely underestimated: it is assessed that by the year 2030 around 30 % of necessary food-related production increases will be attributable to this. This relationship between individual eating habits, global land use and food security is insufficiently well known; it should be brought to the attention of consumers through educational campaigns. Priority should be given to creating awareness of the issue, particularly in the industrialized countries, and encouraging people to change their behaviour. Initiatives at international level, for example in connection with the UN organizations, could also play a part. These initiatives should be supported by international cooperation on the land required for the per capita consumption of food. Measures of sustainability such as the ecological footprint can illustrate the fact that on a global scale natural resources are currently being used at a rate that exceeds their capacity for regeneration.
- *Promptly identify risks posed by land use to food security:* An effective early warning system is needed if societies are to be better prepared for future crises. Existing monitoring capacities, such as those of the FAO and the World Food Programme, should be strengthened and more efficiently networked. In addition, as pressure on global land use increases WBGU recognizes an increasing need for risks to food security arising from competing use to be identified at an early stage. In this connection global monitoring and early warning systems are extremely important.
- *Take account of the coupling of land use, food markets and energy markets:* The challenges of global food security must today be dealt with against the backdrop of increasing pressure on global land use; they can no longer be addressed through national endeavours alone. In a globalized world, policy-making must take account of the ever-closer links between land use and agricultural commodity price trends on the one hand and the energy market on the other. Policy-makers must therefore create regulatory mechanisms to deal with situations such as trends in the energy markets that have undesirable consequences for food security. In the long term it is important for food security that the world agricultural markets should generate an impetus for production increases, particularly in the poorer developing countries. To this end import barriers for agricultural goods should be further dismantled and export subsidies and other production-promoting measures worldwide, but particularly in the industrialized countries, should be reduced. Any liberalization of trade must, however, take account of the fact that developing countries vary in their circumstances and needs. For example, LIFDCs are directly and adversely affected by price rises on the world market. Exceptions to a general liberalization should therefore be made for a group of the predominantly poorer developing countries.

Biodiversity conservation: Utilize the opportunities presented by the CBD

The expansion of bioenergy must not result in the directly or indirectly induced conversion of natural ecosystems. To prevent this, an effective system of protected areas is essential. WBGU recommends that a global, ecologically representative and effectively managed system of protected areas with adequate financing should be set up on 10–20 % of the world's terrestrial surface by 2010. The Convention on Biological Diversity (CBD) is the key interna-

tional agreement for implementing this guard rail for biosphere conservation.

- *Close the funding gap that affects protected areas:* To this end WBGU recommends mobilizing a sum of 20–30 € per capita per year in the high-income countries. In the first instance use should be made of the LifeWeb Initiative, which was set up and provided with considerable funds at Germany's instigation, so that tangible bilateral projects move swiftly forward. At the same time other donor countries should be persuaded to give financial support to LifeWeb. If this is successful, the initiative can in the medium term become a nucleus for a protected area protocol to the CBD that links implementation of measures relating to protected areas with funding instruments. The practical and political feasibility of the protocol and possible links with the emerging REDD regime under the UNFCCC should be researched and evaluated as options. In addition, WBGU supports an expansion of international compensation payments for foregone agricultural and forestry income, in order to make the transition to sustainable land use financially viable for developing countries. Pilot projects are to be used to assess whether national-level habitat banking systems in industrialized countries can be opened to providers of ecosystem services in developing countries. Countries with economies in transition, newly industrializing countries and countries rich in raw materials should also be more closely involved in the financing of international nature conservation. Plans should be being made now for a market-like mechanism in which the assurance that previously certified areas are protected is traded for money.
- *Use the CBD to develop biodiversity guidelines for sustainability standards:* In the light of the outcomes of COP-9 it cannot be assumed that rapid progress will be made, but nonetheless this process should be promoted by the German presidency of the CBD and as far as possible moved rapidly forwards. In order to build the necessary monitoring capacities, the development of the world database on protected areas should be promoted at the same time. The impetus for sustainability standards in the bioenergy sector should be used in the medium term to arrive at general guidelines for all forms of biomass production.

Improve water and soil protection through the cultivation of energy crops

Present trends in global water and soil use are tending in the wrong direction. Without policy change this will result in a worsening water crisis and increasing soil degradation in many areas.

- *Make analysis of regional water and soil availability a requirement:* Since water and soil are highly endangered resources in many regions, any large-scale promotion of bioenergy cultivation systems should be preceded by an integrated analysis of regional water and soil availability. Non-adapted bioenergy cultivation systems and the globally mounting demand for energy can significantly increase the pressure of use on soil and water resources. The cultivation of energy crops should therefore be aligned with regional strategies for sustainable soil and water management.
- *Use the cultivation of energy crops to restore marginal land:* If the proper cultivation system is chosen, the cultivation of energy crops on marginal land (such as degraded land) can actually result in an improvement in soil fertility. The cultivation of energy crops on degraded land is therefore a strategic option – it can be used to restore land at least some of which could later be available for food production. This could play a part in reducing the increasing pressure on land use.

5.4 Making targeted use of bioenergy promotion policies

It is important that, in principle, only those bioenergy pathways are promoted that contribute to climate change mitigation in a particularly sustainable way. In WBGU's view this means that not only is the minimum standard adhered to but that, taking account of total life-cycle emissions, the use of bioenergy is able to avoid emissions of at least 60 t CO_2eq per TJ of raw biomass used. Since for practical reasons promotion needs to be provided at the various stages of the production process (cultivation, conversion and end-use application systems), it is usually necessary to work with default values regarding the emissions of the other stages.

Particularly in connection with the promotion of energy crop cultivation, WBGU regards it as important that, in addition, ecological and social promotion criteria are met. Likewise, where biogenic residues are mobilized, ecological limits should also be observed so that soil fertility is maintained. Finally, promotion of conversion and end-use application systems should be undertaken in such a way as to ensure that they fit with the vision of the transformation towards sustainable energy systems. Undesired lock-in effects should be avoided and promising technologies such as electromobility should be promoted.

Alongside the focus on climate change mitigation, sustainability of energy systems involves addressing

energy poverty. Modernizing off-grid or traditional uses of bioenergy can play a valuable part in this, particularly in the rural regions of developing countries. In such situations WBGU regards promotion of bioenergy-based projects as justified even if climate change mitigation and promotion criteria are not fully met.

Remodel promotion in the agricultural sector

Sustainable biomass production for energy purposes should ideally only be promoted if the land use contributes to nature or soil conservation. At the very least, instances of the promotion of biomass production that do not meet the WBGU minimum standard should be brought to an end within the next few years, and transferred to sustainable methods of production wherever possible. In general, production subsidies in the agricultural sector should as far as possible be removed; this would bring an end to inefficient competition for subsidies between countries and remove market distortions in world agricultural trade. Subsidies that yield substantial benefits in development-related or environmental terms form an exception; they should be explicitly permitted.

Phase out promotion of liquid biofuels and promote electromobility

Technology policy on the use of bioenergy in the transport sector must be re-directed. From the point of view of sustainability, promotion of liquid biofuels for road transport – particularly in industrialized countries – cannot be justified. The reasons for this include the high GHG abatement costs, low or negative GHG reduction potentials per unit of land or per unit of biomass used, and the lock-in effects on an inefficient infrastructure based on the combustion engine. Blending quotas should not be increased any further, and the current blending of biofuels should cease completely within the next three to four years. The road-traffic-related emissions reductions that have been agreed at EU level will then have to be achieved by other means. In the transport sector the highest energy efficiency of biomass is achieved through the generation of electricity and its use in electric vehicles. An appropriate framework for the expansion of electromobility should be developed. Promotion policies can assist businesses in their technological development by helping to expand opportunities for connection to the electricity grid. Demand for electric or hybrid vehicles can be stimulated through taxation policies.

Promote bioenergy pathways for electricity and heat production

Greater incentives for utilizing the potential of organic wastes and residues are created primarily through the promotion of renewables in electricity and heat production. The aim must be to promote the use of biogenic wastes and residues in such a way as to ensure that it is distinctly more attractive than the generation of electricity from energy crops. In tandem with this there is a need for appropriate regulation on the extraction of residues from agriculture and forestry, the dumping of waste and cascade uses. In some countries there is already promotion of the direct combustion of biomass (primarily wood chips and pellets from residues) in coal-fired and cogeneration plants and of the use of biogas, crude gas and biomethane; this should be continued and introduced as a priority in all regions in which coal plays a major part in electricity generation. However, it is essential to ensure that the biomass used meets the minimum standard with regard to sustainability. The production of electricity from biomass that meets the promotion criteria should be particularly encouraged. In addition, particular emphasis should be placed on promoting the use of biomethane if the CO_2 which is captured during the production process can be removed to secure storage. If at the same time the international scaling-up of cogeneration and combined-cycle power plants accelerates as a result of appropriate climate and energy policy measures and suitable promotional approaches, it will be possible to utilize highly efficient bioenergy pathways and hence achieve globally significant reductions in emissions. In WBGU's view it is entirely appropriate to promote the combustion of wood chips or pellets for electricity generation, but state subsidies for pure heat use should be provided in industrialized countries at most for a transition period, until a transformed energy system is in place in which this need is met from CHP plants or from heat pumps running on renewable electricity.

Initiate an international agreement on (bio)energy subsidies

In order to cut back energy subsidies that harm the environment and give a higher priority to sustainability criteria, states need to coordinate their policies at international level. They should enter into agreements whereby non-sustainable energy subsidies are removed in all countries and guidelines for permissible subsidies, based on the principle of sustainability, are established. This could occur in the context of a Multilateral Energy Subsidies Agreement (MESA), which at the outset might involve only the most important energy producers and con-

sumers. In the long term the agreement could form part of the WTO regime.

Strategically manage the use of biomass as an industrial feedstock
In order to pave the way for strategies for the use of biomass from agriculture and forestry as a feedstock in industrial production processes, material flow analyses and land-use inventories should be drawn up both globally and nationally. The scenarios should describe likely developments (competition for land use, substitution processes, etc.) and options for action. For key categories of materials and products (cellulose, paper products, etc.) sustainability standards for the cultivation and extraction of feedstocks should be set and product standards with high recycling quotas should be specified. Through suitable measures it should be possible for high levels of resource and product consumption to be greatly reduced.

5.5 Harnessing the sustainable bioenergy potential in developing and newly industrializing countries

Make tackling energy poverty a priority of development policy
As a target WBGU recommends endeavouring to ensure that traditional forms of bioenergy use that are harmful to health are replaced by 2030. Facilitating access to modern forms of energy does not have to be included as a stand-alone goal in the Millennium Development Goals (MDGs), but it should be explicitly included in the MDGs as a means of tackling poverty and, moreover, should be more strongly anchored in the energy policy portfolios of stakeholders involved in international development cooperation. As a first step, tackling energy poverty should be systematically included in Poverty Reduction Strategy Papers (PRSPs). The international community should particularly promote bioenergy projects that advance rural off-grid energy supply in developing countries.

Base strategies for reducing energy poverty on reliable data
So that alternative ways of providing energy services can be examined and obstacles to implementation can be better understood, actors involved in international development cooperation must work with national actors to draw up strategies for tackling energy poverty. These approaches should be based on reliable empirical findings and must be embedded in suitable policy strategies. WBGU therefore recommends carrying out multi-country cross-sectional evaluations and nationally, regionally and locally specific studies in order to obtain information on best practices.

Support developing countries in drawing up national bioenergy strategies
So that the opportunities and development potentials of bioenergy can be realistically assessed and risks can be minimized, WBGU recommends that strategic issues be discussed in the country context and with as broad a range of stakeholder groups and affected sections of the population as possible, and that decisions then be taken on the priority goals of any promotion of bioenergy. Development cooperation actors should support partner countries in developing these strategies, examining all the forms in which bioenergy and its alternatives can be used and applied, as well as evaluating the suitability of these forms in the context of the local situation. They should also seek to ensure that the minimum standard and promotion criteria are met and that the necessary governance capacities, such as land-use planning and certification, are strengthened. In addition, it is essential that bioenergy strategies be linked to food security strategies.

Promote pilot projects that involve particularly sustainable cultivation systems and the use of wastes and residues
Cultivation methods that are particularly sustainable and that help to combat soil erosion, conserve biodiversity, reduce energy poverty and advance rural development should be promoted in pilot projects. Such methods include, for example, the socially acceptable cultivation of perennial energy crops on degraded land, or agroforestry. WBGU also recommends that the country-specific potentials of wastes and residues be assessed and then utilized in electricity generation, particularly in agro-industrial biogas plants and cogeneration plants where the waste heat is used. Pilot projects can improve the mobilization of the potential of residues and wastes.

Create bioenergy partnerships
Multilateral cooperation for purposes of sustainable bioenergy use can be supplemented by intergovernmental partnerships. Technology agreements are appropriate in this context, for example for scaling up technologies for processing and using biomethane. These technologies can be linked to aspects of sustainable land-use policy or to trade partnerships.

Promote the restructuring of the world energy system
In order to increase the purchasing power of people affected by energy poverty, development coopera-

tion should continue its financial support of microfinancing systems. Cooperation between the private and public sectors should be encouraged in order to mobilize private capital. Greater use can be made of CDM projects for the large-scale substitution of fossil fuels. The technologies recommended by WBGU in connection with the sustainable use of bioenergy in the energy systems of developing countries serve not only to tackle energy poverty; the majority of them also address the issue of climate protection. For instance, making projects that aim to improve the efficiency of traditional uses of bioenergy eligible as small-scale CDM activities is justifiable and can contribute to financing. In addition, the international community should coordinate and support the restructuring of the world energy system. WBGU recommends that the German government should position itself at the forefront of such a process at European level and in the supervisory bodies of the international organizations involved, so that it can continue to maintain its pioneering role in climate change mitigation.

5.6 Building structures for a sustainable global bioenergy policy

Set up a global land-use register

To be able to monitor direct and indirect land-use changes when introducing standards and the requisite certification systems, it is important that a global, GIS-supported land-use register is set up. As a key element of this, rapid further development of the world database of protected areas managed by the World Conservation Monitoring Centre of the United Nations Environment Programme (UNEP-WCMC) is recommended. However, the global land-use register must go beyond this database; for each imported bioenergy carrier it must be able to provide information on the land on which it was produced (geographical coordinates, manner of cultivation, commitment to adherence to sustainability criteria, etc.).

Creation of an institutional framework for the globalization of standards

The Global Bioenergy Partnership (GBEP) should be used as a forum for developing a uniform international bioenergy standard and accelerating multilateral policy formulation. This partnership brings together key stakeholders and includes newly industrializing countries. Efforts should, however, be made to ensure that relevant civil society stakeholders have greater involvement in the dialogue. GBEP or the Task Force on Sustainability should be helped to channel, in their capacity as an intergovernmental forum, the formal and informal processes involved in drawing up global sustainability standards and to work towards the creation of global standards and guidelines. The proposals of WBGU, which has taken up important ideas put forward by the Roundtable on Sustainable Biofuels, could provide a basis for this.

Promote bioenergy through IRENA

The International Renewable Energy Agency (IRENA) is being set up with the aim of promoting worldwide use of renewable energies through policy advice, technology transfer and knowledge dissemination; this is an appropriate step towards the streamlining and institutional strengthening of international energy policy. Nevertheless, in addition to promotion of renewable energies IRENA should include all aspects of the transformation towards sustainable energy systems in its remit. It should be enabled to address aspects of energy demand and issues relating to energy, the environment and development in a comprehensive and integrated manner.

Convene an International Conference on Sustainable Bioenergy

In order to arrive at a shared global understanding of the opportunities and risks of bioenergy and a consensus on appropriate standards in relation to the production and use of different forms of bioenergy, WBGU recommends that an International Conference on Sustainable Bioenergy be convened at an early stage. This conference could be modelled along the lines of renewables 2004. It could be used to formulate objectives and general promotion principles, exchange ideas for best-practice approaches and draw up agreements on international bioenergy partnerships and on the importance of bioenergy for a sustainable global energy system. It is important that it should bring together actors from the policy areas of agriculture, energy, the environment and development.

5.7 Conceiving of global land-use management as a challenge of the future

Inherent in the problem of competing land use, in WBGU's view, is a potential for future conflict that reaches far beyond the sphere of bioenergy. Critical trends in world food security are even now becoming apparent, and they will become more acute as the world population increases to around 9 billion and land-intensive food consumption patterns become ever more widespread. Global land-use management

is therefore set to become a key future task if land-related conflicts are to be avoided.

Set up a global commission for sustainable land use

The increasing pressure on land use is a global challenge of an extent and complexity which is as yet little understood. This calls for the development of a complex new field of global governance in which issues of food, energy, development, environmental and climate policy mesh. On account of the diverse global interactions and linkages involved, it will no longer be possible to see land use solely as an issue for action at individual country level. This is powerfully illustrated by the example of the worldwide effects of indirect land-use changes associated with the expansion of bioenergy, and by the issue of equitable per-capita land use in connection with global food security. A new global commission for sustainable land use should be set up to start these processes at international level and to organize how to approach the issue. The commission's task should be to identify the key challenges arising from global land use and to assemble the scientific state-of-the-art. Drawing on this groundwork, the commission should then elaborate the principles, mechanisms and guidelines required for global land-use management. The commission could be located within UNEP and work closely with other UN organizations such as the FAO. The findings should be regularly placed on the agenda of the UNEP Global Ministerial Environment Forum or the strategically important G8+5 gatherings of heads of state and government.

Publications of the German Advisory Council on Global Change (WBGU)

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