WBGU

German Advisory Council on Global Change

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Transforming Energy Systems

In its flagship report 'World in Transition – A Social Contract for Sustainability' (2011), the German Advisory Council on Global Change (WBGU) shows that a global transformation of energy systems which gives all the world's people access to modern energy services while limiting human-induced warming to 2 °C is technically feasible and economically viable.

The WBGU's main messages

- **Climate-compatible decarbonisation of energy systems is feasible and can be achieved with a variety of technology mixes.**
- **The long-term economic costs of a global decarbonisation of energy systems amount to just a few per cent of global gross domestic product (GDP).**
- **Energy system transformation will yield substantial co-benefits, notably for human health and the security of the energy supply, and will reduce the long-term costs of fuel and adaptation to climate change.**
- **The WBGU recommends a strategy which is primarily based on the improvement of energy efficiency and expansion of renewable energies.**
- **Renewable energies have sufficient potential to provide the world with a long-term sustainable energy supply.**
- **Ambitious global climate change mitigation is possible even without nuclear power. The WBGU advises against nuclear energy use. However, the nuclear phase-out must not lead to a greater reliance on coal.**
- **Global institutions which promote renewable energies and facilitate access to sustainable energy services in developing countries should be strengthened.**
- **To ensure the success of this structural transition, citizens must be more involved in decision-making.**

Energy system transformation will not occur just because of resource scarcity

If all the known and estimated reserves and resources of fossil energy carriers were extracted and used, this would release 100 times more CO_2 emissions into the atmosphere than is permissible by 2050 if dangerous climate change is to be avoided.

If restricting global warming to 2 °C is to succeed with a probability of at least two-thirds, then no more than 750 billion t CO_2 from fossil sources may be released into the atmosphere by 2050. Burning the fossil energy reserves whose extraction is already technically and economically feasible would emit more than 7,000 billion t CO_2 into the atmosphere, and if the proven and estimated resources and other deposits are included, this figure would increase tenfold. So from a climate perspective, awaiting the transformation of energy systems which will have to take place at some point in future anyway, due to resource scarcity, is not an adequate response. On the contrary, this transformation process must start today.

Decarbonisation
The term 'decarbonisation of energy systems' describes the historical trend away from carbon-rich energy sources such as biomass (e.g. wood) and coal towards less carbon-intensive energy carriers, e.g. oil and gas, and, increasingly, zero-carbon energy carriers such as solar, wind and hydropower. In many cases, these modern energy carriers have a much broader range of applications (e.g. electricity) and are safer, cleaner and more convenient for the final consumer.

Renewable energies have sufficient potential to provide the world with a long-term sustainable energy supply

The potential is not just theoretical: renewable energies offer sufficient technical and sustainable potential to exceed current global energy demand by a very substantial margin. In other words, there is a genuine opportunity to establish a 100% renewable global energy supply.

Figure 1 outlines a vision for the transition to a 100% renewable global energy supply, with a focus on technical feasibility. If sufficient renewable energies are to be available for a 100% supply by mid-century, however, the economy's energy intensity must be substantially reduced. The vision is based on the premise that global heating and cooling demand can be cut by 1% per annum through efficiency measures and that both the growth in energy demand for transport and the global growth in demand for electricity will not exceed 1% per annum. Over the long term, solar energy offers the greatest potential for sustainable use, but based on the current low contribution, some time will elapse before it can contribute a relevant share of the global energy supply even if high expansion rates are achieved.

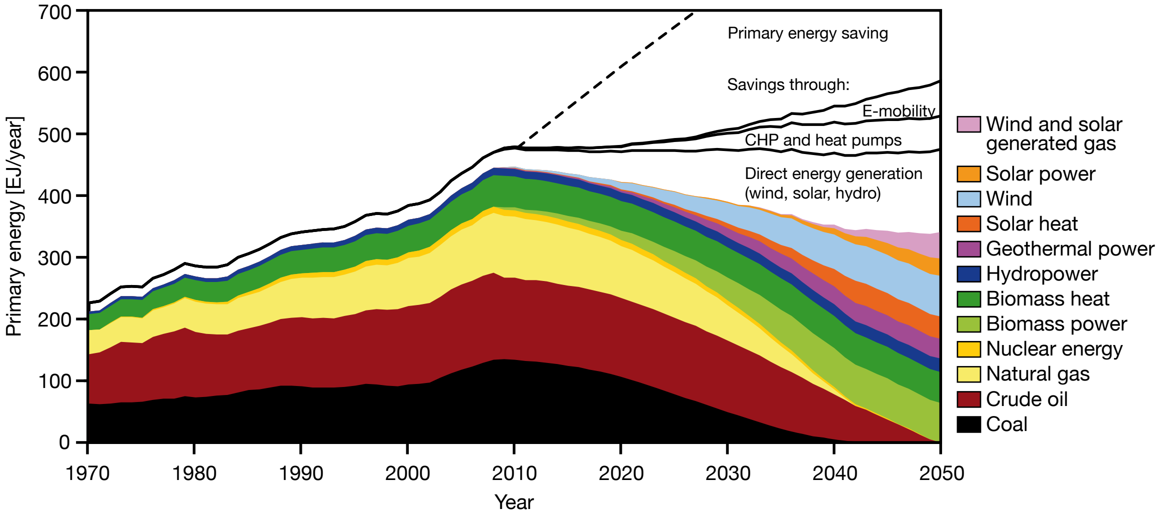

Figure 1: Vision for a global renewable energy supply to 2050
The scenario is based on current and projected or estimated renewable energy expansion rates. The scenario also assumes that renewable energies will be given precedence in the energy system, resulting in the phase-out of conventional energy carriers. Economic optimisation of the technology mix is not the focus of attention here. The availability of key materials may also influence the transformation pathway actually pursued.
Source: WBGU, Flagship Report 2011

Smart grids and storage systems make renewables a reliable energy source

Many renewable energies, such as wind and solar, are not available on a continuous or consistent basis. Continent-wide smart networking of electricity and gas grids and the creation of energy storage systems can compensate for the imbalances.

With a transcontinental high-capacity transmission grid for gas and electricity, wind- and solar-generated electricity produced at high-output locations can be transported to demand centres while allowing for large-scale load balancing to compensate for production fluctuations at the local level. In this way, Europe's substantial offshore wind capacities and solar power from the Mediterranean region, for example, can be integrated into the European energy supply. Existing storage capacities in the gas grids, as well as pumped-storage hydropower in Scandinavia, the Pyrenees and the Alps, can be utilised as well. Long-term fluctuations – such as a week of windless conditions – can be balanced out with the assistance of back-up power plants, such as fast-response gas-fired turbines or virtual power plants comprising synchronised decentralised cogeneration (CHP) facilities. Biogas can be utilised as an energy carrier from the outset, with methane use being a longer-term prospect: this would be produced using surplus wind- and solar-generated electricity during periods of high energy availability.

Reserves and resources

Fossil energy carriers – coal, oil and natural gas – were formed during prehistoric times from the organic remains of plants and animals, so the energy stored within them was created by solar radiation. With fossil energy carriers, it is generally the total amount of stored energy which is considered, comprising the 'reserves' (the stocks at known sites which are technically and economically extractable under present conditions) and the 'resources' (proven or estimated stocks which are regarded as recoverable in future).

Potentials

Unlike fossil fuels, renewable energies are unlimited in terms of the total quantity available. However, they are limited in terms of the amount of energy per unit time that they can supply (known as 'potential'). The potential has upper limits in theory (such as the amount of incoming solar radiation per unit area and time) and in practice (technical usability). The issue of particular relevance to the WBGU is their potential for sustainable use – in other words, the technical but also the ecological and socioeconomic limits to the usability of renewable energy sources.

Energy transformation scenarios

The transformation scenarios depicted in the published scientific literature show that it is possible to restructure the global energy system so as to avoid global warming of more than 2 °C. Energy efficiency and renewable energies have a key role to play in this context.

The WBGU has analysed a number of energy system transformation scenarios contained in the scientific literature. The common feature of all these scenarios is that they are predicated on only moderate growth of energy demand: from the current figure of around 470 exajoules (EJ), energy demand rises to no more than 700 EJ in 2050 and actually decreases to 400 EJ in some scenarios. This illustrates the great significance of energy efficiency measures for the transformation of energy systems. The significance of grid-based energy carriers such as electricity and gas increases at the same time. All the scenarios, without exception, depict ambitious expansion of renewable energies, with annual average growth rates of more than 3 % or even 4 % between 2010 and 2050. However, the scenarios also depict extremely diverse technology mixes, indicating that there is considerable leeway for political and social decision-making about appropriate technologies to promote climate change-mitigating energy system transformation. In scenarios with reduced energy demand, higher renewable energy shares are achievable, along with opportunities to phase out nuclear power and minimise the impact of fossil energies using carbon dioxide capture and storage (CCS). The WBGU advises against the use of nuclear energy due to its high external costs but particularly due to the risk of major disasters, the still unresolved problem of final storage, and the possibility of uncontrolled proliferation. CCS is of relevance to countries which continue to use fossil energy carriers.

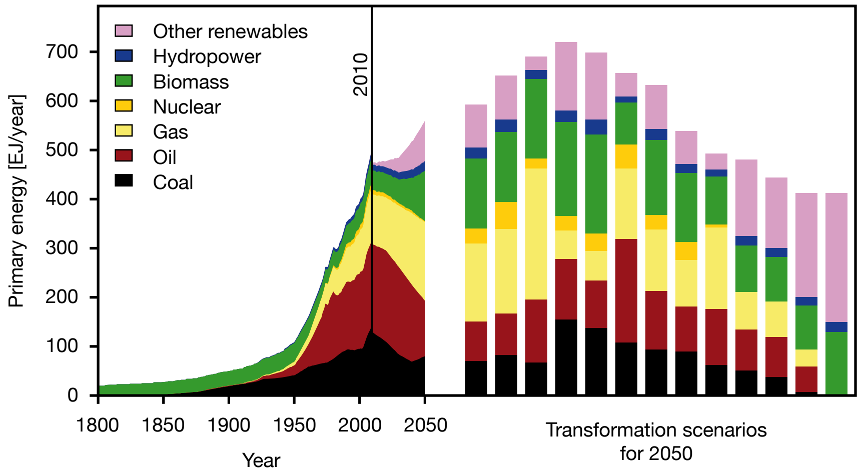

Figure 2: Transformation scenarios: an overview

This figure provides an overview of the energy mixes depicted in various global climate scenarios from the scientific literature. The real-world energy mix to 2008 is shown on the left, together with a mitigation scenario from 2010 onwards. On the right, a projected energy mix for the year 2050 is shown for other scenarios. Each of these scenarios would limit anthropogenic climate change to 2 °C. The common feature of all these scenarios is that they are based on only moderate growth in energy demand, with strong expansion of renewable energies. Around two-thirds of the scenarios are predicated on the use of CCS, while some scenarios rule out the use of both nuclear power and CCS. On the far right, the WBGU vision presented in Figure 1 is shown for the purpose of comparison. The depicted scenarios are explained in more detail in the WBGU's flagship report World in Transition – A Social Contract for Sustainability.

Source: WBGU, Flagship Report 2011

Carbon dioxide capture and storage (CCS)

Carbon dioxide capture and storage is a technical option which mitigates the contribution of fossil fuel emissions to global warming and thus enables at least a proportion of the substantial stocks of fossil energy carriers to be used during the transition to zero-carbon energy sources. The technical process involves capturing carbon dioxide (CO_2) emitted by large point sources and storing the captured CO_2 in geological formations. However, the technology has not yet been tested on a large scale and various problems are still unresolved. CCS increases the required investment and operating costs of fossil power plants and also reduces their efficiency. It is also impossible to capture 100 % of the emitted CO_2. The potential for unintended leakage of CO_2 from the storage formation over time poses a particular risk in relation to long-term climate change mitigation. The WBGU therefore recommends that the only storage facilities used are those where a retention period of at least 10,000 years can be guaranteed. CCS is being discussed, in combination with the use of bioenergy, as a means of actively removing CO_2 from the atmosphere. This option is limited, however, by the amount of sustainably usable biomass available.

Costs, financing and framework conditions for the transformation

Energy system transformation can only be successful if an enabling environment is created: this means, firstly, revealing the true costs of today's emissions-intensive energy system; secondly, providing targeted support for new technologies; and thirdly, identifying opportunities to recoup the high upfront investment costs.

Global decarbonisation of energy systems is feasible not only in technical but also in economic terms. The long-term economic costs of this transformation amount to just a few per cent of global gross domestic product (GDP). The transformation will require substantial additional investments amounting to several hundred billion US$ annually. For the purpose of comparison, however, it should be noted that the current harmful subsidies for fossil energy carriers run to hundreds of billions of US$ as well. Government policies must therefore aim to abolish current misguided incentives and investment barriers and make investment in low-carbon technologies more attractive, for example by minimising investment risks. This requires long-term, stable policy frameworks with ambitious targets, for example within the scope of climate protection legislation or a decarbonisation strategy. Ambitious carbon pricing and the abolition of subsidies for fossil energy carriers have a strong steering effect and enable additional financing to be leveraged. New business models must also be developed to facilitate the transformation process.

Additional benefits of energy system transformation

The global transformation of energy systems, as proposed by the WBGU, would bring other benefits beyond climate change mitigation.

Around three billion of the world's people still have no access to essential modern energy services and rely instead on solid fuels for cooking, for example. The resulting health impairments and deaths could be avoided with energy system transformation. Furthermore, a shift away from fossil energy carriers could make a significant contribution to air pollution control. It would also improve the security of supply and reduce long-term fuel costs and the costs of adaptation to climate change.

International cooperation for energy system transformation

Access to safe, clean and affordable energy for all the world's people, with simultaneous decarbonisation of energy systems, can only succeed if international cooperation is stepped up.

The most important objectives of the global transformation of energy use are: limiting global energy demand and ensuring access to modern, sustainable energy services for all the world's people, decarbonising the energy supply, and introducing new low-carbon technologies in the transport sector, in buildings, and in industry. International cooperation is essential in order to accelerate the development of key technologies and facilitate the global diffusion of technologies. The policies of the influential International Energy Agency (IEA) should focus to a greater extent on sustainable energy use and sustainable energy systems, and access to the IEA for developing and newly industrialising countries should be improved. The new International Renewable Energy Agency (IRENA), established in 2009, can play a key role in the diffusion of renewable energies in future. A fresh agreement in the international climate process could mobilise major technology and financial transfers from the industrialised world to support the transformation process in developing and newly industrialising countries. Feed-in payments for renewable energies and carbon pricing should be introduced worldwide. Overall, international cooperation should focus less on individual projects and more on systemic changes, with a view to developing joint strategies for climate-compatible development and 'green growth'.

German Advisory Council on Global Change (WBGU)

The German Advisory Council on Global Change (WBGU) is an independent scientific advisory body set up by the German government. The WBGU provides policy-makers with recommendations for action and research. Its flagship report 'World in Transition – A Social Contract for Sustainability' can be downloaded from the WBGU website.

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