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YUCHENG CAO[1,2], ARTUR PAWŁOWSKI[2]

BIOMASS AS AN ANSWER TO SUSTAINABLE ENERGY. OPPORTUNITY VERSUS CHALLENGE

Current world economic development is heavily dependent on fossil fuels that are nonrenewable and are main emitter of the greenhouse gases, leading to resources to be exhausted on one side, and the earth being warmer on the other. This in turn creates a shrinking bottleneck to economic development and wealth generation. Therefore, in pursuit of a sustainable future, a shift from fossil fuels to renewable energy should be taken essentially. Biomass is an indispensable element for development of sustainable energy because it is the only renewable energy source that can be used to produce liquid fuel. In the paper, the sustainability of energy from biomass has been discussed, with the focus on an identification of its benefits and challenges. The necessity of deployment of biomass energy and its progress in China and Poland have also been described.

1. INTRODUCTION

The uncontrolled and reckless human activities since the Industrial Revolution have caused a number of environment problems such as fossil fuel depletion, climate change and environmental pollution. Gradually, the importance of moving towards "sustainable development" was realized throughout the world. In 1987, the United Nations' World Commission on Environment and Development conceptualized the sustainable development in the well-known document, *Our Common Future* [1], and presented what is now one of the most widely-recognized definitions: *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. It contains two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposes by the state of

[1]School of Environment and Resource, Zhejiang Agricultural and Forestry University, Hangzhou 311300, PR China.

[2]Faculty of Environmental Engineering, Lublin University of Technology, ul. Nadbystrzycka 40 B, 20-618 Lublin, Poland; corresponding author Y. Cao, e-mail: Cao.y@wis.pol.lublin.pl

technology and social organization on the environments ability to meet present and future needs. What the Bruntland definition implies is an equitable resource distribution and consumption, not only spatially but also temporally.

There are many publications addressing different features of sustainable development: philosophical, mostly ethical [2–9], economical [10–16], environmental [17–20], technical [20–22], policy [23, 24], methodological [25, 26] and educational [27, 28] aspects. A hierarchy (in order of importance) arrangement of the multi-dimensions of sustainable development has been proposed to provide some guides for its implementation [29]. Some researchers claim that we are living in an era of sustainable development revolution affecting all aspects of our lives filled with multidimensional characters. The multidimensional nature requires us to see the world as a system, a system that connects space and time.

Currently, implementation of sustainable development requires changing our unsustainable production and consumption patterns and moves towards a better approach that should integrate economical, environmental and social, technical and political concern into all development processes. Such change is particularly important and urgent for achievement of sustainable energy, as pointed out by Pawłowski [29] *in any attempt to make the principle of intergenerational justice a reality will be utterly dependent on the appropriate management and utilization of energy carriers*.

2. ENERGY ISSUES

Energy is indispensable to most human activities and plays a key role in economic and social development. Fossil fuels (oil, gas and coal) are formed via natural processes taking millions of years, and thus regarded as non-renewable energy resources. Compared to other forms of energy carriers, fossil fuels are relatively easy and accessible to use for heat and electricity generation. Increasingly, the use of fossil fuels as a source of energy has become preferred since the Industrial Revolution. Consequently, seemingly just as usual, the whole world moves forward with an increasing dependency on fossil fuels, together with the rapid expansion of energy-intensive industries and vehicles, as well as the development of population and urbanization.

Unfortunately, our earth cannot consistently provide enough fossil fuels resources as we want; estimates say that the world's reserves would be exhausted 150–200 years later for coal, about 60 years for natural gas, and about 40 years for oil [20]. At the same time, the global demand for fossil fuel resources continues to soar. According to the *World energy outlook* [30], if governments around the world maintain the existing policies, global primary energy demand will rise by one-third from 2010 to 2035, with fossil fuels continuously dominant in global energy supply; by then, fossil fuels will share 75% of the global primary energy mix.

The energy challenge is apparent, in particular for China, the largest developing country comprising about one quarter of the world's population. Over the past four decades, China has maintained rapid economic growth, with annual average gross domestic product (GDP) growth of about 9.8% from 1980 to 2009 [31]. Unfortunately, rapid economic growth in China is heavily dependent on the development of energy-intensive manufacturing and heavy industries, and export and fixed asset investment, thus creating its position as the world's largest energy consumer, and second largest consumer of oil behind the United States [32].

The China's total energy consumption in 2010 reaches 3.25 billion tons coal equivalent, increasing at estimated annual growth rate of 5.8% between 1980 and 2009 [31]. More than 90% of the China's total energy consumption (in 2008) is supplied by fossil fuels, with 71% by coal, 19% by oil, and 3% by natural gas [32]. However, the country is not rich in the resources, possessing recoverable reserves of 176.8 billion tons of coal, 21.2 billion tons of crude oil and 22.03 trillion cubic meters of natural gas [33].

Similar energy issue exists for most developed countries. Taking the European Union (EU) as an example, fossil fuels consumed currently in the EU comprises about 80% of the total energy mix [34], of which above 50% is imported. The dependence on fossil fuels imports has been steadily rising, from 51% in 2000 to 54% in 2005 [35], and was estimated to be 70% by 2030 [34]. It is obvious that fossil energy is becoming less affordable at global level and creating a shrinking bottleneck to economic development and wealth generation.

In addition to energy security, we also face the warning that our earth is being warmer. Unfortunately, the two issues are highly correlated, and both are connected with our unrelenting consumption of fossil fuels. Our contention built upon the following two factors. First, there is a growing consensus that the earth temperature is rising (global warming), and that the principle cause for this is the emissions of greenhouse gases (e.g. carbon dioxide and methane). Second, evidences show that, fossil energy, which currently provides the majority of world total energy supply, is the biggest emitter of greenhouse gases, accounting for 74% of world's total carbon dioxide emissions [36].

Putting together the two factors, we could conclude that, the more energy we consume, the more greenhouse gases we release into the atmosphere, and the warmer the earth is likely to be. The following is an example for the correlation between the first two components by considering China situation: China rapid economic growth powered by fossil fuels creates the country being the biggest energy consumer in the world (as we mentioned earlier), and at the same time, leads to its position as the biggest greenhouse gases emitter. With respect to the correlation between the last two components, even though some scientists have published data raising doubts of the cause and scale of climate changes [11, 37, 38], precautionary principle needs us to take some measures. Possibly more unfavourably, while control of greenhouse gas emissions is capable of relieving climate warming, the current control measures generally cause slowdown or even shutdown of economic development.

It is noteworthy that fossil fuel energy is also the largest producer of air pollutants, including acidic gases (e.g. SO_2 and NO_x), tropospheric ozone precursors (e.g. NO_x, CO, CH_4 and non-methane volatile organic compounds), and particulate matter. For example, the European Environment Agency reported that the EU-27 energy production and consumption in 2005 contributed to about 55% of the EU emissions of acidifying substances, 76% of emissions of tropospheric ozone precursors and 67% of particles emissions [35].

Conclusively, how to sustain the supply of reliable and affordable energy in an environmentally friendly pattern is a projected challenge that needs to be addressed urgently.

3. ENERGY FROM BIOMASS

One critical approach to addressing the energy-related issues, probably the only way, is to develop and deploy renewable energy. It has been universally recognized by both academic and political communities that, implementation of renewable energy is crucial to reduce the dependency on fossil fuel, secure and diversify energy supply, and alleviate climate change, although there still exist some concerns as to the environmental and economical sustainability of particular renewable energy technologies.

As of the beginning of the 21st century, governments around the world, at regional, national and community levels, have endorsed a number of regulations to promote the use of renewable energy. For example, as early as 2001, the EU legislated an average indicative target of 12% share of renewables in the gross final energy consumption by 2010 [39]. This is followed by the release of the Directive 2009/28/EC [40], where a target was set to increase the share of renewable energy in gross final energy consumption to 20% by 2020 for the whole Community (relative to 1990 level); the target established for Poland was set to be 15%.

Following the developed countries, Chinese government endorsed several laws to promote the production and consumption of renewable energy. In 2007, the national government enacted the *Mid- and Long-Term Development Programming for Renewables* [41]. According to the regulation, renewable energy should account for up to 10% of the total energy mix in 2010 and about 15% in 2020.

There are various forms of renewable non-fossil sources that have potential to produce energy, including biomass, wind, solar, geothermal, hydrothermal ocean energy, hydropower and biogas (e.g. landfill gas and wastewater treatment plant biogas). Different from other forms of renewable sources, biomass (biodegradable fraction of biogenic products, e.g. plants and their residues) is available locally and abundantly, technically flexible in energy conversion. Probably more attractively, biomass is the only renewable energy source that can be used to produce liquid fuel. For these reasons, energy from biomass, in particular in the form of oil, has received increasing interest around the world.

Biomass is naturally structured on the basis of carbon, hydrogen and oxygen, and initially formed via biological process by getting energy from sun, and carbon (CO_2) from air. When burned, energy in biomass is transferred to heat, one of the simplest ways of using biomass energy. Therefore, energy from biomass is actually an indirect and controlled solar energy utilization form.

As one of the largest countries in Europe, Poland has initiated promotion of energy from biomass, in particular after accession to the European Union. It was estimated that, in 2010 electricity generated from biomass accounts for about 53% of the total electricity generated from renewable energy sources (e.g. hydro and solar), the largest contributor among the renewable energy sectors [42]. Figure 1 shows the quantity of bioelectricity generation and the installed capacity in biomass power plants in Poland between 2000 and 2006. About 1821 GWh of electricity produced in 2006 comes from biomass, a fivefold increase compared to the 2000 level.

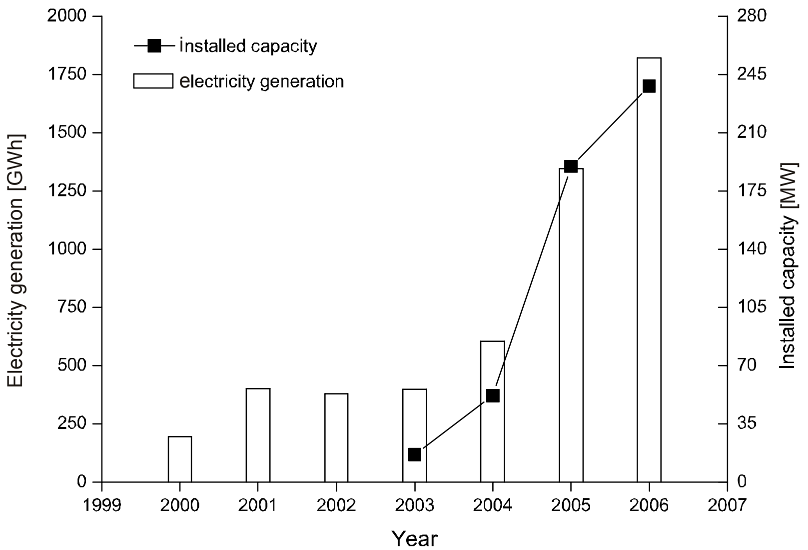

Fig. 1. Electricity generation and the installed power
in biomass power plants in Poland between 2000 and 2006 [42]

Up to now, Poland has developed more than 100 energy crop plantations, each with the area of at least 5 ha [43]. About 44 pellet and/or briquette producers, 100 biomass thermal power plants with installed capacity of at least 0.5 MW, 40 biomass-coal cofiring thermal power plants, and 39 biofuel producers with capacity of 1 million m^3 per year, have been deployed in the country [43].

As the largest agricultural country, China holds substantial potential for development of biomass energy. Table 1 presents a trend of the biomass energy production in China. The employment of biomass energy in China mainly includes burning for heat and electricity production (mostly produced from biomass residues), and production of biofuels (e.g. bioethanol and biodiesel). In northern regions of China, Sorgo seems to be a promising energy crop for biofuels production, as it grows well in cold northern climates and can endure drought. In southern regions, research for biooils production is progressing on colza oil, cottonseed oil, wood oil and Chinese tallow oil [44].

Table 1

China's goals for energy from biomass [41]

Energy from biomass	Unit	Year		
		2005	2010	2020
Bioelectricity	MW	2 000	5 500	30 000
Bioethanol	1000 tons	1 020	3 000	10 000
Biodiesel	1000 tons	50	200	2 000
Solid biomass fuel	1000 tons		1 000	50 000

It is no doubt that displacement of fossil fuels with energy produced from biomass could contribute to energy security and diversity of energy supply, and has potential to reduce or offset greenhouse gas emissions by directly sequestering carbon dioxide from the atmosphere and storing it in crop biomass and soil. Despite these benefits, energy from biomass does not go smoothly, holding some disadvantages and facing some challenges. Our discussion for this is structured as below: first, we divide biomass used for energy production into two categories: commercial energy crops and biomass residues/wastes. Then, we separately discuss their disadvantages and challenges.

Commercial energy crops often refer to intensive plantations of trees (e.g. willow and poplar), grasses (e.g. *Miscanthus* and elephant grass), agricultural crops (e.g. corn and soybean) and others, which are dedicated for energy production, and mostly for production of liquid biofuels. One major dilemma facing energy crops is their competition with food. Currently, the majority of biofuels are produced from food crops (e.g. corn, sugarcane, soybeans and palms), probably because they are easily collected, have high energy content, and facilitate large-scale deployment. This raises an increasing concern as to if these crops should be designated to grow foods or to produce biooils, i.e. biofuels vs. food dispute. Given the facts that the world' arable land is limited and the world population continues to rise, a rush shift from edible oil to energy produced by food crops could lead to an increase in food shortages.

Furthermore, intensive plantations of energy crops are likely to place some detrimental impacts on the environment, as warned by the United Nations that *where crops* *are grown for energy purposes the use of large scale cropping could lead to significant biodiversity loss, soil erosion, and nutrient leaching. Even varied crops could have negative impacts if they replace wild forests or grasslands* [45].

It should be pointed out that our discussion does not argue against development of energy crops and biofuels but implies that the current biofuels based on energy crops are problematic. Solutions to the problems require looking at it as a system, and managing the system in a sustainable way with both positive and negative impact in mind.

In contrast, biomass residues and wastes include forest and agricultural residues (e.g. tree branches, grain husks and straw) which are characterized as byproduct or remainders of forest and agricultural industries, and biowastes (e.g. organic matter in municipal solid wastes and sewage sludge, and animal wastes). Energy from biomass residues/wastes is widely recognized as a helpful way to fight against the energy and climate change issues. At the same time, it represents an opportunity for sustainable management of the residues/wastes, in particular for management of municipal solid wastes and sewage sludge, the main waste streams which are produced in large and increasing amounts. The main challenge facing energy from biomass residues/waste is to develop or employ reliable, cost-effective and energy-efficient conversion technologies. In addition, the distribution of this category of biomass is scattered and difficult to collect, thus placing a barrier to large-scale deployment of energy production. This requires us to do more with less, and may require diversification and integration of feedstock collection and processing, energy conversion processes and utilization of energy produced, in technological, environmental, social and economic terms.

4. CONCLUSIONS

Energy is indispensable to most human activities and plays a key role in economic and social development. Use of fossil fuels as energy source has become preferred since the Industrial Revolution as they are relatively easy and accessible to use. However, fossil fuels are nonrenewable, and their production and consumption emits carbon dioxide to the atmosphere. The long-term dependency of world' economic development on fossil fuels has resulted in diminished reserves and increased temperature of the earth. The question facing the world, *how to sustain the supply of reliable and affordable energy in an environmentally-friendly pattern*, needs to be addressed urgently.

Biomass is the only renewable energy source that can be used to produce liquid fuel, and thus is an indispensable element for development of sustainable energy. However, energy from biomass has several disadvantages and faces some challenges, such as competition with food, possible negative environmental impacts, collection and processing of feedstock, low efficiency of energy conversion process. Solutions to these problems require us to look at energy from biomass as a system, and to manage the system in a sustainable way with technological, environmental, social and economic dimensions in mind.

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