

Bioenergy Potentials and Dynamic Factors

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Abstract

Biomass or bioenergy is attracting growing attention as a sustainable and renewable energy source, which is abundant and available around the world. There are many studies on bioenergy potentials with estimates ranging from less than 100 EJ/yr to more than 500 EJ/yr in 2050. Some studies indicate that by 2100 more than 1000 EJ/yr is conceivable. To comprehend the magnitude of the estimates, the world energy supply in 2004 was 470 EJ. Bioenergy is therefore capable of playing a considerable role in energy supply both globally and regionally. The objective of this paper is to review studies on bioenergy potentials in order to identify and discuss the reasons for the varying estimates and the factors that influence realising bioenergy potentials. First, the availability of land and the magnitude of yields for energy crops are disputed in the studies. Second, the boundaries between the types of bioenergy potentials (theoretical, geographical, technical, economic, and implementation) are blurred. Third, there are different methodologies applied in the studies. Fourth, there are dynamic factors that shape bioenergy potentials. This paper concentrates on the major dynamic factors influencing the development and diffusion of energy crops. Dynamic factors are predominantly external factors to bioenergy systems, including food demands and agricultural policy and management. Additionally, there are internal factors within bioenergy systems, including productivity improvements and sustainable management of soils, water, and ecosystems. Interacting with the dynamic factors are conflicting interests and catalysing synergies.

Keywords

Bioenergy, Biomass, Renewable Energy, Sustainable Development

Introduction

Biomass or bioenergy is attracting growing attention as a sustainable and renewable energy source, which is abundant and available around the world (Hall & Scrase, 1998; Johansson, 2002; Smeets et al., 2004). However, there are diverging estimates on bioenergy potentials. The objective of this paper is to review studies on bioenergy potentials in order to identify and discuss the reasons for the varying estimates and the factors that influence realising bioenergy potentials. This paper comprises several sections. The first section outlines the methodology applied in the research for this paper. The second section provides an analysis of studies on bioenergy potentials from the global perspective and the regional perspective of Europe. The third section enters into a discussion about the relationships between bioenergy potentials and dynamic factors, conflicting interests and catalysing synergies.

Methodology

This paper is based on research conducted by the Bioenergy Network of Excellence (NoE), which is a collaboration of research institutes in the European Union (EU).¹ The Bioenergy NoE is engaged in identifying and analysing barriers to expanding bioenergy. However, the findings are relevant and important beyond the industrialised countries of the EU, particularly for developing countries that are modernising energy systems and expanding renewable energy. This paper presents the results of research on bioenergy potentials. The methods applied in the research included reviewing studies on bioenergy potentials from the global perspective and the regional perspective of Europe, and interviewing authors of several studies and experts from research institutes in the Bioenergy NoE. This paper provides a qualitative perspective on bioenergy potentials. However, further research focused on quantitative analysis is recommended.

Analysis

There are many studies on bioenergy potentials from the global perspective (see Berndes et al., 2003 for an extensive overview of studies). This paper focuses on recent research and studies (Parikka, 2004; Hoogwijk et al., 2005; Fallot & Girard, 2005; Smeets et al., 2004; Moreira, 2005; IEA, 2005). What is striking about the studies are the different estimates ranging from less than 100 EJ/yr to more than 500 EJ/yr in 2050. Some studies indicate that by 2100 more than 1000 EJ/yr is conceivable. To comprehend the magnitude of the estimates, the global energy supply in 2004 was 470 EJ.² Several studies are therefore suggesting that bioenergy is capable of playing a considerable role in energy supply both globally and regionally.

There are several reasons for varying estimates of bioenergy potentials. The availability of land and magnitude of yields for energy crops are disputed in the studies. Furthermore, the contribution of forest residues, agricultural residues, and organic wastes are also debated. Clearly, the intensity of exploiting biomass for energy purposes is dramatically influenced by the extent to which planting and harvesting energy crops is able to expand (Berndes et al., 2003). In recent research and studies there are attempts to explore the relationships between land use patterns, energy crops, and bioenergy potentials.

There are different types of potentials when evaluating biomass for energy purposes (Hoogwijk et al., 2005). The theoretical potential calculates primary biomass resources available from all land area. The geographical potential refers to the land area that is available for biomass production. The technical potential looks at the process of converting primary biomass resources to secondary energy carriers. The economic potential addresses the profitability of secondary energy carriers. The implementation potential reviews constraining and enabling factors for biomass production within a timeframe and scale. It is important to recognise that the implementation potential can be higher (rather than lower) than the economic potential because it can be influenced by supportive policies and measures.

Shifting from a global perspective to the regional perspective of Europe provides further insights into studies on bioenergy potentials. Understanding bioenergy potentials at the regional, national, and local perspective is critical for business to make investments and government to form policies. There is a range of methodologies applied in studies on bioenergy potentials in Europe (see table 1). The *scope* is either EU 15 or EU 25. The challenge with the EU 10 is gathering reliable information. However, the considerable prospects for biomass production in the EU10 is stimulating research. The *timeframe* is often focused on 2010 and 2020. However, the availability and utilisation of biomass for energy purposes is often not recorded, so there are also estimates for 2000 in some studies because of the need to collect data.

¹ Visit <http://www.bioenergynoe.org/> for more information on the Bioenergy NoE.

² Visit <http://www.ren21.net/> for more information on global energy supply.

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There are a range of *methods* adopted to explore bioenergy potentials, including surveys, statistics, scenarios, supply curves, and models. It is important to recognise that studies on bioenergy potentials are either demand-focused (concentrating on the demands for bioenergy) or resource-focused (concentrating on the resources for bioenergy) and that the interactions between supply and demand are complex. It is therefore critical that authors and experts who are engaged in building models and scenarios to estimate bioenergy potentials are explicit about data, assumptions, and methods (Smeets et al., 2004).

Table 1: Comparison of Methodologies for Calculating Bioenergy Potentials

Source	Scope	Timeframe	Methods	Types of Biomass	Factors for Biomass
1	EU 15	2000, 2010	Surveys, statistics	Forest residues, agricultural residues, organic wastes, energy crops	Policy and promotion (targets and schedules)
2	EU 15, EU 10, Belarus, Ukraine	Short (10-20 years), medium (20-40 years), long (more than 40 years)	Scenarios	Forest residues, agricultural residues, energy crops	Land, yields, economic and ecological harvests
3	EU 25	2000	Statistics	Forest residues	Competition (forest industry and nature protection), mechanisation, costs
4	EU 15, EU 10	2010, 2020	Supply curves	Forest residues, agricultural residues, organic wastes, energy crops	Technology, trade, costs
5	EU 15, EU 10, Romania, Bulgaria	2010, 2020	Supply curves, models	Forest residues, agricultural residues, organic wastes, energy crops	Supply and demand, technology, land, yields, trade

1. Alakangas E, Vesterinen P. (2003) EUBIONET: Biomass Survey in Europe. <http://www.eubionet.net/>

2. Ericsson K, Nilsson LJ. (2004) Assessment of the Potential Biomass Supply in Europe using a Resource-focused Approach. <http://www.miljo.lth.se/>

3. Karjalainen T, Asikainen A, Ilavsky J, Zamboni R, Hotari K, Röser D. (2004) Estimation of Energy Wood Potential in Europe. <http://www.metla.fi/>

4. Nikolaou A, Remrova M, Jeliaskov I. (2003) Biomass Availability in Europe. <http://europa.eu.int/>

5. Siemons R, Vis M, van den Berg D, McChesney I, Whiteley M, Nikolaou N. (2004) Bio-energy's Role in the EU Energy Market: A View of Developments until 2020. <http://europa.eu.int/>

There are many ways to categorise biomass. This paper differentiates between several *types of biomass*, including forest residues, agricultural residues, organic wastes, and energy crops. The studies on Europe attempt to incorporate the influence of varying *factors for biomass*, including policy and promotion, land, yields, economic and ecological harvests, competition, mechanisation, costs, technology, supply and demand, and trade. Clearly, the studies recognise that biomass production is shaped by many factors. However, there is no agreement in the studies on how the major factors interact with bioenergy potentials. Consequently, the differences in methodologies produce a range of results, which are not comparable but illustrate diverging opinions on how to estimate biomass production.

Discussion

This paper contends that bioenergy potentials are shaped by dynamic factors. The novel concept of dynamic factors (external and internal) for bioenergy potentials builds on the established concept of critical factors (drivers and barriers) for bioenergy systems (see Roos et al., 1999 for a discussion of factors). Interacting with the dynamic factors are conflicting interests and catalysing synergies, which appear relevant and important in the context of realising bioenergy potentials (Parikka, 2004; Hoogwijk et al., 2005; Fallot & Girard, 2005; Smeets et al., 2004; Moreira, 2005; IEA, 2005).

Dynamic Factors

This paper concentrates on the major dynamic factors influencing the development and diffusion of energy crops (see table 2). Dynamic factors for energy crops are predominantly external factors to bioenergy systems, including food demands and agricultural policy and management. Additionally, there are internal factors within bioenergy systems, including productivity improvements and sustainable management of soils, water, and ecosystems. Put simply, the external factors define the availability of land for energy crops, and the internal factors define the magnitude of yields. However, the type and location of land where energy crops are harvested is important to yields. Energy crops are influenced by environmental conditions (soil quality and water balance) and climatic conditions (temperature and precipitation). The dynamic factors for energy crops therefore illustrate the complex interactions between agricultural and energy systems.

Table 2: Identification of Dynamic Factors Affecting Bioenergy Potentials

Factors for Biomass		Affects on Biomass
External	Agricultural policy and management	The management of agricultural systems (animal products and food crops) is significantly influenced by policy. The availability of land for energy crops and how energy crops are able to integrate into agricultural systems is intimately connected with policy formulation and implementation.
	Food demands	Food demands are shaped by population growth and consumption patterns (levels and types). Growing numbers of people and changing diets of people affect land use patterns and therefore the availability of land for energy crops.
Internal	Productivity improvements	Learning processes are expected to result in productivity improvements for energy crops and bioenergy systems. Experience with many renewable energy technologies and systems suggest considerable productivity improvements are achievable.
	Sustainable management of soils, water and ecosystems	The development and diffusion of energy crops demands the sustainable management of soils, water, and ecosystems to ensure bioenergy systems are both renewable and sustainable. Learning processes are expected to enhance sustainable management.

Conflicting Interests

There is at least 2 debates related to agricultural and energy systems that are expected to influence bioenergy potentials, including: 1) food vs fuels, and 2) centralised vs distributed. Both are simplifications of complex issues, however (perceived or real) conflicting interests are capable of significantly altering the prospects of bioenergy.

Food vs Fuels

The expansion of energy crops is affected by debates over land use conflicts between food and fuels. On the surface land use conflicts appear a major problem. However, there is no lack of food to meet the needs of people around the world rather it is the distribution of food. There are calls to shift from industrial agricultural systems to local agricultural systems that meet the needs of local people and integrate with the local environment.³ Permaculture, as opposed to monoculture, promotes agricultural systems that involve food, shelter, energy, water, wildlife and ecosystems. Furthermore, permaculture shifts attention to low intensity farming systems rather than the high intensity farming systems associated with monoculture. The challenge for research and development on bioenergy is to explore how to utilise degraded land and surplus agricultural land for energy crops, and how to integrate energy crops into agricultural systems to produce food, feed, fibre and fuels.

Centralised vs Distributed

Fossil fuels and nuclear power are large-scale and centralised systems. The emergence of renewable energy has shifted attention to the advantages and disadvantages of small-scale and distributed systems. Bioenergy systems often support Distributed Energy (DE).⁴ Put simply, DE promotes the generation of energy at or near the end users utilising small-scale technologies rather than relying entirely on large-scale plants that require transmission and

³ Visit <http://www.farmingsolutions.org/> for more information on farming systems.

⁴ Visit <http://www.deforum.org/> for more information on DE.

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distribution systems. In some respects there is a 'clash of paradigms' about how to organise energy systems. Bioenergy is suited to providing DE. So exploiting bioenergy potentials is linked to the development and diffusion of DE technologies. However, the types of biomass resources, which are utilised, and the needs of end users also define the scale and design of bioenergy systems.

Catalysing Synergies

There is at least 3 prospects that are capable of stimulating bioenergy potentials, including: 1) bio-refineries, 2) multi-functional agriculture, and 3) carbon capture and storage. All of which involve integrating systems and technologies to provide multiple products and services.

Bio-refineries

Bio-refineries are facilities that utilise biomass resources and integrate conversion technologies to co-produce fuels for transport, power, heat, and chemicals. Bio-refineries are comparable to petroleum refineries, which co-produce fuels and many different products from petroleum. Partial bio-refineries exist in some agricultural and forestry sectors. However, the development and diffusion of full bio-refineries can utilise the natural complexity and diversity of biomass resources and optimise the value derived through coupling conversion technologies. For example, bio-refineries can co-produce low volume, but high value, chemicals and low value, but high volume, fuels for transport, as well as generating power and heat.

Multi-functional Agriculture

Multi-functional agriculture promotes the diversification of activities on agricultural land. For example, energy crops are able to act as visual or wind barriers on the landscape, prevent erosion and degradation, and create habitats for birds and mammals thereby supporting biodiversity on agricultural land. Furthermore, cadmium in fertilisers has resulted in undesired levels of cadmium in agricultural land. Some types of energy crops have the capacity to absorb cadmium, so planting energy crops and storing the ash after combustion contributes to diminishing levels of cadmium in agricultural land. Exploiting biomass for energy purposes is an opportunity to utilise agricultural land (as well as degraded land and surplus agricultural land) for the production of food, feed, fibre and fuels.

Carbon Capture and Storage

Expanding bioenergy diminishes carbon dioxide emissions if replacing fossil fuels, establishing energy crops or integrating with carbon capture and storage. Bioenergy acts as a carbon offset by substituting fossil fuels and acts as a carbon sink by sequestering carbon dioxide through the planting and harvesting of energy crops. When land is utilised for energy crops carbon dioxide is sequestered in both the plants and soils. Interestingly, the investments by the coal industry in carbon capture and storage is expected to support the bioenergy industry. If bioenergy systems can be coupled with carbon capture and storage technology, then carbon dioxide can be removed from the atmosphere. The commercialisation of carbon capture and storage technology is therefore expected to stimulate the development and diffusion of bioenergy systems.

Conclusion

It is important to recognise that calculating bioenergy potentials is different from realising bioenergy potentials. Dynamic factors, conflicting interests, and catalysing synergies illustrate the complex interactions between agricultural and energy systems when assessing bioenergy potentials. The 'bioenergy challenge' is therefore not about estimating bioenergy potentials. Rather it is about the development and diffusion of bioenergy systems utilising the available conversion technologies and the abundant biomass resources. Ultimately, expanding bioenergy and meeting the 'bioenergy challenge' requires supportive policies and measures at the international, national and local levels that respond to conflicting interests and exploit catalysing synergies.

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