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The Joint BioEnergy Institute (JBEI): Developing New Biofuels by Overcoming Biomass Recalcitrance

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Abstract The mission of the Joint BioEnergy Institute is to advance the development of the next-generation of biofuels—liquid fuels derived from the solar energy stored in plant biomass. The papers in this volume describe some of the research conducted in the area of feedstocks development and biomass deconstruction.

Keywords Biofuels · Cellulases · Synthetic biology · Pretreatment

Introduction

Fossil fuels provide 85% of the US energy requirements, a figure that is similar in most countries. Energy demands are increasing with population growth and economic development. This situation is not sustainable for several reasons; oil reserves are limited, and the increasing use of oil and coal leads to ever increasing CO_2 emissions, which carry the risk of climate change. For these reasons, we must explore the potential for developing sustainable and renewable energy sources. For the USA, as for many other countries that are net importers of fossil fuels, the desire to develop more sustainable energy sources is furthermore driven by the prospect of increased energy security and independence. It is estimated that each year the surface of the earth receives about 10^{17}W h of solar energy. Current worldwide human energy consumption is estimated to be 13×10^{12}W h per year. Clearly, there is sufficient energy available in an hour of global sunlight to meet human energy needs for a year. A substantial portion of this solar energy is stored in the form of biomass. Converting solar energy to advanced biofuels could meet most, if not all, US transportation energy needs without producing carbon emissions that contribute to global climate change. Renewable energy produced from other sources, or by direct combustion of biomass, lead to generation of electricity, which can be used for many different purposes. However, for transportation, it is essential to have a supply of liquid fuels that meets the requirements of combustion engines used in cars, trucks, airplanes, and ships. In a longer perspective, it may be possible to develop electric cars for much of the short distance transport needs. However, no alternative to liquid fuels is realistic for truck, ship, and airplane transport (Fig. 1).

The use of lignocellulosic biomass for fuels is limited by several factors. Firstly, biomass is recalcitrant to degradation resulting in large costs and energy consumption in the processes needed to convert biomass into simple molecules that can be used for fuel production. Secondly, fuel production from sugars by current technologies is mostly limited to ethanol, which does not address all the requirements of the

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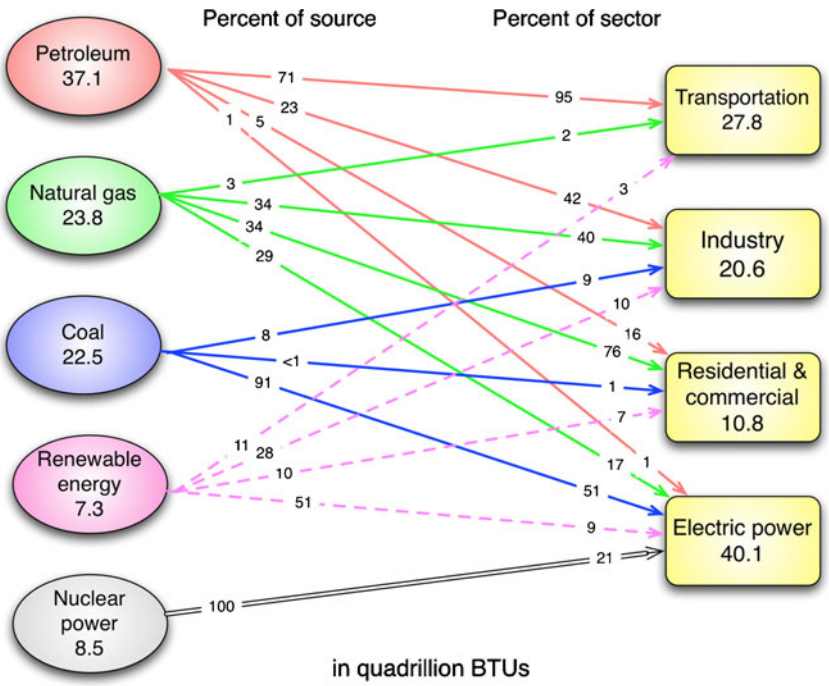

Fig. 1 Overview of US primary energy consumption by source and sector, 2008 [2]

transportation sector. The Joint BioEnergy Institute (JBEI) has been supported by the US Department of Energy for a 5-year period to conduct research to address these challenges [1]. JBEI is located in Emeryville near the University of California, Berkeley campus and Lawrence Berkeley National Laboratory. In JBEI, a total of about 160 researchers and staff that are employed by Lawrence Berkeley National Laboratory, University of California Berkeley, University of California Davis, Lawrence Livermore National Laboratory, and Sandia National Laboratories work alongside each other. JBEI has a structure with four Divisions: Feedstocks, Deconstruction, Fuel Synthesis, and Technology.

Feedstocks Division

The Feedstocks Division is focused on understanding how plants synthesize cell walls. Furthermore, the Feedstocks team is engineering wall composition so that the walls can be more easily broken down to component sugars, and so that these sugars have an optimal composition for fuel synthesis. The Feedstocks team uses the model plants *Arabidopsis* and rice for most of the research and has established switchgrass transformation so that the most promising traits can be tested in a potential biofuel crop.

Deconstruction Division

The Deconstruction Division is focused on developing and optimizing pretreatment methods, and on discovering and improving hydrolytic enzymes for efficient hydrolysis of biomass. The Deconstruction Division has focused much of its efforts on ionic liquid solvents for biomass dissolution. These have excellent pretreatment properties but costs are currently high, and therefore the development of efficient procedures for recovery is an important goal. Several other pretreatment methods are available, and the three bioenergy research centers, JBEI, Great Lakes Bioenergy Research Center, and BioEnergy Sciences Center, have coordinated the research in pretreatment and focus on different methods to avoid futile overlap.

Fuel Synthesis Division

The Fuel Synthesis Division is focusing on developing novel fuels, e.g., long-chain alcohols, esters, and alkanes that may be used as diesel fuels and cyclic hydrocarbons that can be used as jet fuels. The enzymes needed to produce these compounds can be found in natural organisms, but it is a major challenge in synthetic biology to optimize the pathways in a single organism.

Technology Division

We have recognized that many of the needs for advanced techniques and high-throughput platforms are common to the three scientific divisions, and therefore JBEI has a fourth Technology Division, which not only makes these techniques available to all scientists in the center but also

carry out research to develop novel techniques that will benefit bioenergy research both within and outside JBEI.

Dynamic Organization of JBEI at a Single Location

While the research at JBEI is organized in the four Divisions, we emphasize the intricate relationship and dependency of the research. For example, all three scientific divisions have research aimed at limiting inhibition of fermentation by compounds present in the biomass or produced during deconstruction. Hence, the improvements obtained by any of the divisions with respect to inhibitors will immediately affect the goals of the other divisions. To ensure a close coordination of the research, JBEI is designed to be a dynamic organization with researchers located at a single location.

Commercial Perspectives of JBEI Research

JBEI understands that scientific advances must be translated into commercially viable technologies, methods, and tools. Partnering with industry helps us achieve this goal. Companies accelerate innovation through sponsored research and illuminate commercial challenges that might not be apparent from the lab bench. Private industry is also the vehicle to develop JBEI inventions into commercial products and bring them to market. Currently, JBEI has research sponsored by Boeing, General Motors, Statoil, and BP America. As of end of January 2010, JBEI has filed 19 patent applications, two of which have been published [3, 4].

In this special issue, some of the research carried out at JBEI is described. The main focus of the papers in this issue is on feedstocks and deconstruction. However, all divisions have been involved in the work described, and almost all the papers have contributors from more than one division. This clearly illustrates the multidisciplinary mode of operation at JBEI.

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