Importance of bioenergy markets for the development of the global energy system

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Keywords

Global energy system, Bioenergy, TIAM-FR model, bioenergy markets, climate policies

Overview

Fossil fuels such as oil, coal and gas dominate the global energy supply, covering more than 80% of the total primary energy supply of 508 EJ in 2009 [1]. In order to reach climate targets and create low-carbon economies, biomass is expected to play a pivotal role. While the future resource potential of biomass may be significant and the global trade of bioenergy is rapidly expanding, biomass is currently only playing a minor role in the global energy supply. Total biomass primary energy supply was 51 EJ in 2008, of which more than 60% constituted for traditional use such as cooking and heating in developing countries (India and sub-Saharan Africa) [1]. The main applications of modern use of biomass are today firstly, in the industrial sector to produce process steam, and secondly, in the power sector.

Major drivers for the growth of bioenergy are the large resources potential and low production costs of biomass in export countries such as Brazil and Canada, high fossil fuel prices, and a variety of policy incentives to stimulate biomass use in import countries. Recent evaluations of the biomass resource potential show that biomass could in a sustainable manner contribute with as much as 160-270 EJ to the world's primary energy supply by 2050 [2]. However, a number of barriers need to be overcome before such a potential could be realized. One of the main obstacles is that large biomass resources are commonly not located in vicinity to urban and industrial areas. Furthermore, studies have shown that the countries that could become important biomass producers are not the same as the countries that could become important biomass users. The largest biomass production potential will lie in areas with favorable climatic conditions and abundant land resources such as Latin America, North America, Centrally planned Asia, China, and Sub-Saharan Africa [2]. On the other hand, the main demands for biomass have been shown to be in OECD countries and South-East-Asia [3]. As such, international trade of bioenergy may play a pivotal role in the development of low-carbon economies.

While international bioenergy markets are still in their infancy, international trade of biofuels, wood pellets, ethanol, and palm oil are expanding rapidly [4]. Between 2004 and 2006, international trade of bioenergy increased from 770 PJ to 930 PJ [5]. To facilitate long distance bioenergy trade and aid

the development of a global bioenergy commodity market, technological developments are taking place on the production side and on the end-use side. Developments in thermal pre-treatment technologies such as torrefaction, gasification, and pyrolysis are aiding the production of bioenergy commodities that may be transported over long distances as they are highly homogeneous, have high energy density, and are not vulnerable to biodegradation [6]. Developments in co-firing of coal and gas power plants with biomass are increasing the range of end-use applications of biomass commodities [7]. However, the wide implication of a global bioenergy market and increased trade of bioenergy on the development of the global energy system is still unclear. As biomass provides the means of low-carbon power generation, the development of global bioenergy markets may have a large impact on the investments in low-carbon power generation capabilities and deployment of carbon capture and storage (CCS). Energy system models used to estimate the development of the global energy system commonly lacks sufficient data concerning the future growth in biomass supply and thermal pre-treatment technologies. As such, the wide implications of bioenergy trade and the development of bioenergy markets are commonly not considered.

The main aim of this study is to evaluate the importance and wide implication of the developing international bioenergy markets on the long-term development of the global energy system. We evaluate the importance of bioenergy trade for reaching international climate targets, future bioenergy trade patterns, as well as the impact and future use of pre-treatment technologies. Particularly we focus on the possible impacts of bioenergy markets on the energy mix, exploitation of biomass resources, and technological investments.

Methods

For evaluating the significance of bioenergy market and trade of bioenergy commodities, the global and multiregional TIAM-FR [8] energy system model was used. The partial equilibrium TIAM-FR model belongs to the ETSAP-TIMES [9] family of models developed by the international ETSAP (Energy Technology System Analysis Program) [10, 11] organization, and can be used to represent, optimize and analyze the global energy system over a short-, medium-, or long-term planning horizon (20 to 100 years). The TIAM-FR model is driven by the demand of some specific energy services and is based on a technology-rich bottom-up approach in which typically a wide range of technologies and commodities can be employed to fulfill the different demands. In the TIAM-FR model, the world is divided into 15 regions between which trade of commodities may take place.

In this study we particularly focused on the trade of biofuels, wood pellets, and torrefied pellets. On the supply side, current as well as developing conversion and thermal pre-treatment technologies were integrated in the model. As there exist different pre-treatment technologies depending on the water content of the biomass, biomass sources were divided into wet biomass (<50% moisture content) and dry biomass (>50% moisture content). The pre-treatment technologies considered for wet and dry biomass can be seen in Table 1. On the end-use side, technological options for biomass combustion in CHP-plants as well options for co-firing coal and gas power plants were also integrated and considered.

Table 1: Technological options for pre-treatment of biomass sources

Biomass source	Technology	End product
Wet biomass	Anaerobic digestion	Biogas
	Hydrothermal treatment	BioSNG
Dry biomass	Densification	Pellets or briquettes
	Torrefaction	Pellets or briquettes
	Gasification	BioSNG
	Pyrolysis	Bio-oil

As the future development of a number of key factors of the model are highly uncertain, scenario analysis was performed to evaluate the impact of key factors on the bioenergy trade levels and development of the global energy system. A business-as-usual (BAU) scenario of the future development of key factor was constructed in line with recent trends and assumed continued development of thermal pre-treatment technologies as well as continued economic and demographic growth. Along with the BAU scenario, alternative scenarios were developed according to variation in key factors such as:

- Availability of biomass sources.
- Trade possibilities between regions.
- Regional and global climate targets.
- Techno-economic characterization of pre-treatment technologies.

Results

The development of the global energy system was assessed until 2050, divided into time periods of five years. The analysis of the scenarios focused on evaluating the wide implications of international bioenergy markets and bioenergy trade on the long-term development of the global energy system. More precisely, we focused on the future energy mix and the integration of supply and end-use technologies. Furthermore, we identified future bioenergy trade patterns and evaluated the future trade levels of important biomass sources such as biofuels, woody biomass, and torrefied pellets.

The analysis allowed us to discuss the importance of developing global bioenergy commodity markets for the development of low-carbon economies. Also, it indicates how the growth of international bioenergy trade may impact other options of reducing CO_2 emissions carbon and use of renewable energy sources and CCS technologies. Furthermore, we identified and discussed the future integration of currently developing biomass thermal pre-treatment technologies and their implications on the development of the global energy system.

Conclusions

International trade of bioenergy has grown exponentially during the last decade. Given the current high level of investments in production facilities, the high number of nations with governmental incentives to stimulate biomass use, and the fact that climate constraints are expected to become more stringent over time, it is clear that international bioenergy trade will continue to grow over time. In this context, this study speaks to the favorably influence of bioenergy commodity markets and bioenergy trade for the development of low-carbon economies.

As shown by this study, the development of global bioenergy markets is likely to influence future investments in technologies that are currently in pre-industrial development stages. While it will take

time before some of these thermal pre-treatment technologies will be fully commercialized, their potential impact on the global energy system speaks to the importance of the ongoing development projects. For this, it is vital that investments in the development projects are continued, that further demonstration plants are constructed, and that barriers for market introduction of these technologies are removed.

The study shows to the importance of developing global bioenergy markets for the exploitation of the biomass potential. The commercialization and market introduction of pre-treatment technologies that allow for long distance trade will facility the exploitation of biomass sources that are currently under-utilized in a number of regions of the world. This in turn will not only help the creation of low-carbon economies, but also provide a stable and reliable source of income for rural communities in developing countries. As the potential biomass supply can commonly be found in rural areas, exporting bioenergy may provide much needed investment and development of these communities. As such, the development of global bioenergy markets may play an important part in rural development.

All of this confirms the importance of developing and supporting the introduction of bioenergy markets. While numerous governments around the world have supported the introduction of bioenergy markets, further developments of the policies would support continued growth of bioenergy trade. Also, as biofuel support policies – for example in the EU and USA – have prompted an increase in international production and trade in liquid biofuels, it is important to develop national trade policies that also consider international trade implications. Furthermore, it is vital that development of biomass markets is accompanied by international agreements upon environmental sustainability criteria's. While biomass may mitigate carbon emissions, if the biomass is managed in an improper manner it may induce deforestation, loss of biodiversity, water shortages, and reduce food security. As such, for the development of biomass markets to mitigate climate change and not induce environmental damages, it is important that international sustainability standards are agreed upon and respected.

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