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How to close the gap between global energy demand and renewable energy production

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Abstract

One of the main challenges in the years to come is to minimize the climatic changes resulting from global warming. Reducing greenhouse gas emissions (GHG) is necessary to avoid dramatic climatic changes. Implementation of incentives supporting technology development, commercialisation and dissemination of renewable energy projects and more efficient use of energy are necessary to increase the ratio of renewable energy production to the total energy demand. However, energy demand scenarios show that there will be a gap between total global energy demand and renewable energy production over the next decades. Therefore, a short-term strategy must be implemented to minimize GHG emissions from existing energy production. This can be achieved by developing a carbon dioxide (CO_2) value chain including infrastructure for CO2 capture, transport and safe storage.

1. Introduction

Fossil fuels are the most important energy source today, and according to the International Energy Agency (IEA) 80 % of the global energy consumption is based on coal, oil, and natural gas [1]. This extensive use of fossil fuels leads to environmental problems such as local pollution, acidification, and emission of CO_2, which again can result in global warming.

CO_2 is a greenhouse gas (GHG), and emissions of CO_2 increase the CO_2 concentration in the atmosphere, which again result in a rising global average temperature. Such global warming may lead to dramatic climate changes worldwide.

Due to increased emissions of GHG, the global average temperature will increase by 1.4 to 5.8 ^{o}C from 1990 to 2100, according to The Intergovernmental Panel on Climate Change (IPCC) [2]. The increase in global temperature will have dramatic impacts on life on earth. If no action is taken, the sea level will increase with up to one meter within 2100. One consequence of a one meter rise in sea level is that 40 % of Bangladesh will be under water. Other effects of global warming include increasing precipitation, increased frequency of extreme climate events, disrupting ecosystems, and extinction of species [3].

The extent of the increase in global temperatures depends on actions taken to reduce GHG emissions. Models

established by the IPCC indicate that the dramatic climate effects mentioned above will occur if the global average temperature increases by more than 2 ^{o}C. To avoid such a high temperature increase, the IPCC has suggested that global GHG emissions should be reduced by 50 to 80 % within 2050.

Changing the sources of energy production from fossil fuels to renewable energy sources will reduce GHG emissions, and the aim of this paper is to identify the potential for covering the future global energy demand by renewable energy resources. In addition, possible actions to fulfill the IPCC's goal of reducing GHG emissions are discussed. The paper starts by presenting global energy demand scenarios in Section 2. Renewable energy and increasing energy efficiency are outlined in Section 3, followed by barriers towards reducing CO_2 emissions in Section 4. Necessary actions to close the gap between energy demand and renewable energy production are given in Section 5, and, finally, conclusions are given in Section 6.

2. Future global energy demand

The IEA has presented two scenarios for future energy demand [1]. In their Reference Scenario only political incentives, laws and regulations currently implemented are taken into account when calculating future energy demand. Many possible future incentives influencing the energy market are not accounted for in this scenario. The IEA has also set up an Alternative Scenario accounting for implementation of several possible incentives favoring energy production from renewable sources and more efficient use of energy. Both scenarios are shown in Figure 1.

According to the IEA's Reference Scenario global energy demand will increase by 59 % from 2002 to 2030 [1], and from Figure 1 it is seen that fossil fuel is expected to cover for most of the increase. Figure 1 also indicates a clear gap between total energy demand and renewable energy production.

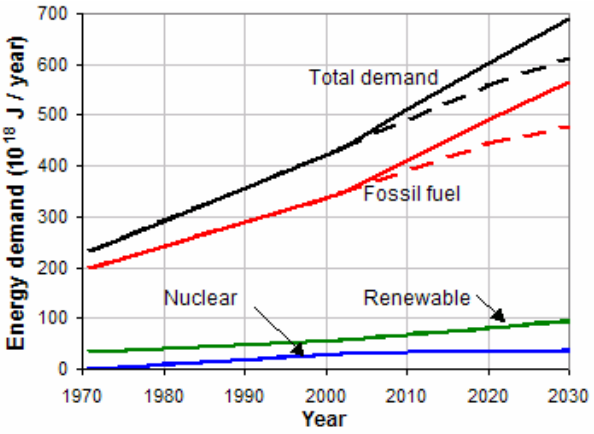

Figure 1. IEA scenarios for global primary energy demand. Full lines represent the Reference Scenario while dotted lines represent the Alternative Scenario.

The IEA has been criticized for assuming a too high increase in energy demand. In addition, opponents maintain that the IEA has neither accounted for the full potential for developing renewable energy resources, nor the potential for increased energy efficiency. Nevertheless, the IEA study is based on a large and comprehensive database, and it is one of the future energy prognoses that is most often referred to. The IEA scenarios have therefore been chosen as a starting point for the present work.

The IEA scenarios can be compared to scenarios established by other organizations, such as the IPCC. [4]. They have developed 40 different scenarios with varying models for demographic, economic, and technology developments throughout the world. The IPCC summarized the results into four main scenarios, which show similar trends to those in the IEA scenarios. The IPCC scenarios indicting the highest and the lowest energy demands in 2030 are scenarios A1 and B2, respectively. These are compared to the IEA scenarios in Figure 2. From this figures it is seen that the span in the IPCC scenarios overlaps the span in the IEA scenarios. Both the IEA

and the IPCC illustrates that the renewable energy potential is too low to supply the total global energy demand in the next decades.

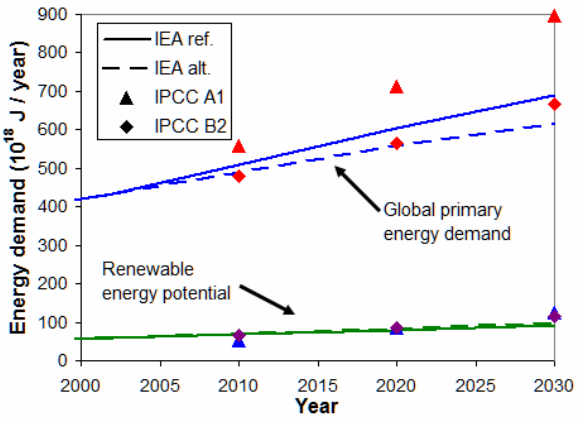

Figure 2. IPCC and IEA scenarios for global primary energy demand and renewable energy potential. Only scenarios A1 and B2 of the four main IPCC scenarios are shown.

3. Renewable energy production and increasing energy efficiency

The most important renewable energy sources today are biomass and hydropower as shown in Figure 3. The IEA expects the annual increase in energy production from biomass and hydropower to be at the same level as fossil fuels in the next decades [1], meaning that hydropower and biomass do not have the potential to close the gap between total energy demand and renewable energy production.

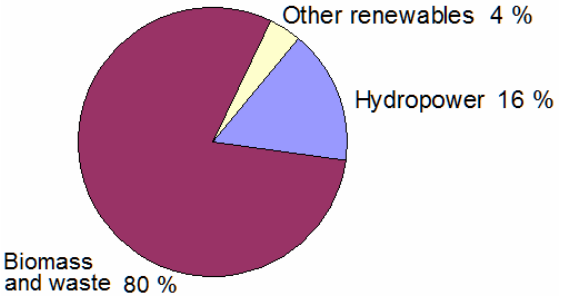

Figure 3. Primary renewable energy sources in 2002 [1]. The numbers represent percent of total renewable energy demand. Other renewables include wind, solar energy, geothermal energy etc.

The annual increase in energy demand from other renewable energy sources such as wind, solar and geothermal energy, etc. is expected to be very high over the next decades as shown in Figure 4. However, total energy production from these sources will be too small to provide any considerable increase in the contribution from renewable energy to the total energy demand. Based on the most optimistic data from the IEA, *i.e.* the Alternative Scenario, renewable energy resources will only cover 16 % of the global energy demand in 2030 as shown in Figure 5, which is only a small increase from the situation today. Even this most optimistic scenario from IEA shows that global energy demand can not be covered by renewable energy sources within the next two decades.

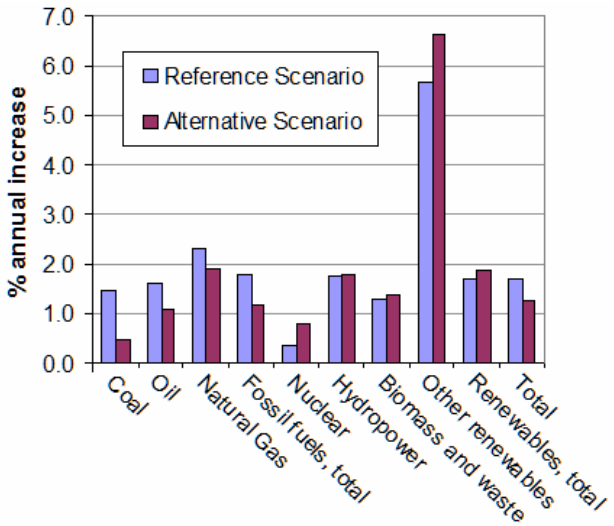

Figure 4. Annual growth in global energy demand from different sources between 2002 and 2030 according to the IEA.

There is a large potential for reductions in GHG emission by ensuring a more efficient use of energy both in industry and households. When energy is produced from fossil fuels, a more efficient use of energy will clearly reduce GHG emissions.

A simple case study can be performed by assuming that the IEA underestimates both the potential of increased energy efficiency and the potential for renewable energy. Let us assume that increasing energy efficiency can maintain global

energy demand in 2030 equal to that of today. This is clearly an underestimation of the future energy demand, especially considering that the economic development in China will lead to an enormous increase in energy demand. Let us also assume that the annual growth for renewable energy is twice as high as the IEA has predicted (*cf.* Figure 4), which is probably an unrealistic overestimation of the potential for renewable energy.

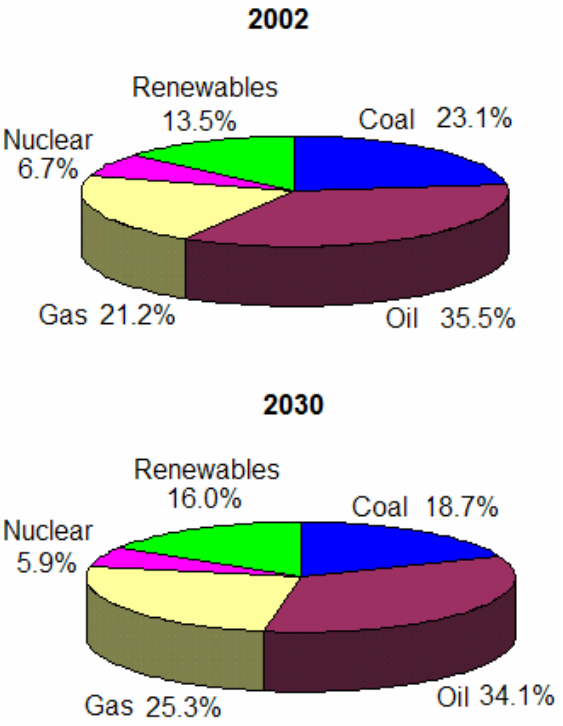

Figure 5. Primary energy demand related to different energy sources in 2002 and 2030. Based on the IEA Alternative Scenario

Given the two assumptions described above, the global energy demand and the renewable energy production will be as shown in Figure 6. This figure indicates that there is still a gap between energy demand and renewable energy production. This case study shows that it is most unlikely that the global energy demand can be covered by renewable energy over the next decades. This will not happen even if the scenarios by the IEA and IPCC should turn out to strongly underestimate the potential for increased energy efficiency and renewable energy production.

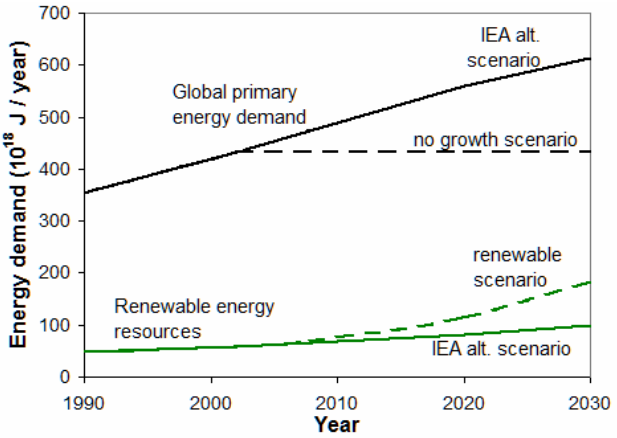

Figure 6. The IEA alternative scenario compared to a case study of increases energy efficiency leading to no growth in energy demand (black dotted line) and increased potential for renewable energy (green dotted line).

4. Barriers towards reducing GHG emissions

There exist economical, technical, social, and environmental barriers to a comprehensive implementation of energy production from renewable energy sources and a more efficient use of energy. The main barrier to implementation of large-scale renewable energy production is often large production cost. In a free market, energy production will in general be based on the energy source with lowest production cost per unit energy produced. In most cases today, the cheapest energy will be produced based on fossil fuels, not on renewable sources.

The lack of infrastructure and regulatory framework are other barriers for the implementation of clean energy production. It is necessary to define elements and measures required for transferring the results of research into commercial scale projects. Once financial risks reach an acceptable low level and business opportunities are created through the establishment of long-term reliable framework conditions, investment in clean energy production and its ensuing infrastructure will take place.

There is a need to identify regulatory and legal barriers to facilitate energy production from renewable energy sources. Once identified, the barriers must be removed in order to ensure the commercial viability of clean energy projects. In addition, government backing of projects requiring incentives to succeed is necessary to ensure that the wider society pays the least possible price for renewable energy.

Measures to protect the environment must be established when renewable energy production is established. The physical environment effects are a vital part of overall infrastructure for renewable energy. Environmental regulations need to ensure compliance and consistency with environmental and safety needs.

5. How to close the gap

In the long-term the best way to reduce GHG emissions is to change the main source of energy production from fossil fuels to renewable sources. However, as previously mentioned, there is a gap between future global energy demand and the potential for renewable energy production. Short-term strategies are therefore necessary to reduce this gap and reduce GHG emissions.

It has been argued by others that nuclear energy production is the best way to reduce GHG emissions and ensure enough energy production. Changing from fossil fuel to nuclear energy production will clearly reduce the global CO_2 emissions. However, because of the hazards linked to nuclear energy production and nuclear waste handling, nuclear energy production is considered as a bad strategy to reduce GHG emissions.

5.1. Carbon capture sequestration

A much safer strategy for reducing GHG emissions is to implement carbon capture sequestration (CCS). Such a strategy includes establishment of infrastructure and technology for CO_2 capture, transportation and storage in locations where CO_2 will be safely isolated from the atmosphere. Due to practical and economic reasons CO_2 capture will be established at large CO_2 sources such as fossil fuel-based power plants. The exhaust gas from fossil fuel power plants contains relatively low concentrations of CO_2. Therefore CO_2 has to be separated from the exhaust gas before transportation to a safe storage location. Technologies for CO_2 capture from exhaust gas exists today, and CO_2 capture plants may be added to existing power plants.

Transportation of CO_2 can be performed either by pipelines or ship. CO_2 storage can be located to geological formations underground. Research and technological development are necessary to ensure that CO_2 injected underground are safely stored and do not leak out.

A cost effective method for CO_2 storage is to use CO_2 for Enhanced Oil Recovery (EOR). By injecting CO_2 into oilfields, the recovery rate of the oilfield can be increased, *i.e.* more oil is produced. Using CO_2 for EOR can lead to increased income for oil companies, and CO_2 therefore becomes a valuable product.

6. Conclusion

The impacts of global warming can be minimized by globally shifting the sources of energy production from fossil fuel to renewable energy sources. However, scenarios for future energy demand shows that renewable energy sources will not be able to cover the total global energy demand over the next decades.

Actions have to be taken now in order to avoid dramatic future climate changes. There is a need for short-term strategies for ensuring energy production with the lowest GHG emissions possible, and the best strategy is to establish carbon capture sequestration. Energy production from fossil fuel power plants combined with CO_2 handling including CO_2 capture, transport and safe storage will minimize GHG emissions. In addition there is a large

potential for reducing GHG emissions from a much more efficient use of energy.

In addition, long-term strategies for substituting fossil fuel energy production with renewable energy sources must be implemented. This will require implementation of incentives favoring both research projects to develop necessary technology and projects aiming to commercialize energy production based on renewable energy sources.

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