State and Local Climate and Energy Program

State BIOENERGY PRIMER

Information and Resources for States on Issues, Opportunities, and Options for Advancing Bioenergy

U.S. ENVIRONMENTAL PROTECTION AGENCY
AND
NATIONAL RENEWABLE ENERGY LABORATORY
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KEY ACRONYMS AND ABBREVIATIONS

ACORE	American Council on Renewable Energy
B100	100 percent biodiesel
B20	A blend of 20 percent biodiesel and 80 percent petroleum diesel
B90	A blend of 90 percent biodiesel and 10 percent petroleum diesel
BCAP	Biomass Crop Assistance Program
BCEX	Biomass Commodity Exchange
BERS	Bio-Energy Recovery Systems
BPA	Bisphenol A
Btu	British thermal units
CHP	Combined heat and power
CMAQ	Congestion Mitigation and Air Quality Improvement program
CNG	Compressed natural gas
CO	Carbon monoxide
CROP	Coordinated Resource Offering Protocol
DG	Distributed generation
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPA	Diphenoloic acid
DSIRE	Database of State Incentives for Renewable Energy
E10	A blend of 10 percent ethanol and 90 percent petroleum
E85	A blend of 85 percent ethanol and 15 percent petroleum
EERE	DOE's Office of Energy Efficiency and Renewable Energy
EGRID	EPA's Emissions & Generation Resource Integrated Database
EIA	DOE's Energy Information Administration
EISA	Energy Independence and Security Act
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ETBE	Ethyl tert-butyl ether
FFVs	Flexible fuel vehicles
FIDO	USFS Forest Inventory Data Online
FPW	Food processing waste
GHG	Greenhouse gas
GIS	Geographic Information System
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GW	Gigawatts
IEA	International Energy Agency
IGCC	Integrated gasification combined cycle

JEDI	Job and Economic Development Impact model
kWh	Kilowatt-hours
LCA	Life-cycle assessment
LCFS	Low carbon fuel standard
LFG	Landfill gas
LMOP	EPA's Landfill Methane Outreach Program
LRAMs	Lost revenue adjustment mechanisms
MACT	Maximum available control technologies
MSW	Municipal solid waste
MTHF	Methyl tetrahydrofuran
MW	Megawatts
MWh	Megawatt-hours
NAAQS	National Ambient Air Quality Standards
NACAA	National Association of Clean Air Agencies
NESHAP	National Emission Standards for Hazardous Air Pollutants
NREL	DOE's National Renewable Energy Laboratory
NSPS	New Source Performance Standards
ORNL	DOE's Oak Ridge National Laboratory
PBF	Public benefits fund
PEDA	Pennsylvania Energy Development Authority
PHMSA	DOT's Pipeline and Hazardous Materials Safety Administration
PLA	Polylactide
PM	Particulate matter
RDF	Refuse-derived fuel
REC	Renewable energy credit
RFA	Renewable Fuels Association
RFS	Renewable fuels standard
RPS	Renewable portfolio standard
SABRE	State Assessment for Biomass Resources
SIP	State Implementation Plan
SSEB	Southern States Energy Board
Syngas	Synthesis gas
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
VOCs	Volatile organic compounds
WARM	EPA's WAste Reduction Model
WGA	Western Governors' Association
WREZ	Western Renewable Energy Zones Project
WWTP	Wastewater treatment plant

Executive Summary

Across the country, states are looking for ways to tackle their energy, environmental, and climate change challenges through a variety of approaches. One frequently discussed option is the use of biomass resources to develop bioenergy—bioheat, biopower, biofuels, and bioproducts.

Many information resources are available that discuss biomass/bioenergy in a highly technical manner and/or that focus only on one feedstock (e.g., forest residues, agricultural crops) or product (e.g., biofuels). Alternately, some entities present bioenergy information that is relevant to the general public but is too simplified for decision makers.

This State Bioenergy Primer is designed to bring many of these resources together and provide useful, targeted information that will enable a state decision maker to determine if he/she wants or needs more details.

The primer offers succinct descriptions of biomass feedstocks (Chapter 2), conversion technologies (Chapter 2), and the benefits/challenges of promoting bioenergy (Chapter 3). It includes a step-wise framework, resources, and tools for determining the availability of feedstocks (Chapter 4), assessing potential markets for biomass (Chapter 4), and identifying opportunities for action at the state level (Chapter 4). The primer also describes financial, policy, regulatory, technology, and informational strategies for encouraging investment in bioenergy projects and advancing bioenergy goals (Chapter 5). Each chapter contains a list of selected resources and tools that states can use to explore topics in further detail.

BIOENERGY CONSIDERATIONS

Biomass energy, or bioenergy—fuel or power derived from organic matter—can be used to produce transportation fuel, heat, electric power, or other products. Bioenergy currently represents approximately 3 to 4 percent of the United States' total energy production (EIA, 2008).

The benefits of increased use of bioenergy depend upon the intended use and source, but can include: improved energy security and stability through reduced dependence on foreign sources of energy; increased economic development and job growth through creation of new domestic industries and expansion of existing industries; and expanded environmental benefits, including reduction of greenhouse gas (GHG) emissions.

Along with the opportunities, however, are potential challenges—among them the need for reliable feedstock supplies, the problems of infrastructure constraints for delivering of feedstocks and distribution of products, the potential for ancillary environmental and land use impacts resulting from increasing biomass supplies to produce bioenergy, and the potential for tradeoffs in air emissions resulting from direct combustion of biomass.

Each state's individual geography, economic base, market conditions, climate, and state-specific incentives and regulations will impact the feedstocks and bioenergy outputs that make economic and environmental sense for that state to pursue.

A decision maker starts identifying potentially fruitful bioenergy opportunities by examining all potential feedstocks—both agricultural/energy crops (e.g., corn, soybeans, switchgrass) and waste/opportunity fuels (e.g., wastewater treatment biogas, wood waste, crop residues, manure, landfill gas, solid waste)—and their specific location and costs within the state. The evaluation of biomass resources is followed by an assessment of the potential markets and competition for those feedstocks and what steps would be required to capitalize on the bioenergy potential.

If a decision maker determines that the benefits of bioenergy outweigh the challenges for their state, numerous options are available for advancing bioenergy goals. Favorable policy development, favorable regulatory development, capitalization of environmental revenue streams, direct investment/financing or incentives, and research and development are all options for effectively promoting bioenergy in a state.

Each of the chapters in this Bioenergy Primer describes how states consider these and other issues as they decide whether or not to develop a bioenergy promotion strategy, and is augmented by case studies about how states have successfully implemented a variety of approaches.

CHAPTER ONE

Introduction

Biomass energy, or bioenergy—fuel or power derived from organic matter—is one of the keys to a sustainable energy future in the United States and throughout the world. Bioenergy has the potential to:

- Improve energy security and stability by reducing dependence on fossil sources of energy.
- Increase economic development and job growth through creation of new domestic industries.
- Produce environmental benefits, including reduction of greenhouse gas (GHG) emissions.

Along with the potential opportunities, however, are challenges—among them the need for reliable feedstock supplies, the problem of infrastructure constraints, and the potential for environmental and land use impacts resulting from increasing biomass supplies to produce bioenergy.

In 2006, and for the sixth year in a row, biomass was the leading source of renewable energy in the United States, providing more than 3 quadrillion British thermal units (Btu) of energy. Biomass was the source for 49 percent of all renewable energy, or nearly 3.5 percent of the total energy produced in the United States (EIA, 2008).

DOCUMENT MAP

CHAPTER ONE CONTENTS

DOES THE MARKET FOR BIOENERGY LOOK PROMISING IN MY STATE?

The questions below can help state officials evaluate the potential for a bioenergy market in their state.

1. Does the state have sufficient biomass resources to support bioenergy development?

2. Are energy (electricity, propane, fuel oil, natural gas, or liquid fuel) costs in the state relatively high?

3. Is the cost of energy (e.g., electricity, gasoline, natural gas, oil) projected to increase?

4. Are electricity demand, renewable electricity demand, and/or biofuels demand projected to increase?

5. Are policy makers in the state inclined to hedg e against potential future volatility?

6. Does the state have an electrical or thermal renewable portfolio standard that requires use of renewable energy?

7. Does the state have a renewable fuel standard that requires use of biofuels?

8. Are financial incentives for production of bioenergy (e.g., production incentives, tax incentives, low-interest loans, rebates, environmental revenue streams) offered in the state?

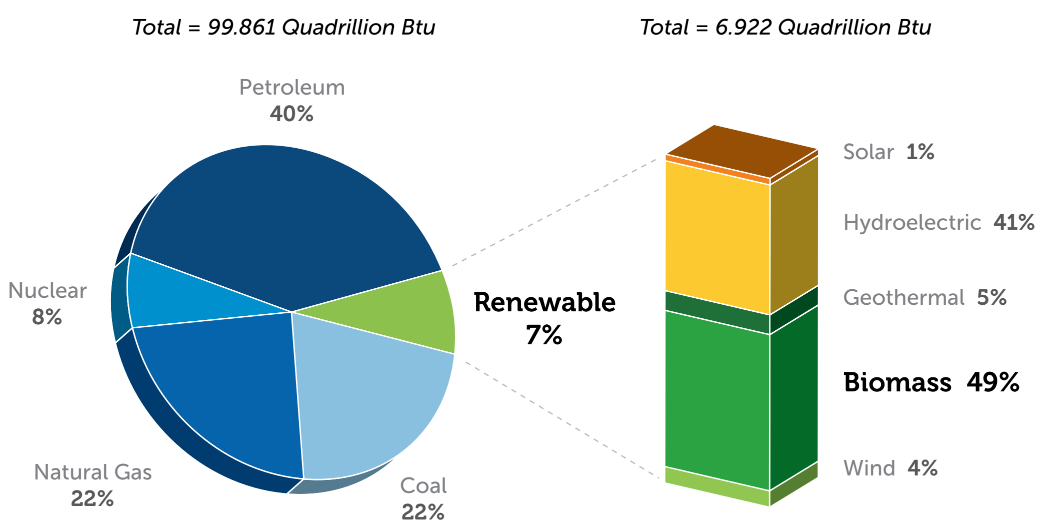
9. Does the state have standardized, simplified utility interconnection requirements for smaller bioenergy producers?

If a state has answered yes to two or more of the questions above, the market for bioenergy could be promising. Chapters 3 and 5 of this primer may be of most interest.

If a state does not yet have the answers to these questions, the resources in this primer should be helpful for determining what approaches can be taken to answer them.

FIGURE 1-1. THE ROLE OF RENEWABLE ENERGY CONSUMPTION IN THE NATION'S ENERGY SUPPLY, 2006

Source: EIA, 2008



The U.S. Department of Energy (DOE) estimates that the land resources of the United States could produce enough biomass to replace 30 percent of the current U.S. demand for petroleum on a sustainable basis by the mid-21st century (U.S. DOE, 2005).

Ultimately, the outlook for bioenergy depends heavily on policy choices made at the state and federal levels. The federal government and many states are exploring the role of biomass as a means to achieve economic, energy, and environmental goals.

EPA has produced this State Bioenergy Primer with the following objectives:

- To provide a basic overview of bioenergy, including what it is, its potential benefits, and its potential challenges.
- To describe the steps that state decision makers can take to assess whether and how to promote bioenergy.
- To identify opportunities for state actions to support bioenergy.
- To present resources for additional information.
- To provide examples and lessons learned from state experiences with bioenergy.

1.1 HOW THE PRIMER IS ORGANIZED

In addition to providing basic information and overviews of relevant issues, each chapter includes an extensive list of resources for additional, detailed information. These resources are also complied into a stand-alone resource kit found in Appendix A.

1.2 REFERENCES

- **EIA (Energy Information Administration)**, 2008. ***Renewable Energy Annual 2006***., Washington, DC, 2008.
- **U.S. DOE (Department of Energy)**, 2005. ***Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply***. DOE/DO-102995-2135. Washington, DC, April 2005. *http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf*.

HOW THE STATE BIOENERGY PRIMER IS ORGANIZED

CHAPTER TWO: What Is Bioenergy?
Describes biomass feedstocks and conversion technologies for producing bioenergy

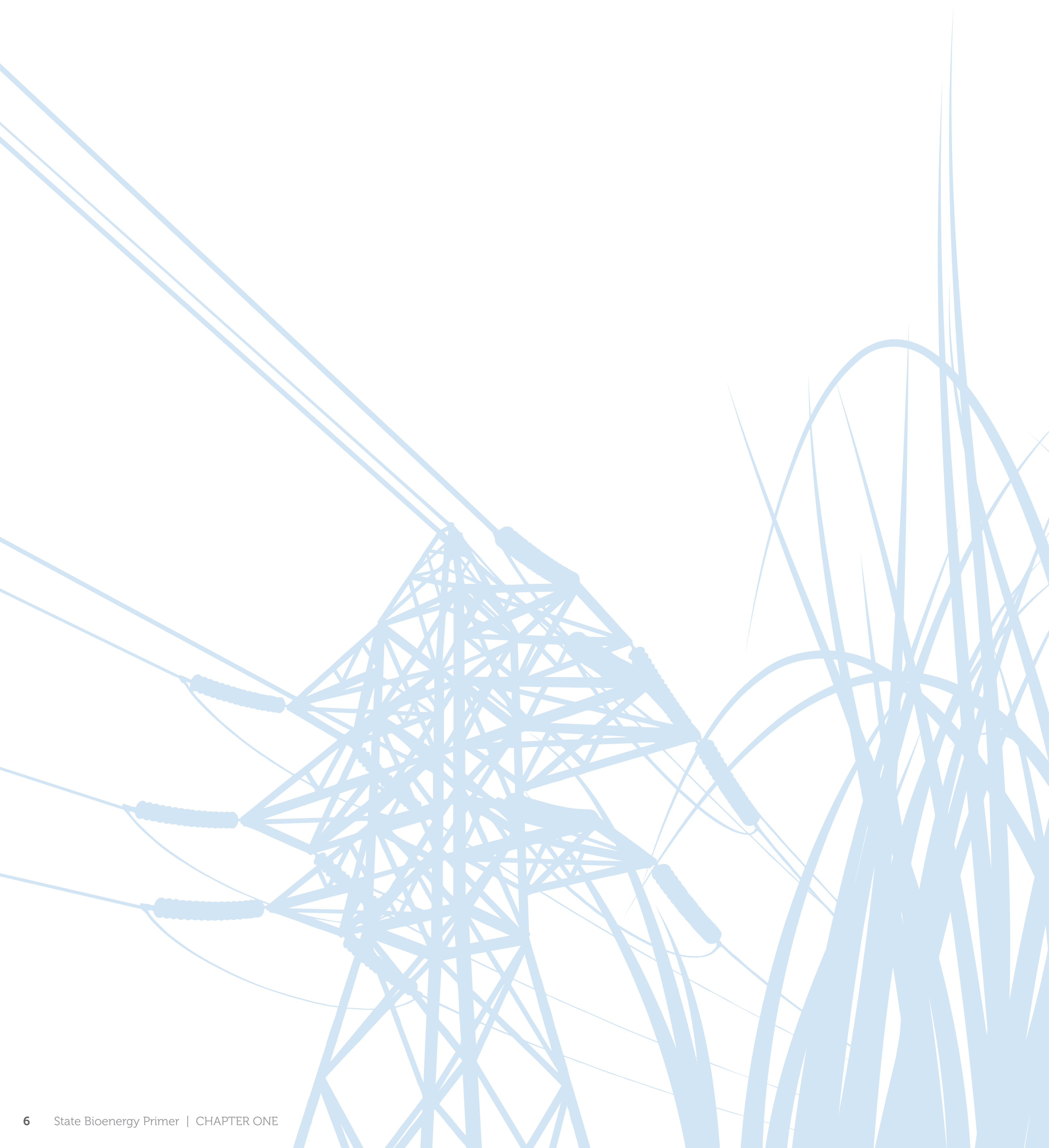
CHAPTER THREE: Benefits and Challenges
Discusses energy security, economic benefits and challenges, and environmental issues

CHAPTER FOUR: Identifying Bioenergy Opportunities
Presents steps for identifying biomass resource availability, assessing market potential, and evaluating existing policies and opportunities for action

CHAPTER FIVE: Options for Advancing Bioenergy
Describes how states can facilitate projects through policies and regulations, incentives, direct investment, research and development, and information sharing

APPENDIX A: Tools and Resources for States
Lists all resources referenced throughout the document

APPENDIX B: Glossary of Bioenergy Terms
Provides an at-a-glance guide to key terms



CHAPTER TWO

What Is Bioenergy?

Bioenergy refers to renewable energy produced from biomass, which is organic material such as trees, plants (including crops), and waste materials (e.g., wood waste from mills, municipal wastes, manure, landfill gas (LFG), and methane from wastewater treatment facilities).

- **Biopower** refers to the use of biomass to produce electricity. Biomass can be used alone or cofired with another fuel, typically coal, within the same combustion chamber.
- **Bioheat** refers to the use of biomass to produce heat.
- **Biomass combined heat and power (CHP)** refers to the cogeneration of electric energy for power and thermal energy for industrial, commercial, or domestic heating or cooling purposes through the use of biomass.
- **Biofuels** are fuels (often for transportation) made from biomass or its derivatives after processing. Examples of commercially available biofuels include ethanol, biodiesel, and renewable diesel.
- **Bioproducts** are commercial or industrial products (other than food or feed) that are composed in whole or in significant part of biomass. Examples of bioproducts include soy ink, cellophane, food utensils, and paints made from biomass-based materials.

DOCUMENT MAP

CHAPTER TWO CONTENTS

Bioenergy is becoming an increasingly attractive energy choice because of high or volatile fossil fuel prices, concerns about national energy independence, the impacts of conventional energy use on the environment, and global climate change. More production and use of bioenergy can improve environmental quality (provided best available technologies and pollution controls are used); provide opportunities for economic growth, often in rural areas; support state energy and environmental goals; and increase domestic energy supplies, which will enhance U.S. energy independence and security.

The basic process for using the energy in biomass to produce biopower, bioheat, biofuels, or bioproducts is shown in Figure 2-1.

2.1 WHAT ARE BIOMASS FEEDSTOCKS?

A feedstock is a material used as the basis for manufacture of another product. Biomass feedstocks are sources of organic matter that are used as key inputs in production processes to create bioenergy. Both agricultural/energy crops and waste/opportunity fuels can be used as biomass feedstocks.

AGRICULTURAL/ENERGY CROPS

Several traditional crops that are grown for food and other uses can also be used to produce bioenergy, primarily as biofuels. Crops currently used as biomass feedstocks include:

- **Corn**. Corn is the primary biomass feedstock currently used in the United States to produce ethanol (and co-products, as described in Section 2.2.2).
- **Rapeseed**. Rapeseed is the primary feedstock used in Europe to produce biodiesel (EERE, 2008).
- **Sorghum**. Sorghum is used in the United States as an alternative to corn for ethanol production. As of 2008, 15 percent of U.S. grain sorghum is being used for ethanol production at eight plants (Biomass Research and Development Initiative, 2008).
- **Soybeans**. Soybeans are the primary biomass feedstock currently used in the United States to produce biodiesel from soybean oil.
- **Sugarcane**. Brazil uses sugarcane to produce ethanol and uses the sugarcane residue for process heat.

Other crops that are planted and harvested specifically for use as biomass feedstocks in the production of bioenergy are referred to as "energy crops." Energy crops are fast-growing and grown for the specific purpose of producing energy (electricity or liquid fuels) from all or part of the resulting plant. The advantages of using crops specifically grown for energy production include consistency in moisture content, heat content, and processing characteristics, which makes them more cost-effective to process efficiently (U.S. EPA, 2007a). Emerging energy crops include:

- **Microalgae**. The oil in microalgae can be converted into jet fuel or diesel fuel (National Renewable Energy Laboratory (NREL), 2006). Microalgae with high lipid content are best suited to production of liquid fuel.

FIGURE 2-1. STAGES OF BIOENERGY PRODUCTION

Source: Biomass Research and Development Board, 2008

Microalgae are highly productive, do not use agricultural land or products, and are carbon-neutral (Mayfield, 2008). More than 50 companies are researching microalgal oil production, including development of new bioreactors and use of biotechnologies to influence microalgal growth (NREL, 2008).

- **Switchgrass; poplar and willow trees**. These energy crops are not yet being grown commercially in the United States for bioenergy, but may have the greatest potential for dedicated bioenergy use over a wide geographic range. The U.S. Department of Energy (U.S. DOE) estimates that about 190 million acres of land in the United States could be used to produce energy crops such as switchgrass and poplar and willow trees (U.S. EPA, 2007a; Antares, 2003). Several states in the Midwest and South could produce significant biopower using switchgrass, which is currently grown on some Conservation Reserve Program[1] acres and on hay acres as a forage crop (U.S. EPA, 2007a; Ugarte et al., 2006).

WASTE/OPPORTUNITY FUELS

Biomass feedstocks from waste materials are often referred to as "opportunity" fuels because they would otherwise go unused or be disposed of; bioenergy production is an opportunity to use these materials productively. Common opportunity fuels include:

- **Biogas**. Biogas, consisting primarily of methane, is released during anaerobic decomposition of organic matter. Facilities that deal with large quantities of organic waste can employ anaerobic digesters and/or gas collection systems to capture biogas, which can be used as a source of on-site bioheat and/or biopower. Major sources of biogas include:

  - ***Wastewater treatment plants (WWTPs)***. Anaerobic digesters can be used during treatment of wastewater to break down effluent and release biogas, which can then be collected for subsequent use as a source of bioenergy. According to an analysis by the U.S. EPA Combined Heat and Power Partnership, as of 2004, 544 municipal WWTPs in the United States use anaerobic digesters. Only 106 of these facilities utilize the biogas produced by their anaerobic digesters to generate electricity and/or thermal energy. If all 544 facilities were to install CHP systems, approximately 340 megawatts (MW) of biogas-fueled electricity could be generated (U.S. EPA, 2007a).

  - ***Animal feeding operations***. EPA's AgSTAR Program has identified dairy operations with more than 500 head and swine operations with more than 2,000 head as the most viable candidates for anaerobic digestion of manure and subsequent methane capture (U.S. EPA, 2007a). As of April 2009, 125 operators in the United States collect and use their biogas. In 113 of these systems, the captured biogas is used to generate electrical power, with many of the farms recovering waste heat from electricity-generating equipment for on-farm use. These systems generate about 244,000 MWh of electricity per year. The remaining 12 systems use the gas in boilers, upgrade the gas for injection into the natural gas pipeline, or simply flare the captured gas for odor control (U.S. EPA, 2009b).

    For more information on how anaerobic digestion is used to produce biogas for bioenergy, refer to Section 2.2.1 — Conversion Technologies for Biopower and Bioheat.

  - ***Landfills***. As the organic waste buried in landfills decomposes, a gas mixture of carbon dioxide (CO_2) and methane (CH_4) is produced. Gas recovery systems can be used to collect landfill emissions, providing usable biogas for electricity generation, CHP, direct use to offset fossil fuels, upgrade to pipeline quality gas, or use in the production of liquid fuels. As of December 2008, EPA's Landfill Methane Outreach Program estimated that, in addition to the approximately 445 landfills already collecting LFG to produce energy, 535 landfills are good candidates for landfill gas-to-energy projects (U.S. EPA, 2008a).

- **Biosolids**. Biosolids are sewage sludge from wastewater treatment plants. Biosolids can be dried, burned, and used in existing boilers as fuel in place of coal, or co-fired with coal to generate steam and power. Biosolids can also be converted into biogas for bioenergy (see Biogas section above). The high water content of most biosolids can present challenges for combustion. As a result, biosolids must generally go through a drying process prior to being used for energy production.

- **Crop residues**. More than 300 million acres are used for agricultural production in the United States. As of 2004, the most frequently planted crops (in terms of average total acres planted) were corn, wheat, soybeans, hay, cotton, sorghum, barley, oats, and rice. Following

1 The Conservation Reserve Program, administered by USDA, provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. For more information see www.nrcs.usda.gov/programs/CRP/.

the harvest of many traditional agricultural crops, residues such as crop stalks, leaves, cobs, and straw are left in the field. Some of these residues could be collected and used as bioenergy feedstocks (U.S. EPA, 2007a).

- **Food processing wastes**. Food processing wastes include nut shells, rice hulls, fruit pits, cotton gin trash, meat processing residues, and cheese whey, among others. Because these residues can be difficult to use as a fuel source due to the varying characteristics of different waste streams, the latter two of these food processing wastes are often disposed of as industrial wastewater. Work is under way in the food processing industry to evaluate the bioenergy potential of these residues, including collection and processing methods to allow more effective use as biomass feedstocks. Utilities and universities have used food wastes such as peanut hulls and rice hulls for biopower. Many anaerobic digester operators are currently adding agricultural and food wastes to their digesters to provide enhanced waste management and increased biogas generation (U.S. EPA, 2007a).

- **Forest residues**. Residues from silviculture (wood harvesting) include logging residues such as limbs and tops, excess small pole trees, and dead or dying trees. After trees have been harvested from a forest for timber, forest residues are typically either left in the forest or disposed of via open burning through forest management programs because only timber of a certain quality can be used in lumber mills and other processing facilities. An advantage of using forest residues from silviculture for bioenergy production is that a collection infrastructure is already in place to harvest the wood. Approximately 2.3 tons of forest residues are available for every 1,000 cubic feet of harvested timber (although this number can vary widely); these residues are available primarily in the West (U.S. EPA, 2007a).

- **Forest thinnings**. Forest thinnings can include underbrush, saplings, and dead or dying trees removed from dense forest. Harvesting, collecting, processing, and transporting loose forest thinnings is costly. The use of forest thinnings for power generation or other facilities is concentrated in the western United States; in other areas not already used for silviculture, there is no infrastructure to extract forest thinnings. Typically, the wood from forest thinnings is disposed of through controlled burning due to the expense of transporting it to a power generation facility (U.S. EPA, 2007a).

CELLULOSIC FEEDSTOCKS

Cellulosic feedstocks include opportunity fuels (e.g., wood waste, crop residues) and energy crops (e.g., switchgrass, poplar, and willow trees). In using cellulosic feedstocks, the fiber, or cellulose, is broken down into sugars or other intermediate products that can be converted to bioenergy. Using cellulosic feedstocks such as wood waste and municipal solid waste for ethanol or other biofuel production or bioproducts development could reduce the waste stream in the United States. Ethanol production from cellulosic feedstocks has not yet occurred on a commercial scale but is actively under development (see Section 2.2.2 — Conversion Technologies for Biofuels). For discussions of the benefits and challenges of ethanol production, see Chapter 3, Benefits, Challenges, and Considerations of Bioenergy.

- **Municipal solid waste**. Municipal solid waste (MSW)—trash or garbage—can be collected at landfills, dried, and burned in high-temperature boilers to generate steam and electricity. Mass burn incineration is the typical method used to recover energy from MSW, which is introduced "as is" into the combustion chamber; pollution controls are used to limit emissions into the air. Some waste-to-energy facilities have been in operation in the United States for more than 20 years. More than one-fifth of incinerators use refuse-derived fuel (RDF), which is MSW that has been thoroughly sorted so that only energy-producing components remain (U.S. EPA, 2008b). RDF can be burned in boilers or gasified (U.S. DOE, 2004). (See the related section above on biogas, which describes collection of biogas from landfills for use as bioenergy.) The waste-to-energy industry currently generates 17 billion kilowatt-hours (kWh) of electricity per year. However, based on the total amount of MSW disposed of in the United States annually (250 to 350 million tons), MSW could be used as fuel to generate as much as 70 to 130 billion kWh per year (U.S. EPA, 2008e).

- **Restaurant wastes**. Used vegetable oils, animal fats, and grease from restaurants can be used as biomass feedstocks to produce biodiesel. Small-scale efforts have been successfully implemented in a number of cities, counties, and universities across the country. For example, San Francisco initiated a program to use restaurant wastes to fuel the city's fleet of more than 1,600 diesel vehicles, which were retrofitted to accept the biodiesel (City and County of San Francisco, 2007). The use of restaurant wastes may be less expensive than using new vegetable oil as the feedstock to produce biodiesel if collection costs can be minimized—collection of small volumes from numerous locations can increase costs (Commonwealth of Massachusetts, 2008).

- **Wood waste**. Wood waste includes mill residues from primary timber processing at sawmills, paper manufacturing, and secondary wood products industries such as furniture makers. It also includes construction wood waste, yard waste, urban tree residue, and discarded consumer wood products that would otherwise be sent to landfills (U.S. EPA, 2007a). Wood wastes such as woodchips, shavings, and sawdust can be compressed into pellets, which offer a more compact and uniform source of energy (Biomass Energy Resource Center, 2007).
  - ***Mill residues***. Mill residues include bark, chips, sander dust, edgings, sawdust, slabs, and black liquor (a mixture of solvents and wood byproducts, usually associated with the pulp and paper industry manufacturing process). They come from manufacturing operations such as sawmills and pulp and paper companies that produce lumber, pulp, veneers, and other composite wood fiber materials. Almost 98 percent of mill residues generated in the United States are currently used as fuel or to produce wood pellets or fire logs, or fiber products, such as hardboard, medium-density fiberboard, particle board, and other wood composites (U.S. EPA, 2007a). The U.S. Department of Agriculture (USDA) estimates that 2 to 3 percent of mill residues are available as an additional fuel resource because they are not being used for other purposes. The largest concentrations of mill residues are in the West and Southeast (U.S. EPA, 2007a).
  - ***Construction (and demolition) wood waste***. Wood waste comprises about 26 percent of the total construction and demolition waste stream; about 30 percent of that debris is uncontaminated by chemical treatment and available for recovery (U.S. EPA, 2007a).
  - ***Discarded consumer wood products***. These products include discarded wood furniture, cabinets, pallets, containers, and scrap lumber (U.S. EPA, 2007a).
  - ***Yard trimmings***. Yard trimmings can be generated from residential landscaping and right-of-way trimming near roads, railways, and utility systems such as power lines. Yard trimmings comprise about 14 percent of the MSW stream. Approximately 36 percent of yard trimmings are recoverable, and thus about 5 percent of the total MSW waste stream is yard trimmings that could be useable as a feedstock (U.S. EPA, 2007a).

» **For more information about biomass feedstocks, see EPA's CHP Biomass Catalog of Technologies at *www.epa.gov/chp/basic/catalog.html#biomasscat*.**

WOOD PELLETS

Wood pellets, briquettes, fire logs, and other compressed wood products are made from byproducts of forest products manufacturing, forest management, and recycled urban wood waste. These products are held together by the lignin in the wood when they are condensed through subjection to heat and pressure. Pellets are manufactured in uniform sizes and shapes (usually between 1-1½ inches by approximately 1/4-5/16 inches in diameter) and have a higher energy content by weight (roughly 7,750 Btu per pound at six percent moisture content) than many other biomass feedstocks due to their high density and low-moisture content. These characteristics alleviate many of the potential issues associated with storing biomass residues. Wood pellets are sold in different grades based on the ash produced during combustion relative to the amount of fuel fed into the wood pellet boiler (ranging from 1 to 3 percent). States regulate the disposal and/or subsequent use of the ash.

Source: Biomass Energy Resource Center, 2007

2.2 POTENTIAL FOR INCREASED PRODUCTION AND USE OF BIOMASS FEEDSTOCKS

CURRENT PRODUCTION AND USE

In 2006, renewable energy accounted for 7 percent of the nation's energy supply; of that, biomass was the source of 49 percent of renewable energy consumption (see Figure 1-1). Wood (used as fuel wood), forest residue, and wood waste feedstocks supplied the most bioenergy in 2005 (64 percent), followed by other types of wastes (e.g., MSW, LFG, agricultural residues, biosolids) (18 percent), and corn and soybean oil used to produce biofuels and related coproducts (18 percent) (EIA, 2008a; EIA, 2008b).

FUTURE PRODUCTION AND USE

Significant potential exists to increase the production and use of many different types of biomass feedstocks. In 2005, U.S. DOE and USDA convened an expert panel to assess whether the land resources of the United States could produce a sustainable supply of biomass sufficient to displace 30 percent of the nation's current petroleum consumption (U.S. DOE, 2005). The panel concluded that by the mid-21st century:

- The amount of wood, forest residue, and wood waste feedstocks sustainably produced for bioenergy each year could be increased nearly three times.
- The amount of agricultural feedstocks sustainably harvested while continuing to meet food, feed, and export demands each year could be increased five times.

The panel believes the potential increases in all of these biomass feedstocks can occur with relatively modest changes in agricultural and forestry practices and land use, including technological advances that increase feedstock yields, adoption of certain sustainable crop cultivation practices (e.g., no-till), and land use changes that allow for large-scale production of perennial crops.

For more information on determining the potential for increased use of feedstocks in a particular state, refer to Chapter 4, How Can States Identify Bioenergy Opportunities?

2.3 HOW ARE BIOMASS FEEDSTOCKS CONVERTED INTO BIOENERGY?

The processes, or "conversion technologies," used to convert biomass feedstocks from solids, liquids, or gases into bioenergy are shown in the middle column of Figure 2-2. This figure illustrates how different biomass feedstocks are converted into power, heat, fuels, and products.

All of the technologies shown in Figure 2-2 can and have been used for converting biomass; however, not all are currently deployed on a commercial scale. Table 2-1 indicates the commercialization status of some of the more commonly used conversion technologies for bioenergy production.

The conversion technologies listed in Figure 2-2 and Table 2-1 are described in Section 2.3.1.

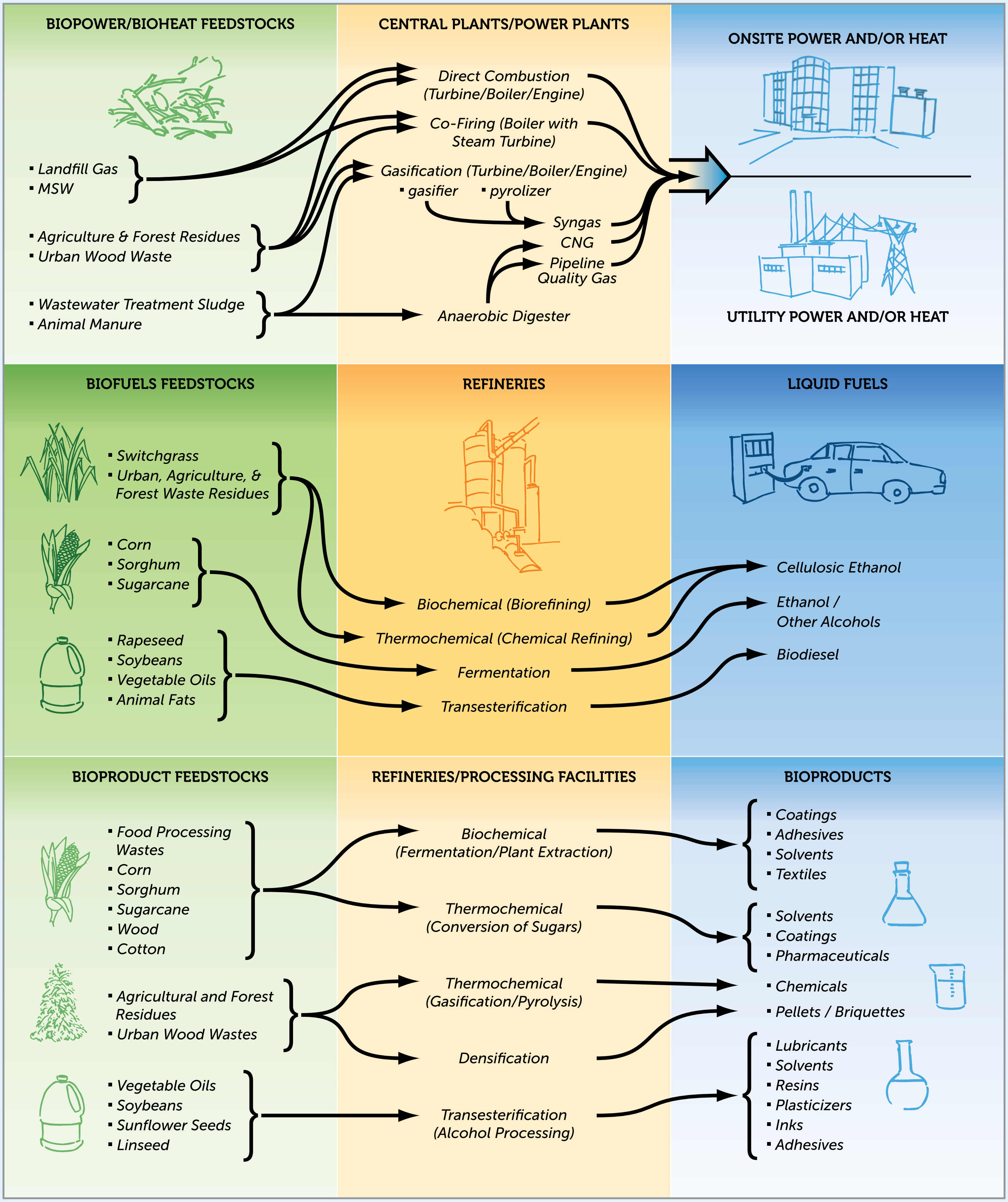
BIOREFINERIES

A biorefinery integrates biomass conversion technologies to produce biopower, biofuels, and/or bioproducts. A biorefinery is similar in concept to a petroleum refinery, producing multiple fuels and products. Biorefineries may play a key role in developing a domestic, bioenergy-based economy. Ideally, a biorefinery would be highly flexible, capable of using a variety of biomass feedstocks and changing its processes as needed, based on product demands. Such flexibility will help make biorefineries economically viable. Successful biorefineries already exist in the forest products and agricultural industries, producing food, feed, fiber, and/or chemicals (including plastics), as well as on-site power generation or CHP for facility operations (U.S. DOE, 2003).

TABLE 2-1. COMMERCIALIZATION STATUS OF COMMON BIOENERGY CONVERSION TECHNOLOGIES

Conversion Technology	Commercialization Status of Technology
Direct combustion	Commercially available
Cofiring	Commercially available
Landfill Gas systems	Commercially available
Anaerobic digestion	Commercially available
Gasification (thermochemical process)	Emerging technology
Pyrolysis (thermochemical process)	Emerging technology
Thermochemical conversion of sugars	Commercially available
Plant extraction (biochemical process)	Emerging technology
Transesterification	Commercially available
Fermentation (biochemical process)	Commercially available for conventional ethanol production and bioproducts Emerging technology for cellulosic ethanol production

FIGURE 2-2. BIOMASS CONVERSION TECHNOLOGIES



2.3.1 CONVERSION TECHNOLOGIES FOR BIOPOWER AND BIOHEAT

The three main types of conversion technologies used for producing electricity and heat are direct combustion, cofiring, and gasification systems. An important smaller scale conversion technology is anaerobic digestion.

Direct Combustion

Solid Fuels to Electricity, Heat, or CHP. In direct combustion systems used to produce **electricity**, a solid biomass feedstock (e.g., agriculture residues, forest residue, municipal solid waste, wood waste) is combusted with excess oxygen (using fans) in a boiler to produce steam that is used to create electricity. Direct combustion, commonly used in existing fossil-fuel power plants, is a dependable and proven technology, and is the conversion technology most often used for bioenergy power plants. However, the typically small size of bioenergy power plants (often due to high costs of transporting feedstocks), coupled with the low efficiency rates associated with the direct combustion process, can result in higher costs to produce electricity than with conventional fossil-fueled power plants (U.S. DOE, 2007). Some new combustion technologies are using compressed hot air (either directly or indirectly through a heat exchanger) to fire a combustion turbine.

In direct combustion systems used to produce **heat**, biomass feedstock loaded into a boiler or furnace can be used to create steam, hot water, or hot air which is then used for thermal applications. Large open buildings can be heated very efficiently with wood-fired furnaces or hydronic heating systems such as radiant floors. Direct combustion technologies for producing heat can utilize modern, computer-controlled systems with automatic fuel feeders, high-efficiency boilers, and add-on controls to reduce particulate matter (PM) and toxics emissions to relatively low levels (provided best available technologies are used). These systems are typically less expensive to operate than systems that use electricity, fuel oil, or propane but more expensive than natural gas systems (U.S. EPA, 2007a). However, all economic comparisons are site-specific.

CHP systems generate electricity and recapture waste heat from the electricity generation process, resulting in higher efficiency of fuel use. The electricity and heat can be used by the entity producing them as on-site power and heat, sold to others (such as an electric utility company), or in some combination of the two approaches. The forest products, chemical, and food-processing industries use on-site CHP systems widely. Increased use of biomass in CHP systems at pulp and paper mills has contributed to bioenergy surpassing hydropower as the leading source of renewable energy in the United States since 1999 (EIA, 2008a). Increasingly, on-site CHP (and to a limited degree, biomass CHP) is also being used at ethanol production facilities due to its increased efficiency and lower fuel costs (U.S. EPA, 2007b).

» **For more detailed information on direct combustion technologies used for combined heat and power from biomass, see EPA's CHP Biomass Catalog of Technologies (U.S. EPA, 2007a) at *www.epa.gov/chp/basic/catalog.html#biomasscat*.**

Gaseous Fuels to Electricity, Heat, or CHP. As solid waste decomposes in a landfill, a gas is created that typically consists of about 50 percent methane and 50 percent CO_2.[2] The gas can either disperse into the air or be extracted using a series of wells and a blower/flare (or vacuum) system. This system directs the collected gas to a central point where it can be processed and treated. The gas can then be used to generate **electricity**, **heat**, or **CHP** via direct combustion; replace fossil fuels in industrial and manufacturing operations; be upgraded to pipeline quality gas, compressed natural gas (CNG) or liquid natural gas (LNG) for vehicle fuel; or be flared for disposal. As of December 2008, approximately 490 LFG energy projects were operational in the United States. These 490 projects generate approximately 11 million megawatt-hours (MWh) of electricity per year and deliver more than 230 million cubic feet per day of LFG to direct-use applications. EPA estimates that approximately 520 additional landfills present attractive opportunities for project development (U.S. EPA, 2007a, U.S. EPA, 2009c).

» **For more information about LFG systems, see information on converting LFG to energy from EPA's Landfill Methane Outreach Partnership at *www.epa.gov/landfill/overview.htm#converting*.**

Cofiring

Solid Fuels to Electricity. Cofiring to produce electricity involves substituting solid fuel biomass (e.g., wood waste) for a portion of the fossil fuel (typically coal) used in the combustion process. In most cases, the existing power plant equipment can be used with only minor modifications, making this the simplest and

2 The amount of methane generated by a landfill over its lifetime depends on the composition of the waste, quantity and moisture content of the waste, and design and management practices of the facility.

most economical option for biopower. Pulverized coal boiler systems are the most widely used systems in the United States; cofiring is also used in other types of boilers, including coal-fired cyclones, stokers, and fluidized bed boilers.

To evaluate the efficacy of biomass cofiring, a study by U.S. DOE and the Electric Power Research Institute (EPRI) modeled the performance of a pulverized coal power plant using only coal and the same power plant operating with biomass cofiring. The study identified a 15 percent biomass cofiring rate as realistic given biomass resource limitations and requirements to maintain unit efficiency. Cofiring biomass for up to 15 percent of the fuel was demonstrated during preliminary testing to result in little or no loss in boiler efficiency (EPRI and U.S. DOE, 1997).

» **For more information on cofiring, see EPA's CHP Biomass Catalog of Technologies (U.S. EPA, 2007) at *www.epa.gov/chp/basic/catalog.html#biomasscat*.**

Gasification and Pyrolysis

Solid Fuels to Electricity, Heat, or CHP. Gasification, plasma arc gasification, and pyrolysis are thermal degradation processes that can convert solid biomass feedstocks to a gas.

- **Gasification** is a chemical or heat process that converts a solid fuel to a gas. To create bioenergy, solid biomass feedstocks (e.g., wood waste) are heated above 700 degrees Celsius inside a gasifier with limited oxygen, which converts the feedstock into a flammable, synthesis gas (syngas). Depending on the carbon and hydrogen content of the biomass and the gasifier's properties, the heating value of the syngas can range from about 15 to 40 percent of natural gas. Syngas can be burned in a boiler or engine to produce electricity and/or heat. Syngas can also be converted thermochemically to a liquid fuel (Kent, 2007).

  Gasification has high efficiencies and great potential for small-scale power plant applications. Because the gas can be filtered to remove potential pollutants, the process can produce very low levels of air emissions.

» **For more information on gasification, see EPA's CHP Biomass Catalog of Technologies at *www.epa.gov/chp/basic/catalog.html#biomasscat* or DOE's Biomass primer at *www.eere.energy.gov/de/biomass_power.html.***

- **Plasma Arc Gasification** is a waste treatment technology that uses the high temperatures of an electrical discharge ("arc") to heat a gas, typically oxygen or nitrogen, to temperatures potentially in excess of 3000 degrees Celsius. The gases heated by the plasma arc come into contact with the waste in a device called a plasma converter and vitrify or melt the inorganic fraction of the waste and gasify the organic and hydrocarbon (e.g., plastic, rubber, etc.) fraction. The extreme heat pulls apart the organic molecular structure of the material to produce a simpler gaseous structure, primarily CO, H2, and CO2 (Beck, 2003).

  Plasma arc gasification is intended to be a process for generating electricity, depending upon the composition of input wastes, and for reducing the volumes of waste being sent to landfill sites (R. W. Beck, 2003). Most plasma arc systems are cost effective at only very large scales (1,000,000 tons of feedstock per year or more). A number of companies are working on the development and deployment of this emerging technology.

- **Pyrolysis** also uses high temperatures and pressure in the absence of oxygen to decompose organic components in biomass into gas, liquid (bio-oil), and char products (bio-char) (U.S. DOE, 2003). The process occurs at lower temperatures than combustion or gasification. Controlling the temperature and reaction rate determines product composition (Southern States Energy Board, 2006).

  - Bio-oil is an acidic complex mixture of oxygenated hydrocarbons with high water content. Most data and research come from the pyrolysis of wood, although it is possible to convert any biomass feedstock into bio-oil through pyrolysis. Bio-oil's composition is influenced by several factors: feedstock properties, heat transfer rate, reaction time, temperature history of vapors, efficiency of char removal, condensation equipment, water content, and storage conditions. Bio-oil can be used for producing thermal energy (e.g., for heating buildings, water, and in industrial processes), for power generation using slow-speed diesel engines or combustion turbines, and for cofiring in utility-scale boilers. Bio-oil cannot be used as a transportation fuel without further refining (Easterly, 2002) (see Section 2.2.2 — Thermochemical and Biochemical Conversion, for a discussion of bio-oil and transportation fuels).

    The energy content of bio-oil ranges from 72,000 to 80,000 Btu per gallon whereas conventional heating oil (No. 2) has an energy content of about 138,500 Btu per gallon. Thus, bio-oil contains about 52 to 58 percent as much energy and almost twice as much bio-oil is required to produce the same amount of heat as No. 2 heating oil. In addition, bio-oil weighs about 40 percent more per gallon than heating oil (Easterly, 2002).

- A coproduct of producing bio-oil is char or bio-char (see Section 2.2.3 — Biochemical).

Anaerobic Digestion

Solid Fuels to Gaseous Fuels for Electricity, Heat, or CHP. Anaerobic digestion is the decomposition of biological wastes (i.e., wastewater treatment sludge or animal manure) by microorganisms in the absence of oxygen, which produces biogas. Digestion occurs under certain conditions (psychrophilic, mesophilic, and thermophilic), which differ mainly based on bacterial affinity for specific temperatures. This process produces a gas that consists of 60 to 70 percent methane, 30 to 40 percent CO_2, and trace amounts of other gases (EPA, 2002). The methane can be captured (and sometimes filtered or cleaned) and used to produce **electricity** and/or **heat**, directly used to offset fossil fuels, upgraded to pipeline quality gas, or used in the production of liquid fuels. Anaerobic digestion is commonly used at wastewater treatment facilities and animal feeding operations.

Anaerobic digestion at wastewater treatment facilities is used to process, stabilize, and reduce the volume of biosolids (sludge) and reduce odors. It is often a two-phase process: First, biosolids are heated and mixed in a closed tank for about 15 days as digestion occurs. The biosolids then go to a second tank for settling and storage. Temperature, acidity, and other characteristics must be monitored and controlled. Many wastewater treatment plants that use anaerobic digesters burn the gas for **heat** to maintain digester temperatures and heat building space. The biogas can also be used to produce **electricity** (e.g., in an engine-generator or fuel cell) or flared for disposal.

Anaerobic digesters at animal feeding operations are used to process, stabilize, and reduce the volume of manure, reduce odors and pathogens, separate solids and liquids for application to cropland as fertilizer or irrigation water, and produce biogas. Farm-based anaerobic digesters consist of four basic components: the digester, a gas-handling system, a gas-use device, and a manure storage tank or pond to hold the treated effluent prior to land application. The biogas can be used to generate **heat**, **hot water**, or **electricity**, directly used to offset fossil fuels, upgraded to pipeline quality gas, or used in the production of liquid fuels. The captured biogas is typically used to generate electrical power, with many farms recovering waste heat for on-farm use. These systems generate about 244,000 MWh of electricity per year in the United States. The biogas can also be used in boilers, upgraded for injection into the natural gas pipeline, or flared for odor control.

» **For more information about anaerobic digestion, see EPA's Guide to Anaerobic Digesters at *www.epa.gov/agstar/operational.html*.**

2.3.2 CONVERSION TECHNOLOGIES FOR BIOFUELS

Conversion of biomass into ethanol and biodiesel liquid fuels has been increasing steadily over the past decade. As of November 2008, there are 180 fuel ethanol production facilities in operation or expansion and another 23 under construction (Renewable Fuels Association [RFA], 2008). Total fuel ethanol production in 2008 was 9 billion gallons (RFA, 2009). In addition, as of January 2008, 171 companies have invested in development of biodiesel manufacturing plants and were actively marketing biodiesel. The annual production capacity from these biodiesel plants is 2.24 billion gallons per year (National Biodiesel Board, n.d.). This discussion focuses on ethanol and biodiesel production; however, other biofuels can also be produced, such as methanol, butanol, synfuels, and algal fuel. Additional details about current and developing technologies for converting solid biomass into liquid fuels are available from the Western Governors' 2008 Association Strategic Assessment of Bioenergy Development in the West, *Bioenergy Conversion Technology Characteristics* (Western Governors' Association, 2008).

Both ethanol and biodiesel can be produced using a variety of feedstocks and processes. Their feedstocks

ETHANOL AND BIODIESEL.

Both ethanol and biodiesel are registered as fuel and fuel additives with the U.S. EPA.

As initially required under the Energy Policy Act of 2005 and subsequently revised in the Energy Independence and Security Act (EISA) of 2007, Congress created a Renewable Fuel Standard (RFS) to ensure that transportation fuel sold in the United States contains minimum volumes of renewable fuel, such as ethanol or biodiesel. The current RFS program will increase the volume of renewable fuel required to be blended into gasoline to 36 billion gallons by 2022.

Source: U.S. EPA, 2009

and conversion technologies are shown in Figure 2-2 and described below.

Thermochemical and Biochemical Conversion

Solid Fuels to Cellulosic Ethanol. Ethanol can be made from cellulosic materials such as grasses, wood waste, and crop residues. Cellulosic ethanol is made from plant parts composed of *cellulose*, which makes up much of the cell walls of plants, and *hemicellulose*, also found in plant cell walls. *Lignin,* another plant part that surrounds cellulose, can also be used to make ethanol. Feedstocks that use both cellulose and lignin are sometimes referred to as "lignocellulosic" feedstocks; for simplicity, this section uses the term cellulosic to refer to both cellulosic and lignin-based ethanol production.

Breaking down the cellulose in cellulosic feedstocks to release the sugars for fermentation is more difficult than breaking down starch (e.g., in corn) to release sugars; thus, cellulosic ethanol production is more complex and more expensive than conventional ethanol production. Cellulosic biofuel production uses biochemical or thermochemical processes (NREL, 2007).

ETHANOL

A type of alcohol that is used as an alternative energy transportation fuel, can be made from crops such as corn, sugarcane, sorghum, and switchgrass, as well as opportunity/waste fuels such as agricultural and forest/wood residue.

- *Conventional ethanol* has been made from corn or sugarcane for decades using processes that have evolved over time, but are nonetheless considered "conventional" ethanol production.
- *Cellulosic ethanol* is created from cellulosic feedstocks using processes that have been developed more recently and are not yet commercially deployed. Cellulosic ethanol is considered "advanced" or "second generation," using more complex processes and potentially a wider variety of biomass feedstocks.

- **Biochemical conversion**. Biochemical conversion for ethanol production from cellulosic feedstocks involves:
  - Pretreatment of the feedstock using high-temperature, high-pressure acid; enzymes; or other methods to break down the lignin and hemicellulose that surround the cellulose.
  - Hydrolysis using enzymes and acids to break down the cellulose into sugars.
  - Fermentation to convert the sugars into ethanol (as in conventional production).
  - Distillation to produce purer ethanol (as in conventional production).

- **Thermochemical conversion**. Thermochemical conversion uses heat and chemicals to break down cellulosic feedstock into syngas. Depending upon the process being used, the gas can be converted to liquid fuels such as ethanol, bio-butanol, methanol, mixed alcohols, or bio-oil (through pyrolysis). Thermochemical conversion is particularly useful for lignin, which cannot be easily converted to ethanol using the biochemical process described above; up to one-third of cellulosic feedstock can be composed of lignin. Forest and mill residue feedstocks generally have high lignin contents, and thus would be more suitable for thermochemical ethanol conversion than biochemical conversion.

  The thermochemical conversion process involves:
  - Drying the cellulosic feedstock.
  - Gasification (using heat to convert the feedstock to a syngas) or pyrolysis (using heat and pressure to produce an oil).
  - Contaminant removal.
  - Conversion of the syngas to ethanol, bio-oil, or other products.
  - Distillation to separate ethanol from water (if producing ethanol).

» **A number of researchers and organizations are evaluating process changes and refinements to make cellulosic ethanol production more commercially viable and cost-competitive. For more information, see NREL's *Research Advances: NREL Leads the Way—Cellulosic Ethanol* at *www.nrel.gov/biomass/pdfs/40742.pdf*.**

» **For more information on cellulosic ethanol production, see *www.afdc.energy.gov/afdc/ethanol/production_cellulosic.html*.**

Solid Fuels to Bio-Oil. Bio-oil has limited market presence and does not yet enjoy the popularity of other biofuels such as ethanol and biodiesel. Current research and development in pyrolysis focuses on maximizing liquid (bio-oil) yields because of the ability to transport and store liquid fuels and the ability of bio-oil to be further refined in existing petroleum refineries into transportation fuels. In 2005, successful tests produced syngas through gasification of bio-oil, which can be further processed into syndiesel. Syndiesel can be used in all diesel end-use devices without modification (Dynamotive, 2005). Recent tests also show that it is possible to take bio-oil and refine it into a green diesel product using existing petroleum refineries. This technology pathway effectively takes advantage of the infrastructure associated with the existing petroleum industry (Holmgren et al., 2005). Beyond energy products, bio-oil can be further refined into a range of specialty chemicals, including flavor enhancers, and fuel additives.

Fermentation

Solid Fuels to Conventional Ethanol. In the United States, all commercially established ethanol production to date has been based on the biochemical process of fermentation, which involves conversion of sugars in starchy plants (such as corn or sugarcane) by microorganisms into alcohol. As of November 2008, 171 of the 180 operating ethanol biorefineries in the United States used corn as the primary feedstock (RFA, 2008).

Ethanol from corn is produced in either dry mills or wet mills. In dry mills, corn is ground into flour, water and enzymes are added, the mixture is "cooked," and yeast is added for fermentation. The mixture is then distilled and water is removed to produce ethanol. In wet mills, corn is soaked in hot water to separate starch and protein, the corn is ground and the germ is separated, the remaining slurry is ground, and some of the remaining starch is further processed to produce sugars. The material is then fermented and distilled to produce ethanol.

In recent years, most new ethanol production facilities have been dry mill plants. As of July 2008, approximately 95 percent of United States corn-ethanol facilities were dry mills, accounting for nearly 90 percent of gallons produced. Dry mills typically produce ethanol, animal feed, and sometimes CO_2 (U.S. EPA, 2008d).

For more information on conventional corn-based ethanol production, see *www.afdc.energy.gov/afdc/ethanol/production_starch_sugar.html*.

Transesterification

Oils to Biodiesel. Biodiesel production converts oils or fats into biodiesel, which can be used to fuel diesel vehicles (or stationary engines). In biodiesel production, fats and oils are converted into biodiesel through a process known as "transesterification." The oils and fats are filtered and pretreated to remove water and contaminants (e.g., free fatty acids), then mixed with an alcohol (often methanol) and a catalyst (e.g., sodium hydroxide) to produce compounds known as fatty acid methyl esters and glycerin (U.S. DOE, 2008). The esters are called biodiesel when they are intended for use as fuel. Glycerin is used in pharmaceuticals, cosmetics, and other markets. Often biodiesel and glycerin are produced as coproducts.

BIODIESEL

Biodiesel is usually blended with petroleum diesel to create either B20 (a 20 percent biodiesel blend) or B90 (a 90 percent biodiesel blend), which can be used in diesel engines with little or no modification and provides better engine performance and lubrication than petroleum fuel (U.S. EPA, 2008e).

In the United States, biodiesel is made primarily from soybeans/soy oil or recycled restaurant grease; in Europe, biodiesel is produced primarily from rapeseed (EERE, 2008). About half of current biodiesel production facilities can use any fats or oils as a feedstock, including waste cooking oil; the other production facilities require vegetable oil, often soy oil. Biodiesel production facilities are often located in rural areas, near biodiesel feedstock sources such as farms growing soybeans. Farmers often use biodiesel in their farm equipment.

Increased demand for biodiesel feedstocks from farms, as well as establishment of locally sited and/or owned biodiesel production facilities, can help boost rural economies.

For more information about biodiesel production, see the U.S. DOE Web site at *www.afdc.energy.gov/afdc/fuels/biodiesel_production.html* and the National Biodiesel Board's Web site at *www.biodiesel.org/pdf_files/fuelfactsheets/Production.PDF*.

2.3.3 CONVERSION TECHNOLOGIES FOR BIOPRODUCTS

Biomass feedstocks are made of carbohydrates, and thus contain the same basic elements—carbon and hydrogen—as petroleum and natural gas. Many products, such as adhesives, detergents, and some plastics, can be made from either petroleum or biomass feedstocks. Like biofuels, technologies for converting biomass feedstocks into bioproducts use three main processes: biochemical conversion, thermochemical conversion, or transesterification.

Biochemical conversion for bioproducts includes fermentation and plant extraction. Thermochemical conversion technologies, such as direct combustion, gasification, and pyrolysis, use heat, chemicals, catalysts, and pressure to break down biomass feedstocks. Transesterification uses alcohols to break down vegetable oils for use in bioproducts.

As of 2003, use of biomass feedstocks provided more than $400 billion of bioproducts annually in the United States (U.S. DOE, 2003). Production of chemicals and materials from bio-based products was approximately 12.5 billion pounds, or 5 percent of the current production of target U.S. chemical commodities (U.S. DOE, 2005).

BIOPRODUCTS

Many industrial and consumer products, such as soap, detergent, soy-based ink, solvents, and adhesives, are already produced totally or partially from biomass feedstocks, primarily corn, vegetable oils, and wood.

In addition, many products currently made from petroleum could instead be made, in whole or part, from biomass feedstocks. Also, new bioproducts and technologies are being developed with the potential to increase production and use of bioproducts.

Current Bioproduct Applications	
Acrylic fibers	Pharmaceuticals
Adhesives	Polymers
Cosmetics	Resins
Detergents	Soaps
Lubricants	Solvents
Paints	Textiles

Biochemical

Biochemical conversion for bioproducts includes fermentation and plant extraction.

Sugars and Starches to Bioproducts. Fermentation with microorganisms or enzymes is commonly used to convert starches and the sugar glucose into a variety of organic acids and ethanol that are then used to create bioproducts or intermediate materials used in manufacturing bioproducts. Food processing wastes are used as biomass feedstocks in the fermentation process for bioproducts (A.D. Little, Inc., 2001).

Specifically, fermentation can also be used to convert sugars into:

- Lactic acid derivatives such as acrylic acid, which can be used in coatings and adhesives;
- Ethyl lactate, which can replace many petroleum-based solvents; and
- Polylactide (PLA), a plastic that can be used in packaging and fiber applications, and can be melted and reused or composted when it reaches the end of its useful life.

Ongoing research and pilot-scale applications of bioproducts made from lactic acid derivatives show great promise. Advances in fermentation technology (e.g., new microorganisms and separation techniques) may allow other sugars (e.g., pentose sugars such as xylose) to be converted to bioproducts. These advances would open up use of cellulosic biomass feedstocks (e.g., corn stover, switchgrass, wheat straw) to make bioproducts. Such advances may allow additional bioproducts to be made through fermentation at costs competitive with conventional petroleum-based products (U.S. DOE, 2003).

Plant Components to Bioproducts. Lumber, paper, and cotton fiber are well-known examples of plants used to make bioproducts. Tocopherols and sterols are substances in plants that can be extracted and purified for use in vitamins and cholesterol-lowering products. A plant known as guayule produces nonallergenic rubber latex that can replace other types of rubber to which many people have developed allergies (U.S. DOE, 2003).

Thermochemical

Thermochemical conversion technologies—sugar conversion, gasification, and pyrolysis—use heat, chemicals, catalysts (such as acids, metals, or both), and pressure to break down biomass feedstocks, directly converting sugars into bioproducts or producing intermediate materials that can be converted into final bioproducts through other means.

Sugars to Bioproducts. Thermochemical conversion has been used for more than 50 years to convert the sugar glucose into sorbitol. Sorbitol derivatives—such as propylene glycol, ethylene glycol, and glycerin—are important commercial products used in solvents, coatings, pharmaceuticals, and other applications. Currently, propylene glycol and ethylene glycol are made from petroleum; thermochemical conversion uses biomass feedstocks (rather than petroleum) to produce these sorbitol derivatives.

Thermochemical conversion can also convert sugars other than glucose (e.g., xylose) to sorbitol. Thermochemical conversion is also used to convert sugar to levulinic acid, which is then used to produce a variety of bioproducts, such as methyl tetrahydrofuran (MTHF), used in primaquine, an antimalarial drug, and diphenoloic acid (DPA), used as an alternative to bisphenol A (BPA) in polymers.

New catalysts and thermochemical technologies are creating new opportunities for bioproducts, including use of cellulosic feedstocks to create sorbitol-related and other bioproducts (U.S. DOE, 2003).

Solid Fuels to Syngas. Gasification uses high temperatures and oxygen to convert solid carbonaceous material into syngas, which is a mixture of carbon monoxide (CO), hydrogen, and sometimes CO_2. Syngas can be converted into chemicals such as methanol, which is then converted into other chemicals such as formaldehyde and acetic acid. Syngas can also be converted into chemicals, such as paraffins and fatty acids, by using catalysts (cobalt or iron) and high temperature and pressure (known as the Fischer-Tropsch process) (U.S. DOE, 2003).

Solid Fuels to Bioproducts. Pyrolysis uses high temperatures and pressure in the absence of oxygen to decompose organic components in biomass into liquids, solids, and gases. The liquids, in particular, can contain chemicals that can be used in bioproduct manufacturing, but isolating these chemicals via separation technology can be difficult. The technology closest to commercialization is pyrolysis of cellulosic feedstocks containing high amounts of lignin. This technology can produce a replacement for the toxic chemical phenol in phenol-formaldehyde resins, used in plywood and other wood composites (U.S. DOE, 2003).

Bio-char is another potential product from the pyrolysis process, which has multiple uses. One option is to use the char as a soil amendment on agricultural lands. Bio-char has been shown to improve soil organic matter, reduce fertilizer and water requirements, improve nutrient delivery to the plant (through adsorption), and sequester carbon (Cornell University, 2009).

Densification

Solid Fuels to Pellets or Briquettes. A robust market exists for solid biomass fuels such as pellets or briquettes, which are a bioproduct formed from compressed wood or agricultural residue feedstocks that can be used as fuel for heating (see Section 2.2.1 — Direct Combustion).

Pellets are typically 1/4" or 5/16" diameter and are the most costly compressed biomass form. Bripells are the same shape as pellets but 1-1/2" in diameter. They are so named because they are between briquettes and pellets in size. Briquettes are compressed biomass forms larger than a pellet. Typically, briquettes are square or rectangular and can be the size of typical backyard barbeque fuel up to the size of a building brick (NREL, Unpublished).

Pellets are a refined product and require the most expensive processing. The higher cost of pellets as a fuel for heating is offset by the convenience of being able to use fuel burning equipment that can be automated and needs minimal attention (particularly when compared to bulk biomass systems). This convenience is important because pellets typically compete for market share against almost zero-maintenance natural gas, propane, or electric heat. Briquettes require less energy to produce and are processed through simpler production methods (NREL, Unpublished).

Transesterification

Oils to Bioproducts. Transesterification uses alcohols to break down vegetable oils for use in bioproducts. Vegetable oils are composed primarily of triglycerides, which can be broken down using an alcohol (such as methanol) into glycerin and fatty acids. The fatty acids are then modified into intermediate products used to make bioproducts. Vegetable oils from biomass feedstocks such as soybeans, sunflowers, and linseed are used to manufacture bioproducts such as lubricants, solvents, resins, plasticizers, inks, and adhesives (U.S. DOE, 2003).

» **For more information on conversion technologies used to manufacture bioproducts, see U.S. DOE's report** ***Industrial Bioproducts: Today and Tomorrow*** **at** ***www.brdisolutions.com/pdfs/BioProductsOpportunitiesReportFinal.pdf*****.**

2.4 RESOURCES FOR DETAILED INFORMATION

Resource	Description	URL
Bioenergy		
Woody Biomass Utilization, U.S. Forest Service and Bureau of Land Management.	This U.S. Forest Service and Bureau of Land Management Web site provides links to a variety of resources and reports on woody biomass utilization, including tools and references specifically targeted at state governments.	*www.forestsandrangelands.gov/Woody_Biomass/index.shtml*
BioWeb, Sun Grant Initiative.	An online catalog of a broad range of resources on bioenergy, including descriptions of biomass resources, biofuels, and bioproducts; explanations of conversion technologies; and summaries of relevant policies. The resources are searchable by both topic and level of detail of information provided. The catalog is a product of the Sun Grant Initiative, a national network of land-grant universities and federally funded laboratories working together to further establish a bio-based economy.	*http://bioweb.sungrant.org/*
Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, U.S. DOE, USDA, 2005.	Describes issues associated with reaching the goal of 1 billion tons of annual biomass production (see especially pp. 34–37).	*www.osti.gov/bridge*
Biomass Energy Data Book, U.S. DOE, September 2006.	Provides a compilation of biomass-related statistical data.	*http://cta.ornl.gov/bedb/index.shtml*
Biomass Feedstock Composition and Property Database, U.S. DOE.	Provides results on chemical composition and physical properties from analyses of more than 150 samples of potential bioenergy feedstocks, including corn stover; wheat straw, bagasse, switchgrass, and other grasses; and poplars and other fast-growing trees.	*www1.eere.energy.gov/biomass/feedstock_databases.html*
A Geographic Perspective on the Current Biomass Resource Availability in the United States, Milbrandt, A., 2005.	Describes the availability of the various types of biomass on a county-by-county basis.	*www.nrel.gov/docs/fy06osti/39181.pdf*
Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology, Kent, 2007.	Detailed, comprehensive, fairly technical explanation of the range of biomass conversion technologies.	
Biopower/Bioheat		
Biomass Combined Heat and Power Catalog of Technologies, U.S. EPA, September 2007.	Detailed technology characterization of biomass CHP systems, including technical and economic characterization of biomass resources, biomass preparation, energy conversion technologies, power production systems, and complete integrated systems. Includes extensive discussion of biomass feedstocks.	*www.epa.gov/chp/documents/biomass_chp_catalog.pdf*
Combined Heat and Power Market Potential for Opportunity Fuels, U.S. DOE, Resource Dynamics Corporation, August 2004.	Determines the best "opportunity fuels" for distributed energy sources and CHP applications.	*www.eere.energy.gov/de/pdfs/chp_opportunityfuels.pdf*

Resource	Description	URL
Biofuels/Bioproducts		
Bioenergy Conversion Technology Characteristics, Western Governors' Association, September 2008.	Investigates the biofuel conversion technologies that are currently available, as well as technologies currently under development that are developed enough to be potentially available on a commercial basis circa 2015.	*www.westgov.org/wga/initiatives/transfuels/Task%202.pdf*
A National Laboratory Market and Technology Assessment of the 30x30 Scenario, NREL, March 2007.	Draft assessment of the market drivers and technology needs to achieve the goal of supplying 30 percent of 2004 motor gasoline fuel demand with biofuels by 2030.	
From Biomass to BioFuels: NREL Leads the Way, NREL, August 2006.	Provides an overview of the world of biofuels, including the maturity levels of various biofuels, how they are produced, and the U.S. potential for biofuels.	*www.nrel.gov/biomass/pdfs/39436.pdf*
Research Advances Cellulosic Ethanol: NREL Leads the Way, NREL, March 2007.	Highlights some of NREL's most recent advances in cellulosic ethanol production.	*www.nrel.gov/biomass/pdfs/40742.pdf*

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CHAPTER THREE

Benefits, Challenges, and Considerations of Bioenergy

Biomass is a low-cost, domestic source of renewable energy with potential for large-scale production. U.S. DOE estimates that, with aggressive action, bioenergy could displace one-third of the current demand for petroleum fuels nationwide by the mid-21st century (U.S. DOE, 2005).

According to the American Council on Renewable Energy (ACORE), biopower projects could see a 10-fold increase—to 100 gigawatts (GW)—by 2025 with coordinated federal and state policies to expand renewable energy markets, promote and deploy new technology, and provide opportunities to encourage renewable energy use in multiple market sectors and applications (ACORE, 2007).

With the potential for increased production and use of biomass and bioenergy comes the potential for states to take advantage of benefits associated with bioenergy, but also the need to guard against pitfalls. Some benefits and challenges will be of greater interest to states in particular regions (e.g., arid vs. wet, nonattainment vs. in attainment) or with particular characteristics (e.g., urban vs. rural). States will want to weigh the challenges and benefits when deciding whether and how to pursue bioenergy development.

DOCUMENT MAP

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A brief overview of benefits and challenges is provided below, followed by a more detailed discussion.

BENEFITS

Policy makers are looking to production and use of biomass for power, heat, fuels, and products as an effective means of advancing energy security, economic, and environmental goals.

For example, an analysis of the primary drivers cited in legislation for state renewable fuel standards (RFSs) found that state goals included (Brown et al., 2007):

- **Energy Security**: Increasing use of domestic fuels to reduce dependence on foreign oil and its potential disruptions, while keeping money for energy in local communities.
- **Economic**: Improving the rural economy by generating jobs, income, and taxes through demand for local biomass resources and construction of biomass conversion facilities.
- **Environmental**: Achieving air quality goals and improving public health by using bioenergy that reduces GHGs and other air pollutants and by turning waste products into bioenergy.

In addition, compared with some energy alternatives, bioenergy may be one of the easier options to adopt in the near term (e.g., coal-fired power plants can cofire biomass and vehicle engines can use biofuels with few if any modifications).

CHALLENGES

At the same time, there are potential challenges associated with deployment of any bioenergy project. While the benefits of using biomass instead of other fuel sources to meet state energy needs are numerous, states should be aware of several potential issues when exploring bioenergy. These include:

- **Environment**: Potentially adverse environmental impacts could result if increased production is not handled sustainably, including air and water pollution, negative impacts of direct and indirect land use changes, and increased water consumption.
- **Feedstock Supply**: For a variety of reasons, securing a suitable and reliable feedstock supply—particularly one that will be available over the long term at a reasonable cost—does not always prove easy. Many feedstocks are seasonal and may only be harvested once a year. In order to cover their fuel needs for energy production over the course of a year, bioenergy producers may need to utilize flexible conversion processes capable of using a variety of feedstocks available in different seasons.
- **Infrastructure**: The location and nature of feedstock inputs or bioenergy outputs produced at bioenergy plants can make their delivery difficult. Additionally, current infrastructure levels may not support market demand or can be constrained by other economic factors despite demand.

These benefits and challenges are described in the following sections. Note that not all are relevant to every type of bioenergy production or use.

3.1 ENERGY SECURITY BENEFITS

3.1.1 INCREASED ENERGY INDEPENDENCE THROUGH BIOFUELS

The United States currently imports 65 percent of the petroleum it consumes—the majority for transportation fuels (U.S. Energy Information Agency, 2008). Relying on foreign energy sources leaves the nation vulnerable to price increases and supply limits that foreign nations could impose. Reliance on foreign petroleum also contributes significantly to the U.S. trade deficit. Increasing the domestic energy supply by expanding biofuels production could help reduce U.S. dependence on foreign oil, thus increasing the nation's energy security.

3.1.2 DECREASED INFRASTRUCTURE VULNERABILITY THROUGH BIOPOWER

The vulnerability of our energy infrastructure to attacks is also an energy security concern. Increased use of domestic bioenergy can help reduce this vulnerability because bioenergy involves a domestic, dispersed energy infrastructure that may be less prone to attack.

When a reliable feedstock supply is available, biopower can be a baseload renewable resource, compared to other renewable resources such as wind and solar, which may be available on an intermittent basis, and compared to fossil fuels, supplies of which may become increasingly limited and more expensive.

ETHANOL'S NET ENERGY BALANCE

Net energy balance is the total amount of energy used over the full life cycle of a fuel, from feedstock production to end use. Technical debate is ongoing about the implications of some forms of bioenergy, most notably ethanol as a transportation fuel. In the 1980s, the net fossil fuel energy balance for corn to ethanol was negative, meaning the fossil energy input to create the ethanol was greater than the fossil energy displaced. Technology improvements have changed this such that most recent studies find that corn-based ethanol reduces petroleum usage. However, some studies find a negative net fossil energy balance for corn ethanol when all fossil energy sources (e.g., coal-fired electricity used to power the production plant) are taken into account (U.S. DOE, 2006).

Study results vary due to differing assumptions about energy sources, by-products, and system boundaries. For example, ethanol plants that take full advantage of CHP opportunities would have greater energy efficiency and a better energy balance. Use of biomass or biogas as the production facility's fuel for power and heat also reduces fossil energy use (E3 Biofuels, 2007; U.S. DOE, 2006).

U.S. EPA studied the effect of CHP on energy use in the dry mill conversion process used to produce ethanol from corn. The Agency analyzed the impact of this technology on total energy consumption (including power fuel use at the plant for ethanol production and subsequent reductions in central station power fuel use) for plants using natural gas, coal, or biomass as fuel. In all cases where plants utilized CHP technology, total net fuel consumption was reduced as electricity generated by the CHP systems displaced less efficient central station power. Energy use reductions of approximately 8 percent were modeled for the plants utilizing biomass-fueled CHP (U.S. EPA, 2007a).

In contrast to the varying net fossil energy balance results for corn-based ethanol, cellulose-based ethanol is found to provide both lower petroleum usage and a positive net fossil energy balance because less fossil fuel is required to acquire cellulosic feedstocks (e.g., grasses, wood waste, etc.) than corn (U.S. DOE, 2006).

U.S. DOE's Biomass Energy Databook (2006) provides detailed comparisons of energy inputs and GHG emissions for various ethanol scenarios compared to gasoline. For more information, see *http://cta.ornl.gov/bedb/pdf/Biomass_Energy_Data_Book.pdf*.

3.1.3 RELIABLE BASELOAD POWER SOURCE

Biomass power is a reliable, cost-effective source of baseload power. Unlike wind or solar, biomass feedstocks can be stored and used to generate power 24 hours a day, seven days a week. The ability to store feedstocks is beneficial for utilities because it enables them to consistently know when they will be available, in what quantities, and at what cost.

3.2 ECONOMIC BENEFITS

3.2.1 PRICE STABILITY FROM BIOPOWER

A key economic benefit of bioenergy is its potential to provide price stability in volatile energy markets. For example, opportunity fuels—waste materials from agricultural or industrial processes—can generally be obtained for no or very low cost, as is the case with biogas collection and use at wastewater treatment plants or animal feeding operations. In addition to displacing purchased fossil fuels, using opportunity fuels for biopower may also free up landfill space and reduce tipping fees associated with waste disposal. As bioenergy technologies continue to improve, the potential for bioenergy to be a cost-competitive energy choice increases.

Even when the cost of bioenergy is greater than fossil fuels, in some cases bioenergy can help stabilize energy prices by providing more diverse sources of energy for the fuel supply. For example, biomass-fueled CHP can provide a hedge against unstable energy prices by allowing the end user to supply its own power when prices for electricity are very high. In addition, a CHP system can be configured to accept a variety of feedstocks (e.g., biomass, biogas, natural gas) for fuel; therefore, a facility could build in fuel-switching capabilities to hedge against high fuel prices.

Using a diversity of renewable resources can also provide economic benefits. Two studies in the United Kingdom compared electric systems that rely on wind alone with systems that combine wind and biomass on the same grid. In both cases, the need for ancillary services and transmission line upgrades, and thus the overall costs of the system, were significantly reduced when wind was complemented with biomass generating capacity (IEA, 2005).

Example

ESSEX JUNCTION WASTEWATER TREATMENT FACILITY ESSEX JUNCTION, VERMONT

Essex Junction's wastewater treatment facility uses two 30 kilowatt (kW) microturbines to generate electricity and thermal energy from the methane gas produced by its digester. Before CHP was installed, the plant used only half of the methane it produced. Now the plant uses 100 percent of the methane produced to heat the anaerobic digester, saving 412,000 kWh and $37,000 each year. These energy savings represent 36 percent of the facility's electricity demand. The project has an estimated payback of seven years.

Source: U.S. EPA, 2007f

3.2.1 ECONOMIC DEVELOPMENT FROM FEEDSTOCK PRODUCTION AND BIOENERGY

A major driver for many states in considering bioenergy expansion is the potential for economic development benefits. It is prudent to keep in mind, however, that the specifics of policy/program design and implementation, combined with the particular market forces at work in a state, will impact the extent to which a state will realize these benefits.

Nonetheless, the bioenergy supply chain has the potential to create jobs, income, and taxes associated with growing and harvesting or collecting the resource, facility construction, operation and maintenance, transportation, and feedstock processing. The funds retained in communities from local feedstock production and conversion create jobs and strengthen the local property and income tax base. Because biomass resources are primarily agricultural or forestry-based, rural communities have tended to benefit most from increased demand for feedstocks; however, if urban communities begin to further develop their use of waste/ opportunity fuels, they may also see localized benefits (U.S. DOE/SSEB, 2005).

Other potential economic benefits that can accrue from use of biomass for power, fuels, or products include (U.S. DOE/SSEB, 2005):

- Creating new uses and markets for traditional commodity crops.
- Creating opportunities to diversify rural income by growing new crops for biomass markets.
- Mitigating land-clearing costs for development or reforestation purposes.
- Providing markets and partially defraying costs for removal of undergrowth for forest health initiatives.
- Eliminating, mitigating, or transforming the need for agricultural and forestry-related subsidies.

Increased bioenergy can create or expand domestic industries nationally and regionally. The United States is already experiencing economic benefits from biofuels, according to a study by RFA. In 2006, the ethanol industry created more than 160,000 direct and indirect jobs; generated nearly $5 billion in federal, state, and local tax revenues; and reduced the federal trade deficit by more than $11 billion (Urbanchuk, 2007). Biomass power is a vital component of America's green economy. This $1 billion-a-year industry provides 14,000–18,000 jobs nationwide and contributes millions of dollars to local tax revenues yearly (Cleaves, Personal Communication, 2009).

Despite the potential economic benefits of biomass cultivation and bioenergy production, farmers may be reluctant to devote land to producing biomass feedstocks due to uncertainty in demand for these crops and up-front investment costs. To help communities and domestic industries take advantage of the economic benefits of biomass cultivation and bioenergy production, the Food, Conservation, and Energy Act of 2008 established the Biomass Crop Assistance Program to provide financial incentives to farmers to grow biomass feedstocks and connect with bioenergy producers (see text box).

PRODUCER PAYMENTS: BIOMASS CROP ASSISTANCE PROGRAM

As part of the Food, Conservation, and Energy Act of 2008, the Biomass Crop Assistance Program (BCAP) was created to financially support the establishment and production of crops for conversion to bioenergy and to assist with collection, harvest, storage, and transportation of eligible material for use in a biomass conversion facility. BCAP provides payments to farmers while they establish and grow biomass crops in areas around biomass facilities. To qualify for payments, potential biomass crop producers must participate in and be approved as part of a "BCAP project area" that is physically located within an economically viable distance from a biomass conversion facility. Contracts run for five years for annual and perennial crops and 15 years for woody biomass. The program provides three types of payments to producers: direct, annual and cost-share (sometimes called delivery) payments.

Source: USDA, 2008; NASDA, 2008

ECONOMIC DEVELOPMENT BENEFITS FROM BIOENERGY FACILITIES

- In 2005, RFA estimated that a typical **ethanol plant** producing 40 million gallons per year would provide a one-time boost of $142 million to the local economy during construction, expand the local economic base by $110.2 million each year through direct spending of $56 million, create 41 full-time jobs at the plant and a total of 694 jobs throughout the entire economy, and boost state and local sales tax receipts by $1.2 million for every $209,000 invested (U.S. DOE/SSEB, 2005).
- A 2002 study conducted in South Dakota estimated that a 24-million-gallon-per-year **biodiesel facility** under consideration would create 29 new jobs at the facility and another 748 jobs in the community. The facility would have a $22-million annual payroll and would generate $4.6 million in state and local tax revenues and $6.4 million in federal tax revenues (Leatherman and Nelson, 2002).
- For each megawatt of **biopower** produced from forest residue, U.S. DOE estimates that at least four jobs are created to procure and harvest the residue. Additional jobs would be created to transport the residue and construct, operate, and maintain the biopower facility (U.S. DOE, 2005).

3.3 ENVIRONMENTAL BENEFITS, CHALLENGES, AND CONSIDERATIONS

This section describes the potential environmental benefits and challenges of bioenergy in terms of air quality, land resources, waste, water resources, and food supply. The environmental effects of bioenergy can vary substantially because of the diversity in feedstock production, chemical content, and conversion processes. As with many multifaceted issues, bioenergy presents a complex set of environmental considerations and potential tradeoffs, some of which require active and attentive policy/program design and implementation to ensure the benefits outweigh the potential for negative consequences of missteps.

In such a complex area, policy makers can turn to detailed state or locally specific evaluations of potential environmental effects to ensure they are making informed decisions. A life-cycle assessment (LCA) can be used to quantify these effects.

LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service by (U.S. EPA, 2008a):

- Compiling an inventory of relevant energy and material inputs and environmental releases.
- Evaluating the potential environmental impacts associated with identified inputs and releases.
- Interpreting the results to help with more informed decision making.

A number of LCAs have been completed on bioenergy technologies and systems (see 3.6—Resources for Detailed Information).

3.3.1 AIR QUALITY BENEFITS AND CHALLENGES

Bioenergy can help improve air quality by reducing GHG emissions as well as emissions of several key air pollutants, depending on which biomass feedstocks and bioenergy conversion technologies are used (see Chapter 2 for descriptions of feedstocks and conversion technologies). These emission reductions can provide economic and environmental benefits by lowering emission-related operating costs, such as allowance/ permit costs and emissions-control equipment expenses (Hanson, 2005). At the same time (again depending on feedstocks and technologies), bioenergy can also increase certain air emissions relative to fossil fuels. These issues are described below.

Decreased GHG Emissions from Bioenergy

Biomass is generally considered to contribute nearly zero net GHG emissions (U.S. EPA, 2007b; IPCC, 2006). The reason for this accounting is because conversion of biomass feedstocks (whether in the form of biopower or biofuels) returns approximately the same amount of CO_2 to the atmosphere as was absorbed during growth of the biomass, resulting in little to no additional CO_2 released to the air. In contrast, when fossil fuels are burned, they release CO_2 into the atmosphere that was captured by photosynthesis and "stored" millions of years ago, thereby increasing the total amount of carbon in the atmosphere today. Fuel sources such as landfill gas and manure digester biogas actually reduce GHG emissions while producing energy.

Some recent studies dispute whether land use changes associated with biofuels (not biopower) production and international agricultural commodity markets counteract this benefit and actually increase GHG emissions (Searchinger et al., 2008; Delucchi et al., 2008; Wang and Haq, 2008). U.S. EPA is responsible for studying this issue carefully as part of the rulemaking process for the Federal Renewable Fuel Standard and ultimately enforcing new GHG reduction standards for renewable fuels as required by the Energy Independence and Security Act (EISA) of 2007.

Biofuels. The Argonne National Laboratory has estimated (excluding indirect land use) that when corn ethanol displaces an energy-equivalent amount of gasoline, GHG emissions are reduced by 18–29 percent; cellulosic ethanol yields an 85–86 percent reduction (Wang, 2005).

REDUCING GHG EMISSIONS WITH WASTE-TO-ENERGY

An example of GHG savings from bioenergy can be illustrated by the diversion of MSW from landfills to incinerators. MSW as a biomass feedstock reduces landfill methane emissions and substitutes for fossil-based power sources. EPA's life-cycle models (WARM and MSW Decision Support Tool) estimate that 0.55 to 1.0 tons of GHG emissions can be saved per ton of MSW combusted when incineration with energy recovery is selected over landfilling. MSW includes a large biogenic component (50 to 66 percent), and this fraction of the total can be considered carbon neutral from an energy generation perspective. Overall, a significant net GHG emissions savings could be realized from MSW combustion with energy recovery.

Source: U.S. EPA, 2008c

Biodiesel is regarded as having significant GHG reduction capabilities, depending on the source of the feedstock. USDA and U.S. DOE performed a comparative life-cycle analysis (excluding indirect land use) of soy-based biodiesel and petroleum diesel used in city buses and estimated that B20 (a blend of 20 percent biodiesel and 80 percent petroleum diesel) and B100 (100 percent biodiesel) can reduce CO_2 emissions by approximately 15 percent and 78 percent, respectively (NREL, 1998).

Biopower. A 2004 NREL study found that overall, compared to coal-generated electricity, producing electricity with biomass feedstocks will substantially reduce GHG emissions (20 to 200+ percent) and the fossil energy consumption per kilowatt-hour of electricity generated (Spath and Mann, 2004). In addition, emissions of methane, a potent GHG, can be reduced by utilizing biomass residues that would otherwise decompose in landfills (e.g., urban and industrial residues). Biopower generated from biogas captured from landfills, wastewater treatment facilities, or animal feeding operations can also reduce methane emissions. On a national scale, if all wastewater treatment facilities that operate anaerobic digesters and have sufficient influent flow rates (greater than 5 million gallons per day) were to install CHP, approximately 340 MW of clean electricity could be generated, offsetting 2.3 million metric tons of CO_2 emissions annually (U.S. EPA, 2007c).

USE OF BIOPOWER FOR OFFSETS

Entities (corporations, facilities, governments) interested in reducing their CO2 emissions are advised to first strive for cost-effective GHG reductions through internal projects, such as energy efficiency and on-site renewable energy projects. As cost-effective direct options are exhausted, entities may also consider supporting GHG reduction projects that occur outside their organizational boundary—known as "offsets."

Offsets represent GHG reductions that are quantified and verified at one location, but whose emission reductions are "credited" to another location or entity. Under all internationally recognized GHG protocols, biopower projects (including converting LFG to energy, capture and use of anaerobic digester gas, and solid fuel biomass feedstocks) can qualify for offset credits under certain circumstances due to their GHG benefits.

EPA's Climate Leaders program, for example, offers protocols for measuring the GHG benefits from biogas and biomass power projects that meet four key accounting principles:

- **Real**. The quantified GHG reductions must represent actual emission reductions that have already occurred.
- **Additional**. The GHG reductions must be surplus to regulation and beyond what would have happened in the absence of the project or in a business-as-usual scenario based on a performance standard methodology.
- **Permanent**. The GHG reductions must be permanent or have guarantees to ensure that any losses are replaced in the future.
- **Verifiable**. The GHG reductions must result from projects whose performance can be readily and accurately quantified, monitored, and verified.

For more information on offsets and other environmental revenue streams for which biomass might qualify, see *www.epa.gov/chp/documents/ers_program_details.pdf*.

Source: U.S. EPA, 2009; U.S. EPA, 2007d

Air Emissions Considerations with Feedstock Production

The application of fertilizers, pesticides, and herbicides associated with agricultural feedstocks (e.g., corn, soybeans, crop residues) can result in air pollutant emissions, including emissions of particulate matter (PM), nitrogen and sulfur compounds, heavy metals, and volatile organic compounds (VOCs) (U.S. DOE, 2003).

In general, crops grown for bioenergy require fewer pesticides and fertilizers than crops grown for food; nevertheless, mitigation of air pollutants from agriculture is important for all crop production, whether the crop is used for food, feed, or bioenergy. Practices that reduce the need for agricultural chemicals and fertilizers while retaining crop yields and quality contribute to sustainability and increase the viability of biomass as a feedstock resource (U.S. DOE, 2003).

Air Emission Considerations with Biopower

Air emissions associated with biopower vary by feedstock, technology, and the extent to which emission controls are used.

SO_2 and NO_X. Using certain biomass feedstocks—such as wood, wood waste, or crop residues—to produce biopower can reduce SO_2 and NO_X emissions because the sulfur and nitrogen content is much lower than in coal.

- Power plants reduce SO_2 and NO_X emissions when they cofire these biomass feedstocks with coal, compared to using coal alone (U.S. DOE, 2004; Mann and Spath, 2001).
- Biopower facilities using biomass feedstocks in certain types of direct combustion technologies (e.g., fluidized bed boilers) and gasification technologies (e.g., integrated gasification combined cycle, or IGCC) have reduced SO_2 and NO_X emissions, compared to coal-only electricity production (U.S. DOE, 2004a; Mann and Spath, 2001).

- Controlled burning of crop residues for power generation also can reduce SO_2 and NO_X emissions by up to 98 percent, compared to emissions from uncontrolled open burning, which many farmers use to burn their crop residues as waste (U.S. DOE, 2004).

Mercury. Mercury emissions from biopower facilities are significantly less—near zero—than those from coal-burning power plants (NREL, 2003).

Particulate matter. Biopower—and in particular, bioheat—can contribute to PM2.5 emissions. Industrial- and utility-scale biomass combustion facilities must comply with federal and state permits for air pollutants, which require controls for PM. As noted in the text box on this page, permitting requirements for small, non-residential boilers will also be in place in 2009.

However, the burning of wood and wood waste in traditional, residential wood stoves is a significant contributor to PM2.5 concentrations in some areas of the country. Since 1988, all wood stoves manufactured in the United States must be EPA-certified, which means they use one-third less wood than older stoves to produce the same heat and emit 50–70 percent less PM; however, only 20–30 percent of the 10 million wood stoves in use are the newer, certified type.

» **For more information, see** ***www.epa.gov/woodstoves/changeout.html.***

RELEVANT FEDERAL AIR QUALITY STANDARDS

States must comply with federal air quality standards, including the National Ambient Air Quality Standards (NAAQS) established under the Clean Air Act for "criteria" pollutants, which include CO, lead, nitrogen dioxide, particulate matter (PM2.5, PM10), ground-level ozone, and sulfur dioxide (SO_2).

Most power generation facilities (both fossil fuel-based and bioenergy), as well as burning of transportation fuels (both gasoline and biofuels) in vehicles, emit some of these criteria pollutants. States that do not meet one or more of the NAAQS standards are considered "nonattainment" areas and are required to develop and submit State Implementation Plans (SIPs) that indicate how they will meet these standards.

To help meet federal NAAQS requirements for criteria pollutants, EPA provides guidance to states for developing SIPs that quantify and include emission reductions achieved from energy efficiency and renewable energy measures, including bioenergy. For more information, see *www.epa.gov/ttn/oarpg/t1/memoranda/ereseerem_gd.pdf*.

Bioenergy (as well as most fossil fuel-based) facilities may also be subject to additional federal standards for combustion sources and air-permitting requirements for new sources, including New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP) for boilers, gas turbines, and internal combustion engines. Existing combustion sources must obtain NESHAP permits; new combustion sources must install maximum available control technologies (MACT) and meet additional requirements to qualify for both NSPS and NESHAP permits. Meeting these permitting requirements can take significant effort by project developers.

In 2009, EPA will be publishing a proposed area source rule that will apply new emission requirements to all non-residential small boilers. All bioenergy boilers—typically used to produce heat or steam—installed after that date will be subject to emission regulations for new boilers. All bioenergy boilers in place prior to that date will eventually be required to comply with regulations for existing boilers. For more information, see *www.epa.gov/woodheaters/resources.htm*.

States may also have their own permitting requirements in addition to, or that are more stringent than, federal requirements.

Air Emission Considerations with Biofuels

Analyses by EPA and others have found that the effects of biofuels on air pollutant emissions depend strongly on the type of renewable fuel, the engine type and performance, and the vehicle emissions control system performance. In addition, biodiesel impacts on emissions can vary depending on the type of biodiesel (soybean, rapeseed, or animal fats) and type of conventional diesel to which the biodiesel was added (U.S. EPA, 2002).

Ethanol

CO. Because ethanol contains oxygen, adding ethanol to gasoline allows engines to burn fuel more completely, reducing emissions of unburned hydrocarbons; CO emissions can be reduced by 20–30 percent. States with CO nonattainment areas require that fuel contain oxygen and ethanol is blended into gasoline for this reason (U.S. DOE, 2008).

NO_X. Past tests have shown that ethanol-gasoline blended fuels, such as E10 (a blend of 10 percent ethanol and 90 percent petroleum), increase NO_X emissions slightly. However, results on the use of E85 (a blend of 85 percent ethanol and 15 percent petroleum; used in flexible fuel vehicles [FFVs]) have shown that NO_X emissions do not increase (U.S. DOE, 2008).

VOCs. Certain VOCs that are present in gasoline, such as benzene (a carcinogen), are not present in ethanol; thus, adding ethanol to gasoline reduces emissions of these and other exhaust-related VOCs (U.S. DOE, 2008). However, other air toxics (formaldehyde, acetaldehyde, and 1,3-butadiene) are present in ethanol and blending ethanol with petroleum can increase non-exhaust VOCs (U.E. EPA, 2007e).

Biodiesel

CO, PM, SO_2. B20, a blend of 20 percent biodiesel and 80 percent petroleum diesel, helps reduce emissions of PM, CO, and hydrocarbons, compared to conventional diesel. These air emissions from biodiesel-diesel fuel blends generally decrease as the concentration of biodiesel increases. Biodiesel does not produce SO_2 emissions (U.S. EPA, 2002).

NO_X. The effect of biodiesel on NO_x can vary with engine design, calibration, and test cycle. At this time, the data are insufficient to conclude anything about the **average** effect of B20 on NOx; some studies indicate emissions slightly increase while others indicate a slight decrease or neutral response (U.S. EPA, 2002; NREL, 2009).

BIODIESEL VS. CONVENTIONAL DIESEL EMISSIONS IN HEAVY-DUTY ENGINES

One of the most common blends of biodiesel, B20, contains 20 percent biodiesel and 80 percent petroleum diesel by volume. When soy-based biodiesel at this concentration is burned in heavy-duty highway engines, the emissions, relative to conventional diesel, contain approximately:

- 11 percent less CO
- 10 percent less PM
- 21 percent less unburned hydrocarbons
- 2 percent more NO_x

Source: U.S. EPA, 2002

Decreased Air Emissions from Bioproducts Manufacturing

Compared to manufacturing that relies solely on fossil fuels, manufacturing of bioproducts can help reduce certain pollutant emissions, including VOCs and GHGs. This is because many biomass feedstocks used to manufacture bioproducts can also be used to generate power and heat for these same manufacturing processes, thus decreasing or eliminating the need for fossil fuels and associated emissions. Also, bioproducts are often manufactured using lower temperatures and pressures than fossil fuel-based manufacturing; therefore, less combustion may be needed, which may result in fewer air emissions (U.S. DOE, 2003).

NATURAL DISASTERS CAN GENERATE A SUBSTANTIAL VOLUME OF DEBRIS

U.S. EPA's Planning Guide for Disaster Debris highlights the need for communities to plan for the cleanup of debris after a major natural disaster. Based on lessons learned from communities that have experienced such disasters, this guide contains information to help communities prepare for and recover more quickly from the increased solid waste generated by a natural disaster. Major categories of disaster debris include damaged buildings, sediments, green waste, personal property, ash and charred wood—much of which can be productively utilized if plans are in place (e.g., through recycling, as fuel for biopower production).

For more information, see *www.epa.gov/osw/conserve/rrr/imr/cdm/debris.htm*.

3.3.2 WASTE REDUCTION BENEFITS

Reduced Solid Waste from Biopower

The use of biomass residues can reduce the amount of waste that must be disposed of in landfills. MSW is sometimes used in bioenergy production, which diverts the MSW from the waste stream. Burning MSW in boilers for heat or power can reduce the amount of waste that would otherwise be disposed of in landfills by up to 90 percent in volume and 75 percent in weight (U.S. DOE, 2004a). With a range of 137 to 266 million tons of MSW currently landfilled on an annual basis, the potential for volume reduction is significant (U.S. EPA, 2008c). Waste reduction not only saves increasingly limited landfill space, but also helps protect the environment (e.g., water quality in rivers and oceans).

In addition, using agricultural and forest residues for bioenergy production allows for these wastes to be disposed of through controlled combustion, rather than burned in open-air slash piles, which helps control and reduce potentially harmful emissions. Such pollution reduction also provides public health benefits (e.g., maintaining or improving drinking water supplies and reducing illnesses associated with air pollution) (U.S. DOE, 2004a).

Reduced Hazardous and Toxic Wastes from Bioproducts Manufacturing

Many bioproduct manufacturing processes use natural catalysts (e.g., enzymes) and solvents (e.g., water) and produce few or no toxic or hazardous by-products. (In contrast, manufacturing of fossil fuel-based products uses large amounts of aromatic solvents or strong inorganic acids and bases.) In most cases, solid wastes and liquid effluents from biological processes used to make bioproducts are biodegradable or can be recycled or disposed of without extensive treatment. Even in cases where bioproduct manufacturing does release wastes of concern (e.g., production of cellophane produces VOC emissions and high-acid wastewater), the pollution generated is often less than that of similar fossil-based products (e.g., cellophane produces two to three times less pollution than polyurethane). In addition, some chemicals used to make bioproducts could be replaced with more environmentally friendly bio-based chemicals (U.S. DOE, 2003).

3.3.3 LAND RESOURCE CONSIDERATIONS

Soil Impacts. Naturally, using biomass to produce energy can have an impact on land resources. These impacts vary with feedstock and can be positive or negative. Biomass grown for feedstock purposes (in contrast to waste/opportunity fuels) requires large areas of land and can deplete the soil over time. For example, there are long-term economic and environmental concerns associated with removal of large quantities of residues from cropland. Removing residue on some soils could reduce soil quality, promote erosion, and lead to a loss of soil carbon, which in turn lowers crop productivity and profitability (U.S. DOE, 2005).

Ecosystem Impacts. When natural areas or otherwise undeveloped land is converted to agricultural uses to produce biofuel feedstocks, the potential exists for damage to local ecosystems and displacement of species. To minimize land use impacts, fuel crops must be managed so they stabilize the soil, reduce erosion, and protect wildlife habitat.

Forest Health. Significant opportunities may exist to link forest health and bioenergy production. In many forests throughout the western United States, natural ecosystems have been significantly altered by fire suppression and logging practices, creating a high risk of intense wildfire. The surplus biomass from thinning unnaturally overgrown forest areas represents a potentially large renewable energy resource. Forest thinning can be done in a sustainable manner to minimize soil erosion and preserve wildlife habitat (Oregon Department of Energy, 2007). Development of forest biomass harvesting guidelines (see box below) can help ensure that thinning or residue removal is performed in line with the many aspects of forest health.

Land Area. Biomass power plants, much like fossil fuel power plants, require large areas of land for equipment and fuel storage. For example, a small biopower facility that processes 100 tons/day of woody biomass would require approximately 12,500 square feet exclusively for storing a 30-day supply of biomass (assuming average storage height of 12 feet and average density of 40lb/cubic foot). For a larger biopower facility that processes 680 tons/day of feedstock, more than 93,700 square feet of storage space could be needed, which is equivalent to more than two football fields (U.S. EPA, 2007d).

However, if biomass plants burn a waste source such as construction wood waste or agricultural waste, they can provide a benefit by freeing areas of land that might otherwise have been used for landfills or waste piles (U.S. EPA, 2008b).

EPA'S FUTURE MIDWESTERN LANDSCAPES STUDY

The rapid growth of the biofuels industry, which uses crops and other biomass to make liquid fuel, is causing changes in agricultural practices and land uses across the United States, and most strikingly in the Midwest. EPA has initiated the Future Midwestern Landscapes Study to examine projected changes in landscapes and ecosystem services in the Midwest. Given its immediate influence, biofuel production will be studied as a primary driver of landscape change.

By conducting this study, U.S. EPA aims to:

- Understand how current and projected land uses affect the ecosystem services provided by Midwestern landscapes.
- Provide spatially explicit information that will enable EPA to articulate sustainable approaches to environmental management.
- Develop web-based tools depicting alternative futures so users can evaluate trade-offs affecting ecosystem services.

For more information, see *www.epa.gov/ord/esrp/quick-finder/mid-west.htm*.

STATES DEVELOP FOREST BIOMASS HARVESTING GUIDELINES

Biomass harvesting guidelines are designed to fill gaps where existing best management practices may not be sufficient to protect forest resources under new biomass harvesting regimes. States that have developed biomass harvesting guidelines or standards that cover biomass removals include: Maine, Minnesota, Missouri, Pennsylvania, and Wisconsin. Existing guidelines cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soli productivity, silviculture, and disturbance. A Forest Guild (2009) report provides an assessment of existing guidelines and provides recommendations for future forestry guidelines focused on woody biomass removal.

For more information, see *www.forestguild.org/publications/research/2009/biomass_guidelines.pdf*.

ENVIRONMENTALLY SUSTAINABLE PRACTICES FOR BIOMASS FEEDSTOCK PRODUCTION

Bioenergy production has the potential to be a low-input, sustainable energy system. Practices that allow bioenergy to be developed in an environmentally sustainable manner include the following:

- Improvements in crop production are increasing crop yields per acre, thus requiring less land and fewer chemical inputs such as fertilizers and pesticides. Minimizing the use of fertilizers and pesticides for energy crops and crop residues can help protect water quality, air quality, wildlife, and public health.
- Degraded lands and abandoned and underutilized farmland can be used to grow biomass feedstocks rather than using existing farmland.
- Agricultural and forest land on which biomass feedstocks are grown can create new wildlife habitats and protect existing ones (e.g., crop harvesting can be prohibited during bird nesting seasons), while providing open spaces that enhance the quality of life in communities.
- Continued adoption of reduced- and no-till field practices for harvesting crop residues (e.g., corn stover, wheat straw) for cellulosic biofuel production can maintain enough residues in fields to control soil erosion and sustain soil quality.
- Development and use of water-efficient crops will help conserve the amount of water needed for both agricultural and energy crops.
- Transitioning from corn-based ethanol production to cellulosic biofuels will contribute to the environmental benefits of bioenergy because using waste/opportunity feedstocks means less water and chemical use, along with ancillary benefits from using waste productively.
- Production of microalgae can be accomplished in tanks or on degraded lands using brackish or saline water.

3.3.4 WATER RESOURCE CHALLENGES

Water Quality Considerations from Feedstock Production

Chemical fertilizers, pesticides, and herbicides associated with agricultural feedstocks pose a risk to water quality if they enter surface waters. These chemicals can contaminate surface water, groundwater, and drinking water supplies.

Fertilizer Runoff. The influx of fertilizer nutrients into water supplies can lead to eutrophic conditions where algae growth becomes excessive. As this increased plant matter dies, oxygen is consumed in the decomposition process, which can lead to hypoxia—the state of extremely low dissolved oxygen that is deadly for many aquatic species. In the Gulf of Mexico this problem is particularly acute due to the high concentration of farms in the Mississippi River watershed. Agricultural runoff enters the Gulf of Mexico via the Mississippi River and creates a hypoxic zone every summer that damages many valuable fisheries.

» **For more information, see *www.epa.gov/owow/msbasin/hypoxia101.htm*.**

Practices that reduce the need for these chemicals while retaining crop yields and quality contribute to the sustainability and viability of bioenergy production (U.S. DOE, 2003). One of the proposed solutions to the nutrient runoff problem has been to increase the acres of perennial crops (e.g., switchgrass) relative to annual crops (e.g., corn). Perennial crops require fewer applications of pesticides and fertilizers. When strategically placed, they can absorb the runoff from annual crop plantings. Other benefits of perennial crops include less erosion and less soil compaction due to less soil disturbance (U.S. DOE, 2005).

Another potential solution to the nutrient runoff problem is to preserve or plant riparian buffers (vegetated regions adjacent to streams and wetlands). Based on recent studies, riparian buffers of various types (grass, forest, wetland, and combinations thereof) can be effective at reducing nitrogen in riparian zones, especially nitrogen flowing in the subsurface, in areas where soil type, hydrology, and biogeochemistry are conducive to microbial denitrification and plant uptake. While some narrow buffers (1 to 15 meters) may remove nitrogen, wider buffers (>50 meters) more consistently remove significant portions of nitrogen (U.S. EPA, 2005).

In contrast to potential adverse water quality impacts from diverting previously uncultivated lands to energy crops, redirecting large quantities of animal manure to bioenergy uses can lessen nutrient runoff and reduce contamination of surface water and groundwater resources (U.S. DOE, 2005).

Herbicides and Pesticides. Bioenergy crops such as tree crops and switchgrass require herbicide application prior to establishment and during the first year to minimize competition from weeds until the crops are well established. However, tree crops and switchgrass need only one-tenth the amounts of herbicides and pesticides required on average by agricultural crops. Studies are showing that herbicide migration into groundwater is less likely to occur with application to biomass crops (ORNL, 2005).

Temperature and Chemical Pollution. Water pollution is also a potential concern with biomass power plants. As is the case with fossil fuel power plants, pollutants can build up in the water used in the biomass power plant's boiler and cooling system. In addition, the water used for cooling is much warmer when it is returned to the lake or river than when it was removed. Pollutants and higher water temperatures can harm fish and plants in the lake or river where the power plant water is discharged. This discharge usually requires a permit and is monitored.

Water Use Changes from Feedstock Production and Biofuels

Water use is another concern associated with feedstock production and biomass processing. Most current agricultural feedstocks have irrigation requirements, and biofuels plants currently use several gallons of water for every gallon of fuel produced. Because these plants are usually built close to where the feedstocks are grown to minimize transportation costs, local water supplies are drawn upon to serve both irrigation and production needs. Water use is a particular concern in arid regions and where water resources are already being depleted (Oregon Environmental Council, 2007).

3.3.5 FOOD SUPPLY CHALLENGES

One concern regarding the expansion of bioenergy is that crops grown for food, particularly corn, could be diverted from the global food chain to the biofuels supply chain. In the case of corn, only a small amount of U.S. corn is currently exported to undernourished populations. The 24 countries where at least one-third of the population is undernourished import less than 0.1 percent of U.S. corn (Muller et al., 2007).

A more pressing concern may be the conversion of land from agricultural crop production to biomass feedstock production in developing countries where food shortages exist. The demand for biofuels from wealthy countries could exacerbate this problem in developing countries. International and national policies may be needed to protect local food supplies. The issue of bioenergy's relationship to agriculture also needs additional analysis, along with further investigation of the many other issues that affect world food, land use, hunger, and poverty (Muller et al., 2007).

3.4 FEEDSTOCK SUPPLY CHALLENGES

3.4.1 LOCATING HIGH-QUALITY FEEDSTOCKS FOR BIOENERGY

It is critical for bioenergy producers to have access to a reliable, high-quality biomass feedstock supply. For both biofuels and biopower, feedstocks should ideally be available:

- For a relatively fixed cost over long periods of time (i.e., for the life of the bioenergy project).
- From a consistent source or sources in close proximity to the bioenergy plant.
- With high-quality characteristics, such as high heating value, low moisture and ash content, and consistent particle size.

Obtaining biomass feedstocks with these qualities can be challenging. Factors that can cause uncertainty in the availability of a suitable feedstock over time include:

- **Transportation Constraints**. Transportation costs impose limits on the areas over which a biomass feedstock can be obtained cost effectively.
- **Competition for Feedstocks**. Competition can include:
  - *Alternative end uses:* If the feedstock has more than one end use, a bioenergy producer might need to compete with other markets for the use of the resource.
  - *Competing land uses:* Biomass producers may shift production to other resources if they become more profitable to grow than the original feedstock.

STORAGE CHALLENGES

Once feedstocks are identified and transported to biorefineries, they are accumulated in piles, pretreated and/or processed, and then placed in buffer storage containers prior to use. Challenges associated with storing feedstocks include:

Volume. Biomass feedstocks can have low bulk densities, and as a result, prep-yards and storage facilities must be large enough to accommodate the large volumes necessary for bioenergy production. For example, a 30-day supply of woody biomass (average density 40 pounds per cubic foot) for a biorefinery with a 680 tons per day conversion system would cover an area larger than two football fields, if piled to an average height of 12 feet.

Pile management. As feedstocks arrive at biorefineries they are piled in prep-yards prior to treatment and processing, using either front end loaders or a radial stacker (depending on the volume required). Piles must be carefully managed to maintain the quality of the feedstock, which may require a range of precautions from dust control to combustion prevention.

Shelf life. Because biomass feedstocks consist of organic material, they are susceptible to degradation and decomposition over time. Feedstocks have a "shelf life" that is dependent on their moisture content and the climate in which they are stored. To ensure that feedstocks remain stable prior to use, storage facilities may need to install environmental control technologies, which can be costly.

Source: U.S. EPA, 2007d; U.S. DOE, 2004b

- *Competition among bioenergy producers:* Bioenergy producers may have to compete with one another for a scarce feedstock supply as an increasing number of bioenergy projects are deployed.

- **Natural causes**. Weather, agricultural pests, and plant disease can decrease the quantity and quality of the desired supply available from a given agricultural or energy crop source.
- **Seasonality of feedstocks**. Some feedstocks are seasonal and may have limited availability depending on the time of year. Bioenergy producers may need to engage with multiple suppliers and/or employ flexible conversion processes capable of using a variety of feedstocks to ensure a steady supply of feedstock and consistent levels of energy output throughout the year. Working with multiple landowners to obtain feedstocks may prove challenging since landowners may have competing objectives related to forest stewardship, forest management plans, financial concerns, and other priorities.

These factors contribute to uncertainty and/or volatility in feedstock prices. The first two factors—transportation and competition—are critical, and can be influenced by policy or program design.

Transportation

The cost of a biomass resource is influenced in large part by transportation costs—the expenditure required to bring the feedstock to the bioenergy plant. Because biomass provides less energy per unit of weight or volume than do fossil fuels, more feedstock is required to generate a given output. Therefore, the resource cannot be profitably transported as far as coal or oil, so bioenergy facilities must be located within an area of concentrated feedstock.

Example

BIOMASS COMMODITY EXCHANGE

Wisconsin is developing the Biomass Commodity Exchange (BCEX) to help organize the way new businesses and landowners connect to provide biomass for bioenergy applications. The BCEX project has been charged with creating an implementation plan for a commodity exchange as a means to increase the efficiency of the supply chain providing biomass to the existing biofuels industries and the emerging concept of the forest biorefinery. The implementation plan will also examines the future trade of closed-loop energy crops, such as willow, poplar and switchgrass and as an approach to offset CO2 emissions through synergies created with other regulated exchanges such as the Chicago Climate Exchange.

For more information, see *www.biomasscommodityexchange.com*.

The distance that biomass can be transported profitably depends on numerous factors, including the cost of transportation fuel and quality of the biomass, which are subject to considerable variability by feedstock and location. DOE estimates feedstock transportation costs as usually in the range of $0.20 to $0.60 per dry ton per mile (U.S. DOE, 2005). All transportation costs will vary with local conditions, but one of the primary factors influencing transportation costs is the cost of diesel fuel. Also, using barges and rail to transport feedstocks is less expensive than trucking per unit of feedstock.

Competition for Feedstocks

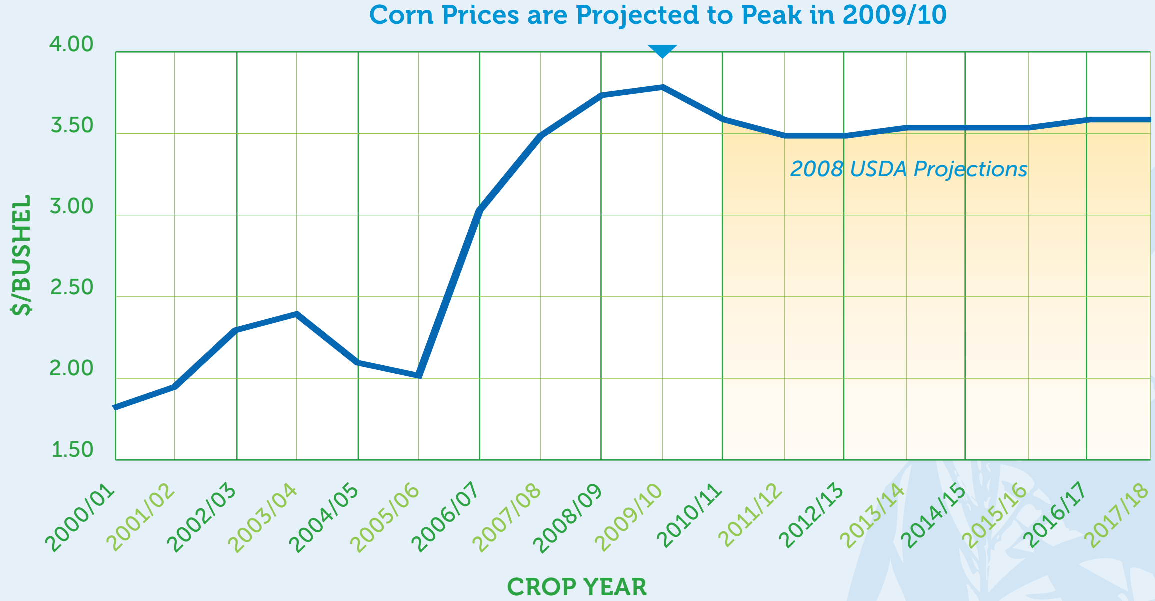
In some situations, biomass producers might be reluctant to agree to long-term supply contracts, which can also contribute to cost uncertainties. For example, biomass producers want the freedom to sell to whichever market or end user is willing to pay the most, and may therefore be hesitant to agree to long-term contracts if the feedstock has multiple end uses. Biomass producers may also be reluctant to enter into long-term contracts when the potential exists for commodities other than the feedstock to become more profitable during the life of the contract (e.g., from soybeans to corn). As producers shift production away from the original feedstock to other resources, the cost of obtaining a given quantity of the feedstock will increase.

For example, as shown in Figure 3-1, the price of corn has increased significantly in recent years and is projected to remain high by historical standards for the foreseeable future. Some studies have attributed these trends to increased corn-based ethanol production, although debate exists as to how much of this price increase can be attributed to other factors such as rising energy prices. Nonetheless, if corn prices are predicted to increase, farmers will be even more reluctant to enter into long-term contracts because they would often prefer to hedge in hopes of higher prices later.

Feedstock availability and price will ultimately determine the feasibility of a proposed bioenergy plant. Potential bioenergy investors will extend the capital needed to finance proposed projects only if the projects will generate an attractive return. Typically, investors look to recover their initial capital outlays in just a few years. Any variability in the availability or cost of suitable biomass feedstocks could significantly reduce the return on their investment. Therefore, investors are unlikely to help finance a project unless both long-term feedstock supply plans and purchase agreements for the energy produced are in place.

FIGURE 3-1. U.S. CORN PRICES, 2000 TO 2018

Source: USDA Agricultural Projections to 2018, February 2008



Some states have enacted policies and other measures to reduce the risk of investing in bioenergy. To learn more about the actions that states can take to make the investments more attractive, see Chapter 5, How Can States Facilitate Financing of Bioenergy Projects?

3.5 INFRASTRUCTURE CHALLENGES

3.5.1 PRODUCT DELIVERY CHALLENGES FOR ETHANOL

Pipeline Limitations

All motor fuels must be transported from refineries to refueling stations as efficiently and cost effectively as possible. When the fuel must be transported a great distance, as is often the case, pipelines are typically the least-cost option.

Unlike conventional refined motor fuels (e.g., gasoline, diesel), which are routinely shipped via pipeline, the distribution of ethanol through the nation's pipeline network poses challenges largely due to several properties of the biofuel:

- Ethanol will easily absorb water that has accumulated in pipelines, potentially rendering it useless as a motor fuel.
- Because it readily absorbs water, ethanol cannot be separated from other products in a petroleum pipeline by the typical method of sending water between batches of different petroleum products.
- Ethanol is an effective solvent/cleansing agent and therefore may be contaminated by residues of other materials that have been shipped through the pipeline.
- Ethanol is corrosive and can damage pipeline parts and storage tanks.

In addition, the current U.S. petroleum pipeline network is not optimally sited for ethanol distribution, production of which is heavily concentrated in the Midwest.

ETHANOL PIPELINE IN CENTRAL FLORIDA

Example

In September 2008, Kinder Morgan Energy Partners, L.P. successfully performed test shipments of batches of denatured ethanol in its 16-inch Central Florida Pipeline—otherwise used to transport gasoline between Tampa and Orlando. Approximately $10 million in modifications were made to the line in preparation for the ethanol shipments, including chemically cleaning the pipeline, replacing equipment that was incompatible with ethanol, and expanding storage capacity at the Orlando terminal. As a direct result of the tests, Kinder Morgan announced in December 2008 that the pipeline would become the first in the United States to carry commercial batches of ethanol. Kinder Morgan has also proposed creating a dedicated 8-inch "inter-terminal" ethanol pipeline to supply its Hooker's Point terminal in Tampa.

Source: Kinder Morgan, 2008a and 2008b

As a result of these factors, ethanol is typically not transported in large quantities by pipeline, but instead by barge, rail, or truck, which are all more costly and less efficient than shipping via pipelines. In 2005, rail was the primary transportation mode for ethanol, shipping 60 percent of ethanol production, or approximately 2.9 billion gallons. Trucks shipped 30 percent and barges 10 percent (USDA, 2007). It typically costs roughly $0.17 to $0.20 per gallon to transport ethanol by rail, whereas it would cost approximately $0.05 per gallon to transport by pipeline (RFA, 2008). This added expense hurts the competitiveness of ethanol relative to conventional refined fuels.

Although it is possible to convert some existing pipelines for ethanol shipment, the cost of doing so is usually prohibitive and difficult to justify. Developing a new, dedicated ethanol distribution infrastructure would help to address many of these challenges; however, the high construction and capital costs and the challenge of obtaining new rights-of-way make building a new pipeline distribution system unlikely unless the need arises to ship very large quantities of ethanol. The U. S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) is researching a variety of technologies that could make large-quantity distribution of ethanol by pipeline more feasible in the future.

» **For more information, see** ***http://primis.phmsa.dot.gov/comm/Ethanol.htm?nocache=406.***

Example

DEVELOPING INFRASTRUCTURE: TENNESSEE'S BIOFUEL GREEN ISLAND CORRIDOR NETWORK

In 2006, the state of Tennessee established a grant program to facilitate development of the Biofuel Green Island Corridor Network along Tennessee's interstate system and major highways. The goal of this program is to help establish readily available "green island" refueling stations for B20 and E85 no more than 100 miles apart along heavily traveled transportation corridors. Ultimately, the state hopes to have at least one B20 and one E85 station in 30 priority counties, and three of each station type within all major urban areas. The state has allocated $1.5 million in state funds and $480,000 in funds from the federal Congestion Mitigation and Air Quality Improvement (CMAQ) program to pay for up to 80 percent of fuel station installation costs, offering grantees a maximum of $45,000 per pump or $90,000 per location. The program has also focused on installing visible and easily recognizable signage along the corridors to indicate where B20 and E85 stations are located and encourage their use. As of October 2008, there were 22 E85 stations and about 27 B20 stations in Tennessee.

Source: Tennessee Department of Transportation, 2009

Fueling System Limitations

A second major infrastructure challenge to increased ethanol use is to ensure there are sufficient fueling stations offering access to E-85 blends of ethanol to support the increasing volumes of renewable fuels as set forth in EISA.

As of 2008, there were more than 1,600 stations offering E85 in the United States. However, due to the distribution issues discussed above, most of these stations are located in the Midwest, where most ethanol production currently occurs. The highest concentrations of E85 stations are found in Illinois, Indiana, Iowa, Minnesota, and Wisconsin; although E85 is commercially available in more than 40 states across the country.

TRANSATLAS INTERACTIVE ALTERNATIVE FUEL MAP

The U.S. Department of Energy (DOE) and the National Renewable Energy Lab (NREL) have developed a comprehensive mapping tool to help industry and government planners implement alternative fuels and advanced vehicles. The new TransAtlas tool combines different types of geographic data to identify areas with potential for developing advanced transportation projects. NREL employed user-friendly Google Maps to display the locations of existing and planned alternative fueling stations, concentrations of different vehicle types, alternative fuel production facilities, roads, and political boundaries.

For more information, see *www.afdc.energy.gov/afdc/data/geographic.html*.

DOE estimates that 6.8 million light-duty FFVs are on U.S. roadways, and this number is likely to grow. FFVs are designed with specific modifications that allow them to run on either traditional gasoline (which may contain as much as 10 percent ethanol, depending on state regulations) or E85.[3] Unfortunately, many owners of FFVs do not realize their vehicles can run on E85 and/or don't know where to find E85 stations. Many more fueling stations offering E85 are needed, as is greater market visibility, if states want to capitalize on the existing potential market of FFV owners.

» **To locate E85 fueling stations, see** ***www.afdc.energy.gov/afdc/ethanol/ethanol_locations.html.***

3 Vehicles that are not designated as E85-compatible should not use E85 fuel because the high content of ethanol can damage the engine and fueling system. http://www.afdc.energy.gov/afdc/e85toolkit/eth_vehicles.html

3.6 RESOURCES FOR DETAILED INFORMATION

Resource	Description	URL
Bioenergy		
Economic Impacts of Bioenergy Production and Use, U.S. DOE, SSEB Southeast Biomass State and Regional Partnership, October 2005.	Summarizes the benefits of bioenergy production in the U.S., including job creation, reduced demand for fossil fuels, and expanded tax bases.	*www.vienergy.org/Economics.pdf*
State Energy Alternatives Web Site, U.S. DOE, National Conference of State Legislatures.	Provides information on state-specific biomass resources, policies, and status as well as current biofuels and biopower technology information.	*http://apps1.eere.energy.gov/states/*
An Assessment of Biomass Harvesting Guidelines, Evans and Perschel, Forest Guild, 2009.	Presents an assessment of existing biomass harvesting guidelines and provides recommendations for the development of future guidelines.	*www.forestguild.org/publications/research/2009/biomass_guidelines.pdf*
Planning for Disaster Debris, U.S. EPA, 2008.	Provides information and examples for developing a disaster debris plan that will help a community identify options for collecting, recycling, and disposing of debris in the event of a natural disaster.	*www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/disaster.htm*
Biopower/Bioheat		
Biomass Power and Conventional Fossil Systems with and without CO_2 Sequestration—Comparing the Energy Balance, Greenhouse Gas Emissions, and Economics, NREL, January 2004.	Provides a comparative analysis of a number of different biopower, natural gas, and coal technologies.	*www.nrel.gov/docs/fy04osti/32575.pdf*
Economic Impacts Resulting from Co-Firing Biomass Feedstocks in Southeastern U.S. Coal-Fired Power Plants, Presentation by Burton English et al., University of Tennessee.	Summarizes the economic impacts in eight southeastern states from using biomass to co-fire power plants that traditionally have only used coal for fuel.	*www.farmfoundation.org/projects/documents/english-cofire.pptprojects/documents/english-cofire.ppt*
Green Power Equivalency Calculator, U.S. EPA.	Allows any bioenergy user to communicate to internal and external audiences the environmental impact of purchasing or directly using green power in place of fossil fuel derived energy by calculating the avoided carbon dioxide (CO2) emissions. Results can be converted into an equivalent number of passenger cars, gallons of gasoline, barrels of oil, or American households' electricity use.	*www.epa.gov/grnpower/pubs/calculator.htm*
Job Jolt: The Economic Impacts of Repowering the Midwest: The Clean Energy Development Plan for the Heartland, Regional Economics Applications Laboratory, November 2002.	Analyzes the economic and job creation benefits of implementing a clean energy plan in the 10-state Midwest region.	*www.michigan.gov/documents/nwlb/Job_Jolt_RepoweringMidwest_235553_7.pdf*

Resource	Description	URL
Biofuels/Bioproducts		
Alternative Fueling Station Locator, U.S. DOE.	Allows users to find alternative fuels stations near a specific location on a route, obtain counts of alternative fuels stations by state, view U.S. maps, and more. The following alternative fuels are included in the mapping application: compressed natural gas, E85, propane/liquefied petroleum gas, biodiesel, electricity, hydrogen, and liquefied natural gas.	*www.afdc.energy.gov/afdc/data/geographic.html*
Biomass Energy Data Book, ORNL, September 2008.	Describes a meta-analysis of energy balance analyses for ethanol, revealing the sources of differences among the different studies.	*http://cta.ornl.gov/bedb/pdf/Biomass_Energy_Data_Book.pdf*
Changing the Climate: Ethanol Industry Outlook 2008, Renewable Fuels Association (RFA), 2008.	Forecasts that 4 billion gallons of ethanol production capacity will come on line from 68 biorefineries being constructed in 2008 and beyond, increasing the 2007 figure by nearly 50%.	*www.ethanolrfa.org/objects/pdf/outlook/RFA_Outlook_2008.pdf*
Contribution of the Ethanol Industry to the Economy of the United States, RFA, 2007.	Finds that the industry spent $12.5 billion on raw materials, other inputs, and goods and services to produce about 6.5 billion gallons of ethanol in 2007. An additional $1.6 billion was spent to transport grain and other inputs to production facilities; ethanol from the plant to terminals where it is blended with gasoline; and co-products to end-users.	*www.ethanolrfa.org/objects/documents/576/economic_contribution_2006.pdf*
Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion, University of Tennessee, 2006.	Finds that producing 60 billion gallons of ethanol and 1.6 billion gallons of biodiesel from renewable resources by 2030 would likely result in development of a new industrial complex with nearly 35 million acres planted dedicated to energy crops.	*http://beag.ag.utk.edu/pp/Ethanolagimpacts.pdf*
Ethanol and the Local Community, RFA, 2002.	Summarizes possible effects of ethanol production on local economic development.	*www.ethanolrfa.org/objects/documents/120/ethanol_local_community.pdf*
Greener Fuels, Greener Vehicles: A State Resource Guide, National Governors' Association, 2008.	Discusses alternative transportation fuels and vehicle technologies.	*www.nga.org/Files/pdf/0802GREENERFUELS.PDF*
Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use, U.S. EPA, April 2007.	Provides a summary of GHG emissions from a variety of advanced fuel options.	*www.epa.gov/oms/renewablefuels/420f07035.htm*
New Analysis Shows Oil-Savings Potential of Ethanol Biofuels, National Resources Defense Council (NRDC), 2006.	Describes NRDC's meta-analysis of energy balance papers and its standardized methods.	*www.nrdc.org/media/pressreleases/060209a.asp*
A Rebuttal to "Ethanol Fuels: Energy, Economics and Environmental Impacts," National Corn Growers Association, 2002.	Refutes the contention in a previous article that more energy goes into producing ethanol than ethanol itself can actually provide, creating a negative energy balance.	*www.ethanolrfa.org/objects/documents/84/ethanolffuelsrebuttal.pdf*
Renewable Fuel Standard Program, U.S. EPA.	Describes efforts undertaken by U.S. EPA toward a National Renewable Fuels Standard under requirements of the Energy Policy Act of 2005. While these requirements are superseded by more recent legislation, links from this page provide useful background. In particular, the discussion of estimated costs summarizes the expected incremental costs of policies advancing ethanol.	*www.epa.gov/oms/renewablefuels/*

Resource	Description	URL
Regulatory Impact Analysis: Renewable Fuel Standard Program, U.S. EPA, 2007.	Examines proposed standards that would implement a renewable fuel program as required by the Energy Policy Act of 2005. It notes, however, that renewable fuel use is forecast to exceed the standards due to market forces anyway.	*www.epa.gov/OMS/renewablefuels/420r07004-sections.htm*
SmartWay Grow & Go Factsheet on Biodiesel, U.S. EPA, October 2006.	Describes how biodiesel is made, its benefits versus vegetable oil, performance, availability, affordability, and other characteristics.	*www.epa.gov/smartway/growandgo/documents/factsheet-biodiesel.htm*
SmartWay Grow & Go Factsheet on E85 and Flex Fuel Vehicles, U.S. EPA, October 2006.	Describes E85-fuel and flex-fuel vehicles, including their affordability and benefits.	*www.epa.gov/smartway/growandgo/documents/factsheet-e85.htm*
State-Level Workshops on Ethanol for Transportation: Final Report.	Summarizes a series of DOE-sponsored, state-level workshops exploring and encouraging construction of ethanol plants.	*www.nrel.gov/docs/fy04osti/35212.pdf*
TransAtlas Interactive Alternative Fuel Map, U.S. DOE.	Provides user-friendly Google Maps to display the locations of existing and planned alternative fueling stations, concentrations of different vehicle types, alternative fuel production facilities, roads, and political boundaries.	*www.afdc.energy.gov/afdc/data/geographic.html*
Analysis of Potential Causes of Consumer Food Price Inflation, RFA, 2007.	Asserts that the "marketing bill," not increased ethanol production, is responsible for rising food prices.	*www.ethanolrfa.org/resource/facts/food/documents/Informa_Renew_Fuels_Study_Dec_2007.pdf*
Ethanol Juggernaut Diverts Corn from Food to Fuel, Raloff, Janet, Science News, 2007.	Makes the case that ethanol is driving up food prices.	*www.sciencenews.org/view/generic/id/8179/title/Food_for_Thought__Ethanol_Juggernaut_Diverts_Corn_from_Food_to_Fuel*
Food versus Fuel in the United States, Institute for Agriculture and Trade Policy, 2007.	Finds that biofuel production is not diverting food from tables in the U.S. or abroad.	*www.iatp.org/iatp/publications.cfm?accountID=258&refID=100001*
U.S. Corn Growers: Producing Food and Fuel, National Corn Growers Association, 2006.	Provides the corn growers' perspective that producing food and fuel from corn is working out well, without undue impact on food prices.	*www.ncga.com/files/pdf/FoodandFuelPaper10-08.pdf*
Aggressive Use of Bioderived Products and Materials in the U.S. by 2010, A.D. Little, Inc., 2001.	The presentation and report summarize near-term opportunities to dramatically increase the use of biomass to make nonfuel products.	*www.p2pays.org/ref/40/39031.pdf*
Industrial Bioproducts: Today and Tomorrow, U.S. DOE, July 2003.	The report finds that a bioindustry could harness the energy and molecular building blocks of biomass (crops, trees, grasses, crop residues, forest residues, animal waste, and municipal solid waste) to create products now manufactured from petroleum, making us far less dependent on fossil fuels.	*www.brdisolutions.com/pdfs/BioProductsOpportunitiesReportFinal.pdf*
Preliminary Screening Technical and Economic Assessment of Synthesis Gas to Fuels and Chemicals with Emphasis on the Potential for Biomass-Derived Syngas, NREL, 2003.	Summarizes opportunities for biomass to be used to manufacture a variety of products beyond fuels alone.	*www.nrel.gov/docs/fy04osti/34929.pdf*

3.6 RESOURCES FOR DETAILED INFORMATION *(cont.))*

Resource	Description	URL
Environmental Life Cycle Implications of Fuel Oxygenate Production from California Biomass – Technical Report, NREL, 1999.	Looks at the costs and benefits of biomass-derived ethanol, ETBE, and E10 as fuel oxygenates across their life cycles.	*www-erd.llnl.gov/FuelsoftheFuture/pdf_files/lifecyclecalif.pdf*
Quantifying Cradle-to-Farm Gate Life-Cycle Impacts Associated with Fertilizer used for Corn, Soybean, and Stover Production, NREL, May 2005.	Documents the costs, such as eutrophication, and benefits of nitrate and phosphate fertilizers used in production of three crops.	*www1.eere.energy.gov/biomass/pdfs/37500.pdf*
Life Cycle Analysis of Ethanol from Corn Stover, NREL, 2002.	This comprehensive accounting of ethanol's flows to and from the environment focuses on ethanol produced from corn stover	*www.nrel.gov/docs/gen/fy02/31792.pdf*
Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus: Final Report, NREL, 1998.	Examines the relative costs and benefits of using biodiesel versus petroleum diesel in an urban bus.	*www.nrel.gov/docs/legosti/fy98/24089.pdf*
Life Cycle Assessment of Biodiesel versus Petroleum Diesel Fuel, Institute of Electrical and Electronics Engineers, 1996.	The proceedings of the 31st Intersociety Energy Conversion Engineering Conference, held August 11–16, 1996, in Washington, DC.	Accessible by subscription only
Life Cycle Assessment of Biomass-Derived Refinery Feedstocks for Reducing CO2, NREL, 1997.	Discusses the two processes for producing 1,4-butanediol. The first process is the conventional hydrocarbon feedstock-based approach, utilizing methane to produce formaldehyde, and acetylene with synthesis under conditions of heat and pressure. The second is a biomass-based feedstock approach where glucose derived from corn is fermented.	Not available online
Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant, NREL, 2001.	Reports on a cradle-to-grave analysis of all processes necessary for the operation of a coal-fired power plant that co-fires wood residue, including raw material extraction, feed preparation, transportation, and waste disposal and recycling.	Accessible by subscription only
Understanding Land Use Change and U.S. Ethanol Expansion, RFA, November 2008.	Discusses historical agricultural land use and crop utilization trends, explores the role of increased productivity, looks at the contributions of ethanol feed co-products, and examines global agricultural land use projections obtained from Informa Economics.	*www.ethanolrfa.org/objects/documents/2041/final_land_use_1110_w_execsumm.pdf*
National Biofuels Action Plan, Biomass Research and Development Board, October 2008.	Outlines areas where cooperation between federal agencies will help to evolve bio-based fuel production technologies into competitive solutions for meeting U.S. fuel demands. Seven key areas for action are identified: feedstock production; feedstock logistics; conversion of feedstock to fuel; distribution; end Use; sustainability; and Environment, Health, and Safety.	*www1.eere.energy.gov/biomass/pdfs/nbap.pdf*
Tools for Evaluating Benefits		
AirCRED, Argonne National Laboratory, August 2007.	This tool is used to support local air emission reductions claims associated with alternative-fuel vehicles within the State Implementation Planning process.	*www.transportation.anl.gov/modeling_simulation/AirCred/index.html*

3.6 RESOURCES FOR DETAILED INFORMATION *(cont.))*

Resource	Description	URL
Biomass Technology Analysis Models and Tools.	Web sites of models and tools that demonstrate biomass technologies and uses, and can be used in life-cycle assessments. Most tools can be applied on a global, regional, local, or project basis.	*www.nrel.gov/analysis/analysis_tools_tech_bio.html*
Biomass Feedstock Composition and Property Database.	Provides data results from analysis of more than 150 samples of potential biofuels feedstocks, including corn stover, wheat straw, bagasse, switchgrass and other grasses, and poplars and other fast-growing trees.	*www1.eere.energy.gov/biomass/feedstock_databases.html*
CHP Emissions Calculator, U.S. EPA.	Enables a quick and easy analysis of the criteria air pollutant and GHG emission reductions from incorporating CHP designs into plants and production facilities. It also translates these reductions into "cars" and "trees" to convey their value to a nontechnical audience.	*www.epa.gov/chp/basic/calculator.html*
Clean Air Climate Protection Software, ICLEI and NACAA.	Helps local governments create greenhouse gas inventories, quantify the benefits of reduction measures, and formulate local climate action plans.	*www.cacpsoftware.org/*
Emissions & Generation Resource Integrated Database (EGRID), U.S. EPA.	Provides a comprehensive database of electric-sector emissions at the plant, state, and regional levels. These can be compared to emissions from biopower to estimate emissions' effects.	*www.epa.gov/cleanrgy/egrid/index.htm*
Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, Argonne National Laboratory, August 2007.	Includes full fuel-cycle and vehicle-cycle emissions and energy estimation capability. While not a full life-cycle assessment tool, it allows estimation of upstream emissions and energy effects. For some state policy questions, it may provide sufficient analytic detail on its own. For decisions with greater financial implications, it may be most appropriate to use for initial screening to support development of a more detailed study. States may wish to use GREET directly or to consider analyses that have been done using this tool.	*www.transportation.anl.gov/modeling_simulation/GREET/*
Job and Economic Development Impact (JEDI) Models.	Easy-to-use, spreadsheet-based tools that analyze the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels.	*www.nrel.gov/analysis/jedi*
Power Profiler, U.S. EPA.	Provides a quick estimate of electricity emissions rates by location, which could be compared to emissions from biopower to estimate emissions effects.	*www.epa.gov/grnpower/buygp/powerprofiler.htm*
Standard Biomass Analytical Procedures.	Provides tested and accepted methods for performing analyses commonly used in biofuels research.	*www1.eere.energy.gov/biomass/analytical_procedures.html*
Theoretical Ethanol Yield Calculator.	Calculates the theoretical ethanol yield of a particular biomass feedstock based on its sugar content.	*www1.eere.energy.gov/biomass/ethanol_yield_calculator.html*
Thermodynamic Data for Biomass Conversion and Waste Incineration, NREL, National Bureau of Standards.	Provides heat of combustion and other useful data for biopower and biofuels research on a wide range of biomass and non-biomass materials.	*www1.eere.energy.gov/biomass/pdfs/2839.pdf*

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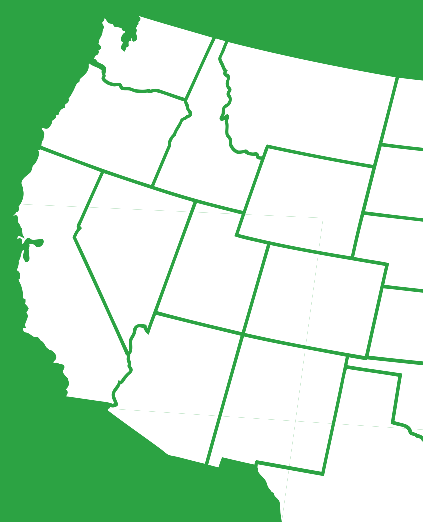
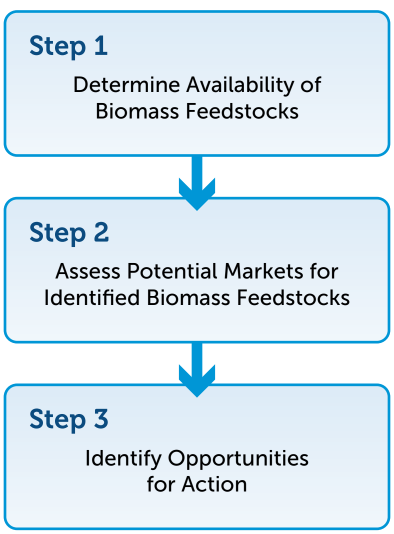


CHAPTER FOUR

How Can States Identify Bioenergy Opportunities?

After learning about the benefits and challenges of bioenergy (Chapter 3), state decision makers can consider whether they want to use bioenergy to meet state energy, environmental, and economic goals.

If states decide they want to promote bioenergy, they should consider the three steps shown below. Following these steps will help ensure that states (1) fully understand the most appropriate bioenergy activities for them, and (2) design policies and programs tailored to the market conditions and resource availability unique to each state.



Note: The order in which Steps 1 and 2 are completed is not critical as both steps are equally important to develop a rational approach.

DOCUMENT MAP

CHAPTER FOUR CONTENTS

Example

FLORIDA'S FARM TO FUEL INITIATIVE

In September 2005, inspired by the "25x'25" initiative—a group of stakeholders promoting expansion of biomass from farms, forests, and ranches to provide 25 percent of the total energy consumed in the United States by 2025—the state of Florida looked closely at its energy profile and resource base to determine how more biomass could be used sustainably in the state.

Through an assessment of market conditions Florida determined that the state was one of the nation's largest consumers of both petroleum gasoline and nonrenewable electricity in the United States. Florida also identified more than a dozen types of produce for which it is ranked first or second in production and sales value in the United States (i.e., determined potential feedstocks and markets). The Florida Department of Agriculture and Consumer Services held its first stakeholder meeting in January 2006 to develop a proposal to match the state's needs with available resources, and identified opportunities for action.

As a result, the Farm to Fuel Initiative was enacted in June 2006 as a comprehensive strategy for promoting renewable energy within the state. The main objective of the program is to enhance the market for and promote production and distribution of renewable energy from Florida-grown crops, agricultural wastes and residues, and other biomass to enhance the value of agricultural products and expand agribusiness in the state. The program offers competitive renewable energy matching grants for research and development, demonstration, and commercialization projects relating to bioenergy based on Florida-specific criteria. The program awarded $25 million to 12 projects across the state in 2008.

For more information, see: *www.floridafarmtofuel.com/*.

Source: Florida Department of Agriculture and Consumer Services, 2008 and 2007

4.1 STEP 1: DETERMINE AVAILABILITY OF BIOMASS FEEDSTOCKS

A complete inventory of its biomass feedstocks will allow a state to fully assess the range of options for bioenergy development. Biomass feedstocks are available across the United States, especially in the Midwest and Southeast (see Figure 4-1). However, each state possesses its own unique blend of bioenergy feedstocks. State-specific information is necessary to ensure pursuit of the most technically and economically viable bioenergy activities for a state.

When assessing the availability of potential biomass feedstocks, it is important for decision makers to consider all types, including waste/opportunity fuels and energy crops, as discussed in Chapter 2. States should pay particular attention to obtaining accurate estimates of biomass feedstock availability because miscalculations can greatly impact the economic viability and successful operation of bioenergy projects.

The key question each state must answer while assessing its available feedstocks and completing Step 1 is:

What is the total fuel potential of all biomass feedstocks, by location, in the state?

To develop an assessment of biomass resource availability, states should first see whether they can use existing data sources (see Section 4.1.1). If existing sources prove insufficient, states may want to consider conducting a biomass assessment (see Section 4.1.2). Nothing takes the place of a detailed, on-the-ground biomass resource assessment when considering a project.

REGIONAL BIOMASS FEEDSTOCK AVAILABILITY

Locations in all regions of the country have opportunities to take advantage of waste and opportunity fuels for biopower and bioheat generation. With respect to advanced biofuels production, regionally, cellulosic ethanol production from corn and wheat residues would probably occur most in the Midwest; dedicated crop production would most likely occur in the South/Southeast; and cellulosic ethanol production from wood and forest residues would occur in the West, Southeast, and Northeast (assuming relatively short transportation distances from feedstock to production facility) (Ugarte et al., 2006).

4.1.1 USE EXISTING RESOURCES TO DETERMINE BIOMASS FEEDSTOCK AVAILABILITY

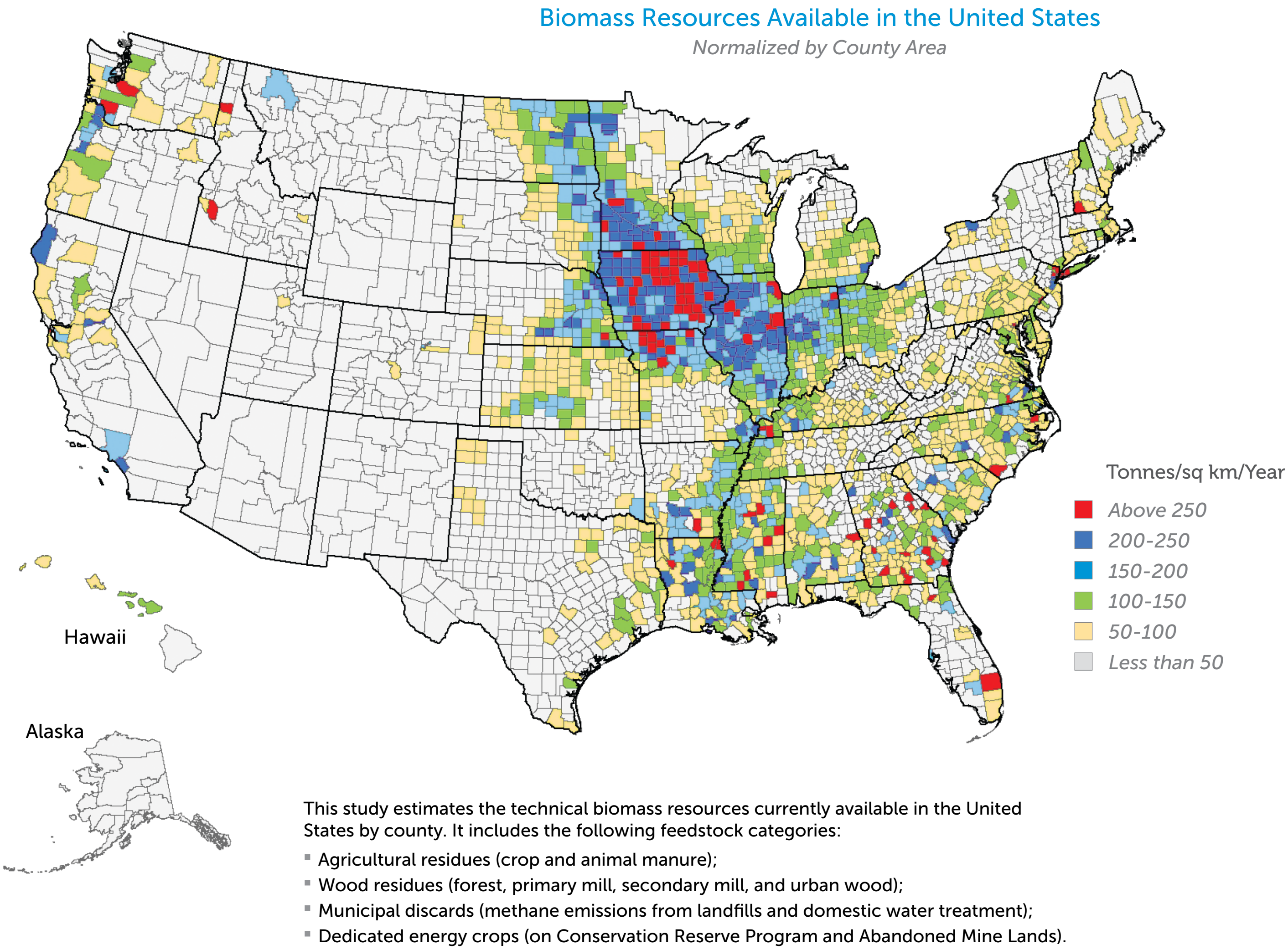
Numerous existing resources provide data on potential biomass feedstocks by state and information on how to conduct a biomass assessment (as discussed later in this chapter). For example, key state agencies (e.g., the state Department of Agriculture) are often valuable sources of information about potential biomass feedstocks. In-state expertise can also be found among local USDA rural development representatives (*www.rurdev.usda.gov/recd_map.html*), as well as local academic and business experts in agriculture, forestry, and waste.

The following resources provide information about potential biomass feedstocks and/or data on feedstock availability by geographic location. Each specializes in particular types of data, as described below:

- **Biomass Resource Assessment Tool**. This online biomass mapping tool, developed by NREL for the U.S.

FIGURE 4-1. TOTAL BIOMASS RESOURCES AVAILABLE IN THE UNITED STATES PER SQUARE KILOMETER BY COUNTY

Source: Milbrandt, 2005



EPA Blue Skyways program, allows users to select a location on the map, quantify the biomass resources available within a user-defined radius, and then estimate the total thermal energy or power that could be generated by recovering a portion of that biomass. The tool acts as a preliminary source of biomass feedstock information; however, it will not take the place of an on-the-ground feedstock assessment. The tool also contains numerous layers including landfills, waste water treatment plants, anaerobic digesters on animal feeding operations, EPA brownfields, biopower plants, fossil power plants, ethanol manufacturing facilities, and alternative fuel filling stations. The tool can be found at *http://rpm.nrel.gov/biopower/biopower/launch*.

- **Biomass Feedstocks**. The U.S. DOE Biomass Program works with industry, academia, and national laboratory partners on a balanced portfolio of research in biomass feedstocks and conversion technologies. The Web site provides a gateway to a wealth of biomass information, including feedstock availability. In particular, the program's site lists several U.S. DOE reports on the potential of different feedstocks, including corn stover, woody biomass, and switchgrass, which states across the nation may find useful.

» To locate these publications, visit *www1.eere.energy.gov/biomass/publications.html#feed*. The U.S. DOE Biomass Program homepage can be accessed at *www1.eere.energy.gov/biomass/biomass_feedstocks.html*.

- **State Assessment for Biomass Resources**. Produced by the U.S. DOE Office of Energy Efficiency and Renewable Energy (EERE) Alternative Fuels and Advanced Vehicles Data Center, this tool provides detailed information on biomass resources and utilization throughout the United States. It features state-specific information on conventional fuel and biofuel use, ethanol and biodiesel stations and production plants, and biofuel production capacities. In addition, it offers state-by-state snapshots of available feedstocks, data on potential production capacities, and projections on the future use of biofuels. The site is particularly useful for states interested in evaluating biomass resource potential for producing biofuels.

  This resource can be found at ***www.afdc.energy.gov/afdc/sabre/index.php***.

- **Dynamic Maps, GIS Data, and Analysis Tools**. This NREL Web site provides county-level biomass resource maps, which are useful for states interested in their feedstock potential in the following categories: crop residues, forest residues, primary mill residues, secondary mill residues, urban wood waste, methane emissions from landfills, methane emissions from manure management, methane emissions from wastewater treatment plants, and dedicated energy crops. The maps are derived from data contained in a report, *Geographic Perspective on the Current Biomass Resource Availability in the United States* (described below).

  The NREL Biomass Web site is ***www.nrel.gov/gis/biomass.html***. *Note that these maps present technical biomass resource data. The economic biomass resource availability will most likely be somewhat less than what is presented here.*

- **Geographic Perspective on the Current Biomass Resource Availability in the United States**. This NREL report provides the basis for the maps and data presented in NREL's *Dynamic Maps, GIS Data, and Analysis Tools* Web site described above. The report provides a geographic analysis of biomass resource potential at the county level, and can give officials a sense of the major biomass resources available within their state and their technical potential relative to other states.

  The report is available at ***www.nrel.gov/docs/fy06osti/39181.pdf***.

- **USFS Forest Inventory Data Online (FIDO)**. This online tool provides access to the National Forest Inventory and Analysis databases. It can be used to generate tables and maps of forest statistics (including tree biomass) by running standard reports for a specific state or county and survey year, or customized reports based on criteria selected by the user.

  This tool can be accessed at ***http://199.128.173.26/fido/index.html***.

- **Market Opportunities for Biogas Recovery Systems**. This report published by U.S. EPA's AgStar program assesses the market potential for biogas energy projects at swine and dairy farms in the United States. For the top ten swine and dairy states, the guide characterizes the sizes and types of operations where biogas projects are technically feasible, along with estimates of potential methane production, electricity generation, and greenhouse gas emission reductions.

  The report is available at ***www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf***.

- **U.S. EPA's Landfill Methane Outreach Program (LMOP) Landfill Database**. This online database provides a nationwide listing of operational and under construction LFG energy projects; candidate municipal solid waste landfills having LFG energy potential; and information on additional landfills that could represent LFG energy opportunities. The database can be accessed as a series of downloadable Excel spreadsheets, which are updated and posted to the Web site each month. The information contained in the LMOP database is compiled from a variety of sources, including annual voluntary submissions by LMOP Partners and industry publications.

  The database can be accessed at ***www.epa.gov/lmop/proj/index.htm***.

- **Coordinated Resource Offering Protocol (CROP) Evaluations**. This U.S. Forest Service and Bureau of Land Management Web page provides the results of ten CROP evaluations that have been conducted for more than 30 million acres of public forestlands potentially vulnerable to wildfires. The evaluations contain detailed resource-offering maps that illustrate the growing fuel load problem within major forest systems and quantify the biomass available for removal within five years.

  The evaluations can be accessed at ***www.forestsandrangelands.gov/Woody_Biomass/supply/CROP/index.shtml***.

- **State Assessment for Biomass Resources (SABRE)**. This comprehensive U.S. DOE tool provides detailed information on biomass resources and utilization throughout the United States. It features state-specific information on conventional fuel and biofuel use, ethanol and biodiesel stations and production plants, and biofuel production capacities. In addition, it offers state-by-state snapshots of available feedstocks, data on potential production capacities, and projections on the future use of biofuels.

This tool can be accessed at *www.afdc.energy.gov/afdc/sabre/index.php*.

4.1.2 CONDUCT A BIOMASS ASSESSMENT IF MORE INFORMATION IS NEEDED

If more information is needed about biomass feedstock availability after tapping into the resources discussed above, a state can consider conducting its own biomass feedstock assessment. The advantages of a state conducting its own assessment include the ability to tailor the study to meet specific state goals for bioenergy use (i.e., focus on resources that the state knows it wants to tap) and determine the level of data specificity (i.e., state level, county level, within 50 miles of existing energy and industrial infrastructure, etc.). Disadvantages of a state conducting its own assessment are the time and cost of doing so.

Some considerations for determining whether to conduct a state-specific biomass assessment include:

- **Identify priorities**. First, consider using existing information to decide generally what priorities are of greatest interest, for example feedstock types (e.g., forest residues, energy crops), geography (e.g., economic development in southeast portion of the state), or output (e.g., biopower, biofuels) based on the state's resources and goals.
- **Look closely to analyze data gaps in existing information**. Based on the scope of interest, a state can decide whether existing data meet its needs or information gaps need to be addressed by completing its own assessment. In addition to general data availability, some considerations will include how recent the information is (i.e., to determine whether it is out of date), and the degree of data specificity (e.g., an estimate for the whole state, or detailed county-level data).
- **Determine resource availability**. Once a state knows its data needs, it will need to determine whether it has the resources to perform any needed assessment itself (i.e., using state staff) or whether it needs to hire a contractor or tap into the expertise at state universities. Costs to do so will need to be considered, as they will impact the extent of the analysis that can be completed.

Some states have already conducted assessments or related studies of renewable energy (including biomass) potential and can provide examples and guidance. Examples include:

- **Guide to Estimates of State Renewable Energy Potential**. This guidebook lists existing studies of renewable energy potential and describes how to conduct these studies.
- **State Biomass Resource Assessments**
  - ***California***: *An Assessment of Biomass Resources in California, 2007*

    Provides an updated biomass inventory for the state along with an assessment of potential growth in biomass resources and power generation that could help to satisfy the state renewable portfolio standard (RPS). *http://biomass.ucdavis.edu/materials/reports%20and%20publications/2008/CBC_Biomass_Resources_2007.pdf*
  - ***Georgia:*** *Biomass Wood Resource Assessment on a County-by-County Basis for the State of Georgia, 2005*

    Provides a biomass wood resource assessment at the county level for Georgia. *www.gfc.state.ga.us/ForestMarketing/documents/BiomassWRACounty-byCountyGA05.pdf*
  - ***Hawaii:*** *Biomass and Bioenergy Resource Assessment: State of Hawaii, 2002*

    Provides an assessment of current and potential biomass and bioenergy resources for Hawaii. Includes animal wastes, forest product residues, agricultural residues, and urban wastes. *www.hawaii.gov/dbedt/info/energy/publications/biomass-assessment.pdf*
  - ***Mississippi:*** *Mississippi Institute for Forest Inventory Dynamic Report Generator*

    Provides a continuous, statewide forest resource inventory necessary for the sustainable forest-based economy. The inventory information is derived from sampling estimation techniques with a presumed precision of +/- 15 percent sampling error with 95 percent confidence. *www.mifi.ms.gov/*
  - ***South Carolina:*** *Biomass Energy Potential in South Carolina: A Conspectus of Relevant Information, 2007*

SUMMARY OF BIOMASS RESOURCES AND THEIR DEGREE OF UTILIZATION IN THE STATE OF HAWAII BY COUNTY

Hawaii's 2002 Biomass and Bioenergy Resource Assessment was developed through five tasks:

1. Collecting and reviewing relevant prior studies.
2. Collecting current bioenergy data from public and private sector sources.
3. Compiling, reducing, and analyzing data and information collected in Task 2.
4. Summarizing economic and other considerations related to development and operation of bioenergy facilities.
5. Inventorying public and private sector bioenergy facilities in the state.

The results of these activities are summarized below; the full report is available at *www.hawaii.gov/dbedt/info/energy/publications/biomass-assessment.pdf.*

	tons yr[1]	Hawaii	Maui	Kauai	Honolulu
Swine Manure	dry	410	540	180	1,560
Dairy Manure	dry				8,300
Poultry	dry	1,520[1]			4,830
Bagasse Fiber	dry		275,000 (275,000)[2]	74,000 (56,000)[2]	
Molasses	as-received		80,000	15,000	
Cane Trash	dry		137,000	37,000	
Pineapple Processing Water	dry		7,500 (7500)[2]		
Macademia Nut Shells	dry	19,000 (18,000)[2]			
Municipal Solid Waste	as-received	110,000	96,000	56,000	668,000 (6000,000)[2,3]
Food Waste[4,5]	as-received	24,000	15,000	5,800	90,000
Sewage Sludge[5]	dry	183	3,352 (3,352)[2,3]	246	16,576 (891)[2,3]
Fats/Oil/Grease[6]	dry	1,850	1,850	800	10,000

[1] *combined poultry waste estimate for Hawaii, Maui, and Kauai*
[2] *amount currently used*
[3] *tipping fee associated with utilization*
[4] *amount entering landfills*
[5] *included in municipal solid waste value*
[6] *processed grease, contains minimal moisture*

Summarizes studies conducted on various actual and potential feedstock resources in South Carolina and the Southeast, as well as relevant nonregional studies and other information. The report describes the existing information base, as well as information gaps. *www.energy.sc.gov/publications/Biomass%20 Conspectus%204-10-07.pdf*

- **Oregon:** *Biomass Energy and Biofuels from Oregon's Forests, 2006*

  Assesses the statewide potential for production of electricity and biofuels from woody biomass, including the available wood supply and the environmental, energy, forest health, and economic effects. Reviews and summarizes efforts underway to promote electric energy and biofuels from woody biomass, and identifies gaps in existing efforts. Assesses constraints and challenges to the development of biomass energy and biofuels from Oregon forests, including economic, environmental, legal, policy, infrastructure, and other barriers and develops recommendations on how to overcome these barriers. *www.oregonforests.org/assets/uploads//Biomass_Full_Report.pdf*

- **Regional Biomass Resource Assessments**
  - ***Northeastern states (CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT)***: *Securing a Place for Biomass in the Northeast United States: A Review of Renewable Energy and Related Policies, 2003*

    Provides a biomass feedstock assessment for northeastern states. *www.nrbp.org/pdfs/nrbp_final_report.pdf*

  - ***Western states (AK, AZ, CA, CO, HI, ID, KS, MT, NE, NV, NM, ND, OR, SD, TX, UT, WA, WY)***: *Biomass Task Force Report, 2006*

    Focuses on use of biomass resources for production of electricity as part of an overall effort of the Western Governors' Association (WGA) to increase the contribution of clean and renewable energy in the region. *www.westgov.org/wga/initiatives/cdeac/Biomass-full.pdf*

  - ***Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, OK, ND, SD, NE, KS, AK and HI)***: *Western Bioenergy Assessment, 2008*

    Includes a series of technical reports produced for the Western Governors' Association. These reports extensively evaluate biomass resources in the western states, biofuel conversion technologies, spatial analysis and supply curve development, and deployment scenarios and potential policy interactions. *www.westgov.org/wga/initiatives/transfuels/index.html*

  - ***Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, OK, ND, SD, NE, KS, AK and HI)***: *Transportation Fuels for the Future Initiative Working Group Reports and Final Report, 2008*

    Analyzes the potential for the development of alternative fuels and vehicle fuel efficiency member states of the Western Governors' Association. *www.westgov.org/wga/initiatives/transfuels/index.html*

Example

WESTERN RENEWABLE ENERGY ZONES

WGA and U.S. DOE launched the Western Renewable Energy Zones Project (WREZ) in May 2008. The central goal of the WREZ project is to utilize areas of the West with vast renewable resources to expedite development and delivery of clean and renewable energy, including wind, solar, and biomass resources. The project will generate:

Reliable information for use by decision makers that supports cost-effective and environmentally sensitive development of renewable energy in specified zones.

Conceptual transmission plans for delivering that energy to load centers within the Western Interconnection.

The project also will evaluate all feasible renewable resource technologies that are likely to contribute to the realization of WGA's goal for development of 30,000 MW of clean and diversified energy by 2015. For the latest information and geographic information system (GIS) maps of the proposed WREZ, see *www.westgov.org/wga/initiatives/wrez/index.htm*.

Source: Western Governors' Association and U.S. DOE, 2009

4.2 STEP 2: ASSESS POTENTIAL MARKETS FOR IDENTIFIED BIOMASS FEEDSTOCKS AND BIOENERGY

Once a state understands the availability of potential biomass feedstocks, the next step is to evaluate how the feedstocks can be employed by the market. In this step, analysis is conducted to determine the viability of using a state's feedstocks, as identified in Step 1, to produce bioenergy. To develop an evaluation that can withstand the scrutiny required to justify state policy, it is important to examine potential markets quantitatively and under a number of scenarios given different economic or market activities. The following sets of questions can be useful in assessing potential markets for biomass feedstocks:

1. **At what cost can the feedstocks reasonably be used?**
    - Are crop and waste feedstocks available at competitive prices?
    - What is the relative proximity of feedstocks, processing facilities, and markets?
    - How cost-competitive is the bioenergy with fossil-based resources?
    - What are the economics of using bioenergy?
2. **Who might use biomass feedstocks?**
    - What industries can use the available feedstocks?
    - What is the current and potential competition for feedstocks in the region?
    - Does the state have policies in place that could create a market for bioenergy?
3. **What does the state's energy and environmental profile look like?**
    - What are the state's anticipated energy demands?
    - What environmental issues should be considered?

4.2.1 AT WHAT COST CAN THE FEEDSTOCKS REASONABLY BE USED?

Are Crop and Waste Feedstocks Available at Competitive Prices?

The economics of bioenergy production are highly dependent on feedstock prices, and it is important that state officials considering actions to promote bioenergy explore whether a sufficient supply of competitively priced feedstocks exists to support a profitable bioenergy industry. This undertaking is typically challenging, in part because the prices of biomass feedstocks are subject to considerable uncertainty.

Many of the factors that influence the availability of feedstocks over time, such as weather, plant disease, feedstock demand, and transportation costs, will also affect feedstock prices (see Chapter 3, Benefits and Challenges of Bioenergy, for a more in-depth discussion of these factors). Other factors, such as fossil fuel prices, can also significantly impact the price of feedstocks if their harvest requires the use of fertilizer and other chemicals (the prices of which are highly dependent on the cost of fossil fuels), if they need to be transported any significant distance, and if higher fossil fuel prices are passed through and impact the biofuels supply chain. Financial speculation by commodities traders will also affect the price of energy crop feedstocks.

When evaluating the cost-effectiveness of a given feedstock supply, it is important to consider how changes in these factors could affect feedstock prices; volatility, uncertainty, and or/changes in any of these factors will be reflected in the price of feedstocks. With all these factors in mind, some of the questions that should be considered when evaluating the cost effectiveness of a given biomass feedstock supply over the long term include:

- Will bioenergy producers likely have to compete with other industries for access to the resource?
- What are projected fossil fuel prices?
- How might financial speculators influence prices, if at all?
- Could a feedstock supply that is currently ample become easily exhausted?
- How much will feedstock prices change as the bioenergy industry grows?

What Is the Proximity of Feedstocks, Processing Facilities, and Markets?

In addition to understanding the industries or potential industries that can utilize a state's biomass feedstocks, it is important to know the limitations that might impede cost-effective bioenergy use. Foremost among these is whether biomass feedstocks, processing facilities, and markets exist in close enough proximity to deliver a competitive product. Proximity considerations are discussed below.

How far can each biomass feedstock be transported cost effectively? One critical factor that affects the financial viability of using a biomass feedstock is the proximity of the feedstock to where it would be used. The most cost-effective bioenergy applications often site the conversion facility as close as possible to the feedstock source (and to the end user). For wood feedstocks, a general rule of thumb is that 50 to 100 miles is the maximum distance that feedstocks can be transported at competitive cost; however, this depends on the cost of competing sources (e.g., of power/heat) and on the specific type of bioenergy feedstock. EIA (2006) uses the following assumptions in its National Energy Modeling System (NEMS):

- Urban wood waste and mill residues transportation cost: $0.24/ton-mile, maximum supply distance 100-mile radius.
- Forest residues, agricultural residues, energy crops transportation cost: $10 to $12/ton-mile, within a maximum supply distance of 50 miles.

Another question that needs to be answered is who, specifically, will collect and transport the biomass to the end-use facility? There are different answers to this question depending upon whether one is using urban wood waste, forest residues, or crop residues. What contractual requirements for feedstock delivery need to be developed? What is the quality and quantity of feedstock to be supplied?

Are sufficient biomass resources available within the distance identified to support a processing facility? Sufficient feedstocks must be close enough to the potential processing facility to support its long-term operation. For example, it would not make financial sense to invest substantial capital for a plant that relies on feedstock that will be exhausted within a few years. Proposed projects may need long-term contracts for feedstock supplies. Because bioenergy costs are frequently highly dependent on feedstock transportation costs, detailed scenario building and certainty analyses will be needed to answer this question with confidence.

As an example, one analysis of biomass-fueled boiler power generation systems and CHP configurations showed that 100 tons/day of dry biomass fuel (assuming 8,500 Btu of energy per pound) could be used to generate 500 kW to 4 MW of electricity depending on the conversion technology used, plus thermal energy for process steam. (A 100 tons/day system would require about four to five standard semi-trailer trucks for feedstock delivery each day.) A system receiving 900 tons/day of dry biomass fuel could produce roughly 8 MW to 24 MW of electricity depending on the conversion technology and how much thermal energy was desired (U.S. EPA, 2007d – Chapter 7).

Are markets for fuel, heat, and/or power readily accessible? Available markets require critical infrastructure to be in place and may require contractual arrangements. For example, biofuels require access to populations of consumers who need fuel. Bioenergy for heat and power, especially if not used primarily or exclusively for on-site demand, may require long-term contracts with the electric utility (as discussed with interconnection standards in Section 4.3.2). Markets for renewable energy, such as green power or renewable energy credits (RECs), may or may not be open to biopower.

How Cost-Competitive Is Bioenergy with Fossil-Based Resources?

The most promising markets for bioenergy will typically share several characteristics. Perhaps most importantly, the cost of bioenergy will be competitive (in some cases without government support; in other cases with direct or indirect support) with energy that is generated from other sources, including fossil fuels. High or volatile energy prices will generally help to improve the cost effectiveness of bioenergy.

The increase in gasoline prices over the last several years, for example, has helped to make ethanol a more attractive alternative motor fuel economically. Similarly, volatility in electricity prices over this same period has generally increased the appeal of biomass power as facilities look for ways to stabilize energy prices or hedge fuel costs. It is important, therefore, that any assessment of the market for bioenergy take prevailing and forecasted energy prices into account.

» **Data on gasoline and electricity prices are available on EIA's Web site at *www.eia.doe.gov*.**

» **For information on prevailing energy prices by state, see *http://tonto.eia.doe.gov/state/SEP_MorePrices.cfm*.**

» **Forecasts of projected energy prices through 2030 are available in EIA's Annual Energy Outlook reports. The 2008 version of the report is accessible on the Web site at *www.eia.doe.gov/oiaf/aeo/index.html*.**

Energy prices and forecasts are also important to consider in later evaluations if a state decides to develop incentives or policy measures to support bioenergy. A state will want to understand the level of support necessary to achieve its objectives given prevailing and projected cost effectiveness—to decrease the likelihood that states offer too many or too few incentives for

PRICE VOLATILITY

Noteworthy, of course, is that petroleum prices spiked and crashed in 2008—from a high of more than $100/barrel to a low of less than $40/barrel—making biofuels in many parts of the country uneconomical after a period of cost competitiveness. This extreme type of volatility is difficult to predict; having flexible policies that are robust to different price trajectories can buffer the effects of volatile prices.

bioenergy development and are therefore inefficient or ineffective in the long run.

Using biomass to produce heat is currently one of the most cost effective applications for biomass energy. This is especially true if one is replacing propane or fuel oil, which are typically more expensive than biomass on a $/Million Btu basis. Depending on the price, it may also be possible to compete with natural gas.

Example

COST-COMPETITIVE WOOD CHIP BOILER

In the winter of 2009, the National Renewable Energy Laboratory (NREL) installed a central, wood chip fired boiler to provide thermal energy for its main campus. NREL estimates that wood can be obtained for less than $3/million Btu, compared to natural gas costs of $6-$10/million Btu. The system is expected to meet up to 80% of NREL's heating load with biomass energy.

Source: NREL, 2008

What are the Economics of Using Bioenergy?

Once information on availability, proximity, and cost competitiveness of feedstocks and other considerations has been gathered, it is important to conduct an economic analysis of the various options for sourcing and using biomass to produce bioenergy. At the minimum, a 20-year pro-forma analysis should be developed to evaluate various options. Bioenergy options should be compared with other options such as fossil fuels (e.g., if looking at using biomass to offset natural gas in a school, what are the life-cycle costs of the biomass technology vs. the natural gas technology?)

4.2.2 WHO MIGHT USE BIOMASS FEEDSTOCKS?

What Industries Can Use the Available Feedstocks?

An understanding of the key market factors that will allow potential feedstocks to become actual bioenergy projects is essential. Foremost among these factors is knowing what drives demand for biomass resources in the state, that is, which industries can use the available feedstocks.

Industries in a state can make greater use of bioenergy in several ways:

- Existing industries can expand their facilities or construct new facilities.
- Industries can use their waste streams as biomass feedstock.
- Existing energy production facilities can initiate or increase their use of biomass.
- New industries that use biomass feedstocks can be encouraged to locate in the state.

Understanding the relationships between feedstocks, conversion technologies, products, and markets, and their implications for industry, commerce, and end users within a state's borders, is essential.

Figure 2-2 in Chapter 2 illustrates the conversion pathways of different biomass feedstocks into various final forms of bioenergy. As the diagram shows, states with abundant waste or opportunity fuels may have an advantage if they focus support toward industries that can generate on-site heat or power or utilities that can provide heat and power. However, states with abundant energy crops are in a better position to support biofuel development using current technologies.

Although a wide variety of industrial, commercial, and institutional facilities could potentially benefit from the use of biomass as an energy source, there are several types of facilities for which biomass could be a particularly attractive and economical source of energy. Some examples of these facilities include (DOE, 2004):

- **Schools, prisons, hospitals, and municipal WWTPs**. Facilities with large, fairly constant electricity and heating requirements are good candidates for on-site biopower/bioheat production. In 2008, four prisons and one high school in the United States were using biomass CHP systems to produce energy (ICF, 2008). For facilities with potentially sensitive populations (i.e., schools and hospitals) it is especially important to utilize best available pollution control technologies to reduce the risk of exposure to air emissions.

FUELS FOR SCHOOLS

The Fuels for Schools program is an innovative venture between public schools and state and regional foresters of the northern and intermountain regions of the U.S. Forest Service. This program helps public schools retrofit their current fuel or gas heating systems to biomass-based systems through knowledge sharing, information dissemination, identifying potential financing opportunities, supply assessment, and overall support and assistance as needed. As of 2008, Fuels for Schools had initiated projects in Idaho, Montana, Nevada, and North Dakota.

For more information on Fuels for Schools, see: *www.fuelsforschools.info/*.

There are dozens of schools in the United States that are heating their buildings with automated wood chip boilers. These facilities may also be capable of generating anaerobic digester gas for use as a fuel by treating wastewater in on-site treatment plants (DOE, 2004).

- **Landfills**. Landfills can capture the gas that is produced as a byproduct of the decomposition of solid waste for use as an energy source. This LFG can be used to generate electricity and/or heat for the landfill itself or other nearby facilities.

» **For more information, tools, and links to landfill and LFG databases, visit EPA's LMOP Web site, *www.epa.gov/lmop*.**

- **Lumber yards and pulp and paper mills**. Both the lumber processing and pulp and paper industries produce wood residues and black liquor that can be used as a source of energy to generate electricity and/or heat, typically for on-site use. Pulp and paper mills also produce large quantities of wastewater that can be treated with anaerobic digesters to create biogas.

- **Food and beverage processing facilities**. Food and beverage processing facilities can use the food processing waste (FPW) they generate as a fuel source. A 2004 study found that even though FPW could significantly reduce fuel costs for these facilities, its use as a fuel is minimal. The facilities are also good candidates for anaerobic digestion of wastewater to produce biogas for on-site use (DOE, 2004).

- **Petroleum refineries**. There are opportunities to integrate biomass feedstocks into existing fossil fuels industries. For example, petroleum refineries can take bio-oil and process it within existing refineries, blending the renewable diesel product into petroleum diesel and using existing pipeline infrastructure for distribution. This alternative to biodiesel (sometimes called "green diesel") overcomes the distribution infrastructure challenge described in Chapter 3. The same approach can apply to bio-produced gasoline—"green gasoline."

- **Power plants and other large energy users**. Power plants, typically coal fired, can substitute biomass for a portion of the fossil fuel used in the combustion process, in most cases with only minor equipment modifications. As of 2006, 52 coal-burning power plants in the United States were utilizing cofiring technology (EIA 2008). Other large energy users, such as cement plants, may also be good candidates for biomass cofiring.

» **One source of information to help states identify industries that are in a position to initiate or increase their use of biomass is the U.S. Bureau of Economic Analysis. The bureau provides information on state-by-state output (gross domestic product) of industries, such as those described above, that might be poised to incorporate bioenergy feedstocks into their operations. This information is accessible online at *www.bea.gov/regional/gdpmap/*.**

The presence of related industries, including oil and gas refining, blending, terminals, transportation corridors, and distribution networks, can create more demand for bioenergy. Transportation infrastructure limitations (discussed below) may place constraints on building centralized conversion facilities while creating opportunities for distributed ones.

Example

BREWERY BIOENERGY PRODUCTION

Anheuser-Busch, a member of EPA's Climate Leaders partnership program, utilizes Bio-Energy Recovery Systems (BERS) at nine of its 12 breweries. These systems feature anaerobic digesters that break down nutrients in the wastewater from the brewing process, creating biogas. The biogas is captured and used by CHP systems to fuel boilers that provide heat and power for the breweries. Where they are in use, BERS meet 15 percent of Anheuser-Busch facilities' on-site fuel needs. In 2007, the nine systems generated enough energy to heat more than 25,000 homes.

For more information, see: *www.abenvironment.com/Environment/BioEnergyRecovery.html* and *www.epa.gov/stateply/partners/partners/anheuserbuschcompaniesinc.html*.

What is the current and potential competition for feedstocks in the region?

When doing a market assessment, it is very important to consider whether there are any current users of biomass and what the future competition for feedstocks will be in the region. For example, a 50 MW biomass power plant or ethanol plant could be sourcing feedstocks from within a 100-mile radius. Other plants located within this radius will likely compete with it for feedstocks, and competition will increase as the distance between plants decreases. So when planning new bioenergy facilities, it is crucial to examine how siting plants will create and/or affect competition. Additionally, there are other competitors for feedstocks that need to be taken into consideration, such as composters, wood recyclers, and landscape mulch companies. All current and potential users of biomass need to be assessed.

Does the State Have Policies that Could Create a Market for Bioenergy?

States with promising markets for bioenergy may also have enacted policies and incentives to encourage and/or require use of renewable energy, including biomass. Renewable portfolio standards (RPS), RFS, production and tax incentives, low-interest loans, rebates, environmental revenue streams, grants, and standardized utility interconnection standards are examples of the measures states have enacted to improve bioenergy markets.

In addition, policies that are not specifically intended to promote renewable energy can also enable a market for industrial or commercial entities that might become users of bioenergy, such as rural economic development policies, designations of industrial development zones with environmental restrictions, waste reduction or processing requirements, etc. Chapter 5 provides information about evaluating state policies and incentives.

4.2.3 WHAT IS THE STATE'S ENERGY AND ENVIRONMENTAL PROFILE?

What Are the State's Anticipated Energy Demands?

Besides evaluating existing markets in a state that can utilize available biomass feedstocks, state officials can assess anticipated rates of increase in electricity demand, renewable electricity demand, and biofuels demand. Rapid increases in these demands could create a promising market environment for biomass feedstocks and bioenergy. EIA, the state public utilities commission, state energy plan, or regional economic modeling results are likely sources of energy demand forecasts.

Voluntary markets for renewable electricity and green power can also spur demand.

For more information about green power, states can refer to the Green Power Network at *www.eere.energy.gov/greenpower/*. This online resource created by U.S. DOE provides information about utility green pricing, green power marketing, and renewable energy credits.

Interested states can also join U.S. EPA's Green Power Partnership, a voluntary program that supports organizational procurement of green power by offering expert advice, technical support, tools, and resources.

For more information about the Green Power Partnership, see *www.epa.gov/greenpower/*.

GREEN POWER MARKETING

The Green Power Network publishes a report series, *Green Power Marketing in the United States: A Status Report*, which identifies market trends. The report covering 2007 notes that in that year, total retail sales of renewable energy in voluntary purchase markets exceeded 18 billion kWh, a capacity equivalent of 5,100 MW of renewable energy, including 4,300 MW from new renewable energy sources. Biomass energy sources (including LFG) provided 28 percent of total green power sales.

For more information, see *www.nrel.gov/docs/fy09osti/44094.pdf*.

What Environmental Issues Should Be Considered?

Due to the complexity of the interaction between bioenergy and the environment, some types of bioenergy production can be more beneficial to the environment than others. In addition, some types of biomass are more appropriate for certain climates or areas with particular resources. For example, ethanol production typically requires access to significant and reliable water resources and is therefore less likely to have positive environmental effects in a drought-prone area. In contrast, some evidence suggests that biomass CHP requires less water than traditional natural gas-fired electricity generation, making it a regionally appropriate bioenergy option in a drier climate.

It is important for decision makers to understand the net environmental effects of growing, collecting, and processing biomass feedstocks into bioenergy in the context of their state's environmental features and challenges.

Examples of some environmental considerations that could be important to a state when considering bioenergy opportunities include:

- Lower GHG emissions from biofuels and biopower compared to fossil fuels can contribute to achieving goals of state and local climate action plans.
- Reduced air emissions (e.g., lower SO_2, NO_x, and PM emissions) from cofiring biomass with coal can make bioenergy more attractive to regulated facilities in a nonattainment area by lowering emissions-related operating costs. However, if gas or oil fueled operations are converted to woody biomass, PM emissions will increase.
- When large areas of undeveloped land are converted to agricultural uses to produce biofuel feedstocks, the po-

tential exists for damage to local ecosystems (e.g., from pesticide and fertilizer use) and displacement of species.

- Unregulated biomass boilers and furnaces can increase PM emissions, contributing to air quality problems.

As discussed in Chapter 3, Benefits and Challenges of Bioenergy, LCAs can help identify strategies to maximize the environmental benefits of biomass because they reveal the environmental effects of alternative approaches to biomass production, transportation, and conversion. Because of the level of detail involved, LCAs are not often tailored to specific geographic regions; however, state-specific analysis of policy options can draw on LCA results. This type of analysis can support major state decisions about policies and incentives.

Section 4.4.2 — Bioenergy and State Planning, describes the inclusion of bioenergy in comprehensive state environmental planning. Additional resources for evaluating environmental effects of bioenergy, including LCAs, are presented in Chapter 3.

4.3 STEP 3: IDENTIFY OPPORTUNITIES FOR ACTION

Working through Steps 1 and 2 should provide a state with a solid foundation for understanding the basics about biomass feedstock availability and potential markets for expanded bioenergy production. Before identifying specific actions to promote bioenergy, a state should have also considered the economic and environmental benefits and challenges outlined in Chapter 3. Once these considerations are weighed, a state can decide whether to move ahead with policies and initiatives that will promote bioenergy.

One final step before developing a bioenergy promotion plan is to identify some key opportunities for action. States have found success by examining their policy and regulatory situations for typical barriers (see Section 4.3.1); considering including bioenergy issues in the content of state planning processes to enable cohesive approaches with all stakeholders (see Section 4.3.2); and reviewing policy, regulatory, and financial opportunities for further action.

4.3.1 TYPICAL BARRIERS TO BIOENERGY DEVELOPMENT

After developing an understanding of the processes, products, and markets that are relevant to a state, the next step is to assess current policies that present barriers to bioenergy development and those that can remove barriers.

Because states have primary jurisdiction over many areas related to bioenergy, including electricity generation, agricultural development, and land use, state policies are particularly important in advancing or impeding bioenergy. The key to successful advancement is a policy environment that is flexible enough to support diverse and changing utilization of different biomass resources and conversion technologies, and that can adapt as the industry grows, markets change, and technology advances.

Policy areas that can impact the use of bioenergy include regulatory requirements and market-based incentives. Policies that remove barriers to bioenergy development can include favorable utility rate structures, interconnection standards, state RPS, public benefits funds, and financial incentives.

Policy Barriers to Biopower/Bioheat

Some policies create barriers to biopower development, such as unfavorable utility rate structures, lack of interconnection standards, and difficulties securing environmental permits. Listed below are some key policy barriers to biopower development and ways that states have overcome them to enable a healthy market for biopower:

- **Utility Rate Structures**. Unfavorable utility rate structures have perennially been a barrier to increased deployment of renewable energy technologies, including those that use bioenergy. Unless carefully monitored to encourage development of distributed generation (DG) bioenergy resources, rate structures can increase the cost of DG (with biomass or other fuels) or completely disallow connection to the electrical grid.

  - ***Decoupling or Lost Revenue Adjustment Mechanisms***. Traditional electric and gas utility ratemaking mechanisms unintentionally include financial disincentives for utilities to support energy efficiency and DG. This misalignment can be remedied through "lost revenue" adjustment mechanisms (LRAMs) or mechanisms that "decouple" utility revenues from sales.

    LRAMs allow a utility to directly recoup the lost revenue associated with not selling additional units of energy because of the success of energy efficiency or DG programs in reducing electricity consumption.

The amount of lost revenue is typically estimated by multiplying the fixed portion of the utility's prices by the energy savings from energy efficiency programs or the energy generated from DG. The lost revenue is then directly returned to the utility.

- ***Revised Standby Rate Structures***. Facilities that use bioenergy usually need to contract with the utility for standby power when the biopower system is unavailable due to equipment failure, during maintenance, or in other planned outages. Electric utilities often assess standby charges on on-site generation to cover the additional costs they incur as they continue to provide adequate generating, transmission, or distribution capacity (depending on the structure of the utility) to supply on-site generators when requested (sometimes on short notice). The utility's concern is that the facility will require power when electricity is scarce or at a premium cost, and that it must be prepared to serve load during such extreme conditions.

  The probability that any one generator will require standby service at the exact peak demand period is low, and the probability that all interconnected small-scale DG will need it at the same time is even lower. Consequently, some states are exploring alternatives to standby rates that may more accurately reflect these conditions. These states are looking for ways to account for the normal diversity within a load class and consider the probability that the demand for standby service will coincide with peak (high-cost) hours versus the benefits that renewables provide to the system.

- ***Exit Fee Exemptions.*** When facilities reduce or end their use of electricity from the grid, they reduce the utility's revenues that cover fixed costs on the system. The remaining customers may eventually bear these costs. This can be a problem if a large customer leaves a small electric system. Exit (or stranded asset recovery) fees are typically used only in states that have restructured their electric utilities.

  To avoid potential rate increases due to load loss, utilities sometimes assess exit fees on departing load to keep the utility whole without shifting the responsibility for those costs to the remaining customers. States can exempt renewable projects from these exit fees to recognize the economic value of the projects, including their grid congestion relief and reliability enhancement benefits.

- **Lack of Interconnection Standards for Clean Distributed Generation**. The absence of standard interconnection rules, or uniform procedures and technical requirements for connecting DG systems to the electric utility's grid, can make it difficult, if not impossible, for DG systems to connect to the grid. This barrier can hinder biomass CHP in particular.

  - ***Standardized Interconnection Rules and Net Metering***. A lack of interconnection standards can make it difficult, if not impossible, for renewable energy DG systems, including those using biopower, to connect to the electric grid. Once established, however, these statewide standards reduce uncertainty and delays that bioenergy systems can encounter when connecting to the grid.

    Standard interconnection rules establish uniform processes and technical requirements that apply to utilities within a state; in some states, municipally owned systems or electric cooperatives may be exempt from rules approved by state regulators. Standard interconnection rules typically address the application process and technical interconnection requirements for small DG projects of a specified type and size.

    Net metering provisions are a subset of interconnection standards for small-scale projects. When DG output exceeds the site's electrical needs, the utility can pay the customer for excess power supplied to the grid or have the net surplus carry over to the next month's bill. Some states allow the surplus account to be reset periodically, meaning that customers might provide some generation to the utility for free. Net metering provisions streamline interconnection standards but are often limited to specified sizes and types of technologies, as well as fuel types.

    Several groups are actively working to provide information about and/or follow and facilitate development of improved net metering standards. These include:

    - *Database of State Incentives for Renewable Energy*, which includes a summary table and summary database on interconnection standards. ***www.dsireusa.org/*** (click on Summary Tables, and then Rules, Regulations, and Policies [Renewable Energy]).
    - The Interstate Renewable Energy Council, which publishes a newsletter, "Connecting to the Grid." ***www.irecusa.org/index.php***
    - EPA's *Clean Energy-Environment Guide to Action* provides information about interconnection and

net metering benefits, design elements, interaction with state and federal programs, implementation and evaluation, and case studies. *www.epa.gov/cleanenergy/energy-programs/state-and-local/state-best-practices.html*

- **Environmental Permitting**. Major new industrial facilities that produce and/or use bioenergy must obtain a number of different permits from state agencies including construction permits from state environmental officials to ensure that plans meet environmental standards; operating permits for air emissions during operation; and stormwater and/or wastewater discharge permits. New bioenergy facilities and projects are subject to federal and state emission standards for combustion sources and to air permitting requirements for new sources.

The federal standards that could apply to biomass combustion units are the New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants for boilers, gas turbines, and internal combustion engines. The process of obtaining multiple permits from different entities within state agencies—particularly for newer technologies/processes—can add significant uncertainty to construction timing and the cost of emission controls that will be required.

4.3.2 BIOENERGY AND STATE PLANNING

One way to facilitate creation of a policy environment conducive to bioenergy is to include bioenergy considerations during comprehensive state energy, environmental, or climate change planning.

Energy Plans

Energy planning involves a strategic effort to develop energy-related goals and objectives and formulate related policies and programs. As the nexus for a variety of state concerns, energy planning can serve as an umbrella mechanism for simultaneously addressing energy, environmental, economic, and other issues. Energy planning can be undertaken at both state and regional levels.

Many states have used their energy plans to support development and use of cost-effective clean energy, including bioenergy, and to help address multiple challenges, including energy supply and reliability (e.g., concerns with availability, independence, and security), energy prices, air quality and public health, and job development. States can also develop strategies completely devoted to bioenergy. For example, in 2006 California released the *Bioenergy Action Plan for California*, which provides specific actions and timelines to advance bioenergy in the state (Bioenergy Interagency Working Group, 2006).

Environmental Plans

Opportunities also exist to consider biomass in environmental planning. States facing nonattainment under NAAQS are required to develop and submit SIPs. EPA provides guidance to state and local governments on quantifying and including emission reductions from energy efficiency and renewable energy measures in SIPs. (A guidance document is available at *www.epa.gov/ttn/oarpg/t1/memoranda/ereseerem_gd.pdf*.)

Climate Change Plans

In addition, many states have completed climate action plans to encourage clean energy as a way to decrease carbon emissions. Given that biomass is "carbon-neutral," it does and can play an important role in state climate plans.

Example

BIOMASS AND THE MASSACHUSETTS CLIMATE PROTECTION PLAN

In 2004, Massachusetts published the Massachusetts Climate Protection Plan as an initial step in a coordinated effort to reduce GHG emissions and improve energy efficiency throughout the state. The plan entails a set of near-term actions, including development of a comprehensive state biomass policy to ensure:

- Biomass material is grown and harvested in an environmentally sound manner.
- Strong air quality standards are maintained.
- Low emissions and advanced biomass conversion technologies, as defined by the Massachusetts RPS, are utilized for both heat and electricity.
- State agencies provide incentives and work together to implement pilot biomass projects in various sectors (public and private applications) in rural regions.

For more information, see *masstech.org/renewableenergy/public_policy/DG/resources/2004_MA_Climate_Protection_Plan.pdf*.

4.3.3 REVIEW POLICY OPTIONS

Whether a state explores bioenergy through a comprehensive energy strategy, a SIP, or a climate change action plan, several policies should be developed simultaneously to enhance the likelihood that biomass usage increases, as discussed in Chapter 5.

4.4 RESOURCES FOR DETAILED INFORMATION

Resource	Description	URL
Bioenergy		
Biomass Resource Assessment Tool, U.S. EPA and NREL.	Online mapping tool that takes various biomass resource datasets and maps them, allowing user queries and analysis. For example, users can select a point on the map and determine the quantity of feedstock within a certain radius, and the quantity of energy that could potentially be produced from that biomass.	*http://rpm.nrel.gov/biopower/biopower/launch*
Coordinated Resource Offering Protocol (CROP) Evaluations, U.S. Forest Service and Bureau of Land Management.	Provides the results of ten CROP evaluations that have been conducted for over 30 million acres of public forestlands potentially vulnerable to wildfires. The evaluations contain detailed resource-offering maps that illustrate the growing fuel load problem within major forest systems and quantify the biomass available for removal within five years.	*www.forestsandrangelands.gov/Woody_Biomass/supply/CROP/index.shtml*
USFS Forest Inventory Data Online (FIDO).	Provides access to the National Forest Inventory and Analysis databases. It can be used to generate tables and maps of forest statistics (including tree biomass) by running standard reports for specific states or counties and survey year, or customized reports based on criteria selected by the user.	*http://fiatools.fs.fed.us/fido/index.html*
Biomass Feedstocks, U.S. DOE.	U.S. DOE Biomass Program Web site	*www1.eere.energy.gov/biomass/biomass_feedstocks.html*
Dynamic Maps, GIS Data, and Analysis Tools, NREL.	Provides county-level biomass resource maps. The feedstock categories include crop residues, forest residues, primary mill residues, secondary mill residues, urban wood waste, methane emissions from landfills, methane emissions from manure management, methane emissions from wastewater treatment plants, and dedicated energy crops. The maps are derived from data contained in a report, Geographic Perspective on the Current Biomass Resource Availability in the United States (described below). Note that these maps present technical biomass resource data. The economic biomass resource availability will most likely be somewhat less than what is presented in the maps.	*www.nrel.gov/gis/biomass.html*
Geographic Perspective on the Current Biomass Resource Availability in the United States, NREL, 2006.	Provides the basis for the maps and data presented in NREL's Dynamic Maps, GIS Data, and Analysis Tools Web site described above. The report provides a geographic analysis of biomass resource potential at the county level, and can give state officials a sense of the major biomass resources available within their state and their technical potential relative to other states.	*www.nrel.gov/docs/fy06osti/39181.pdf*
State Assessment for Biomass Resources (SABRE), U.S. DOE.	Provides detailed information on biomass resources and utilization throughout the United States. It features state-specific information on conventional fuel and biofuel use, ethanol and biodiesel stations and production plants, and biofuel production capacities. In addition, it offers state-by-state snapshots of available feedstocks, data on potential production capacities, and projections on the future use of biofuels.	*www.afdc.energy.gov/afdc/sabre/index.php*

Resource	Description	URL
State Woody Biomass Utilization Policies, University of Minnesota, Department of Forest Resources, Staff Paper 199. Becker, D.R., and C. Lee. 2008.	Documents information on state policies to facilitate comparison of the types of approaches used in certain areas, policy structures and incentives employed, program administration, and relationships to complementary local and federal actions.	*www.forestry.umn.edu/publications/staffpapers/Staffpaper199.pdf*
Biopower/Bioheat		
Initial Market Assessment for Small-Scale Biomass-Based CHP. National Renewable Energy Laboratory, NREL, January 2008.	Examines the energy generation market opportunities for biomass CHP applications smaller than 20 MW. Using relevant literature and expert opinion, the paper provides an overview of the benefits of and challenges for biomass CHP in terms of policy and economic drivers, and identifies primary characteristics of potential markets.	*www.nrel.gov/docs/fy08osti/42046.pdf*
Green Power Marketing in the United States: A Status Report, NREL.	Documents green power marketing activities and trends in voluntary markets in the United States.	*http://apps3.eere.energy.gov/greenpower/resources/pdfs/38994.pdf*
U.S. EPA's Landfill Methane Outreach Program (LMOP).	Promotes the use of landfill gas as a renewable, green energy source. Its Web site contains general information, tools, and links to databases containing specific landfill data.	*www.epa.gov/lmop/*
U.S. EPA's Landfill Methane Outreach Program (LMOP) Landfill Database.	Provides a nationwide listing of operational and under-construction LFG energy projects; candidate municipal solid waste landfills having LFG energy potential; and information on additional landfills that could represent LFG energy opportunities. The database can be accessed as a series of downloadable Excel spreadsheets, which are updated and posted to the Web site each month. The information contained in the LMOP database is compiled from a variety of sources, including annual voluntary submissions by LMOP partners and industry publications.	*www.epa.gov/lmop/proj/index.htm*
Landfill Gas Energy Project Development Handbook, U.S. EPA Landfill Methane Outreach Program.	Provides landfill gas energy project development guidance, with individual chapters on the basics of landfill gas energy, gas modeling, technology options, economic analysis and financing, contract and permitting considerations, and selection of project partners.	*www.epa.gov/lmop/res/handbook.htm*
Market Opportunities for Biogas Recovery Systems, U.S. EPA AgStar.	Assesses the market potential for biogas energy projects at swine and dairy farms in the United States. For the top ten swine and dairy states, the guide characterizes the sizes and types of operations where biogas projects are technically feasible, along with estimates of potential methane production, electricity generation, and greenhouse gas emission reductions.	*www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf*
U.S. EPA's Combined Heat and Power (CHP) Partnership.	Promotes the use of biomass-fueled CHP and the use of biogas at wastewater treatment facilities.	*www.epa.gov/chp*

4.4 RESOURCES FOR DETAILED INFORMATION *(cont.))*

Resource	Description	URL
Biofuels/Bioproducts		
State Assessment for Biomass Resources, U.S. DOE.	Provides detailed information on biomass resources and utilization throughout the United States. It features state-specific information on conventional fuel and biofuel use, ethanol and biodiesel stations and production plants, and biofuel production capacities. It offers state-by-state snapshots of available feedstocks, data on potential production capacities, and projections on the future use of biofuels. The site is particularly useful for states interested in evaluating resource potential for producing biofuels.	*www.afdc.energy.gov/afdc/sabre/index.php*
Environmental Laws Applicable to Construction and Operation of Ethanol Plants, U.S. EPA.	This compliance assistance manual, issued by EPA Region 7, serves as a road map of information on federal environmental programs and federal and state agency roles applicable to the construction, modification, and operation of ethanol plants.	*www.epa.gov/region07/priorities/agriculture/ethanol_plants_manual.pdf*
Environmental Laws Applicable to Construction and Operation of Biodiesel Production Facilities, U.S. EPA.	This compliance assistance manual, issued by EPA Region 7, serves as a road map of information on federal environmental programs and federal, state, and local agency roles applicable to designing, building, and operating biodiesel manufacturing facilities.	*www.epa.gov/region07/priorities/agriculture/biodiesel_manual.pdf*
State Examples		
California	***An Assessment of Biomass Resources in California***, 2007, provides an updated biomass inventory for the state along with an assessment of potential growth in biomass resources and power generation that could help to satisfy the state renewable portfolio standard (RPS).	*http://biomass.ucdavis.edu/materials/reports%20and%20publications/2008/CBC_Biomass_Resources_2007.pdf*
Georgia	***Biomass Wood Resource Assessment on a County-by-County Basis for the State of Georgia*** provides a biomass wood resource assessment on a county-level basis for Georgia.	*www.gfc.state.ga.us/ForestMarketing/documents/BiomassWRACountybyCountyGA05.pdf*
Hawaii	***Biomass and Bioenergy Resource Assessment: State of Hawaii*** provides an assessment of current and potential biomass and bioenergy resources for the state. Includes animal wastes, forest products residues, agricultural residues, and urban wastes.	*www.hawaii.gov/dbedt/info/energy/publications/biomass-assessment.pdf*
Mississippi	***Mississippi Institute for Forest Inventory Dynamic Report Generator*** provides a continuous, statewide forest resource inventory necessary for the sustainable forest-based economy. The inventory information is derived from sampling estimation techniques with a presumed precision of +/- 15% sampling error with 95 percent confidence.	*www.mifi.ms.gov/*
South Carolina	***Potential for Biomass Energy Development in South Carolina*** quantifies the amount of forestry and agricultural biomass available for energy production on a sustainable basis in South Carolina. Also includes an analysis of the economic impacts of transferring out-of-state costs for coal to in-state family forest landowners and biomass processors.	*www.scbiomass.org/Publications/Potential%20Biomass%20Energy%20in%20SC.pdf*

Resource	Description	URL
Oregon	***Biomass Energy and Biofuels from Oregon's Forests*** assesses the statewide potential for production of electricity and biofuels from woody biomass, including the available wood supply and the environmental, energy, forest health, and economic effects. Reviews and summarizes efforts underway to promote electric energy and biofuels from woody biomass, and identifies gaps in existing efforts. Assesses constraints and challenges to the development of biomass energy and biofuels from Oregon forests, including economic, environmental, legal, policy, infrastructure, and other barriers and develops recommendations on how to overcome these barriers.	*www.oregonforests.org/assets/uploads/Biomass_Full_Report.pdf*
Northeastern states (CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT)	***Securing a Place for Biomass in the Northeast United States: A Review of Renewable Energy and Related Policies*** provides a biomass feedstock assessment for northeastern states.	*www.nrbp.org/pdfs/nrbp_final_report.pdf*
Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, OK, ND, SD, NE, KS, AK, HI)	The ***Western Bioenergy Assessment*** includes a series of technical reports produced for the Western Governors' Association. These reports extensively evaluate biomass resources in the western states, biofuel conversion technologies, spatial analysis and supply curve development, and deployment scenarios and potential policy interactions.	*www.westgov.org/wga/initiatives/transfuels/index.html*
Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, OK, ND, SD, NE, KS, AK, HI)	The ***Western Governors' Association Transportation Fuels for the Future Initiative*** provides seven working group reports and a final report analyzing the potential for the development of alternative fuels and vehicle fuel efficiency in the West.	*www.westgov.org/wga/initiatives/transfuels/index.html*
Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, ND, SD, NE, KS, AK, HI)	***Biomass Task Force Report*** focuses on the use of biomass resources for the production of electricity as part of an overall effort of the Western Governors' Association to increase the contribution of clean and renewable energy in the region.	*www.westgov.org/wga/initiatives/cdeac/Biomass-full.pdf*

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CHAPTER FIVE

Options for States to Advance Bioenergy Goals

States interested in promoting bioenergy can take active roles in removing financial, policy, regulatory, technology, and informational barriers hindering development of biomass projects. As diverse as these approaches are, they are all aimed at reducing investor risk in order to increase the likelihood of bioenergy projects moving forward to completion.

Bioenergy developers often need to raise capital to cover significant project expenses, such as construction costs, the cost of equipment, installation fees, and any costs incurred during the regulatory and permitting process. The terms under which investors and lenders provide this capital—should they agree to provide any at all—can significantly impact the cost of producing bioenergy, and therefore its competitiveness with other energy sources. All else constant, the greater the investors' and lenders' perception of risks related to a particular project, the greater the cost of capital. States can help reduce the cost of financing for many bioenergy developers by enacting policies and other measures that reduce lending and investment risks.

DOCUMENT MAP

CHAPTER FIVE CONTENTS

States can promote bioenergy by facilitating:

- Favorable policy development
- Favorable regulatory development
- Environmental revenue streams
- Direct investment/financing
- Incentives
- Research, development, and demonstration
- Information sharing

Although not a comprehensive list, these options have been implemented in many states and provide numerous lessons.

The following sections provide details on how states can implement each of these options to promote investment in bioenergy.

5.1 FAVORABLE POLICY DEVELOPMENT

Many states have promoted bioenergy by seeking to create new or expanded markets for biopower, biofuels, or bioproducts. Enacting policies that encourage or require use of bioenergy does not necessarily financially support development, but does provide certainty for producers that a market will exist for their products, which in turn reduces investor risk.

State policies that require use of renewable energy, such as RPS and renewable fuels standards, have proven to stimulate growth in renewable energy markets and reduce investor risk by ensuring each year that a given amount of electricity or motor fuel is supplied from renewable sources, including biomass.

Typical state policies that create markets for bioenergy—including detailed information about program benefits, design elements, interactions with state and federal programs, implementation and evaluation, and case studies—are discussed in EPA's *Clean Energy-Environment Guide to Action* at *www.epa.gov/cleanenergy/energy-programs/state-and-local/state-best-practices.html*. Best practices in design and implementation have a significant impact on policy effectiveness.

Several policy options that states can implement to remove barriers to bioenergy development are presented below. Although not a comprehensive list, these options have been implemented in many states and provide numerous lessons.

- **State "Lead by Example" Initiatives**. State and local governments are implementing a range of programs and policies that advance clean energy, including bioenergy within their own facilities, fleets, and operations. These "lead by example" (LBE) initiatives help state and local governments achieve energy cost savings while promoting adoption of clean energy technologies by the public and private sectors. States are leveraging their purchasing power, control of significant energy-using resources, and high visibility of their public facilities to demonstrate clean energy technologies and approaches that lower their energy costs and reduce emissions.

  State LBE initiatives that can support development of bioenergy include:

  - Purchasing and using renewable energy and clean energy generation in public facilities.
  - Implementing "green fleet" programs that require state vehicles to use biomass-based renewable fuels.
  - Implementing procurement rules that require state agencies to purchase biomass-based products.

» **For more information, see EPA's Clean Energy Lead by Example Guide at *www.epa.gov/cleanenergy/documents/epa_lbe.pdf*.**

- **Renewable Portfolio Standard (RPS)**. An RPS requires utilities and other retail electricity providers to supply a specified minimum percentage (or absolute amount) of customer load with eligible sources of renewable electricity. These laws create a new market for renewable energy and DG projects by outlining the specific minimum amount or percentage of clean energy that must be produced by a specified date (e.g., 25 percent of in-state electricity production must come from renewable resources by January 1, 2050). As of November 2008, 35 states, including the District of Columbia, have adopted RPS laws or goals. All state RPSs include bioenergy as an eligible resource.

- **Fostering Voluntary Green Power Markets**. Voluntary green power programs are a relatively small but growing market that provides electricity customers the opportunity to make environmental choices about their electricity consumption. Green power can be offered in both vertically integrated (i.e., regulated) and competitive (i.e., deregulated) retail markets as bundled renewable energy that consumers can purchase voluntarily, either through green pricing programs or green power marketing. States can play key roles in shaping green power markets:

- For regulated markets, states can play important roles in increasing voluntary participation rates in green pricing programs by requiring utilities to offer them to consumers as an option and/or conduct outreach, education, or marketing campaigns about green pricing programs to consumers.
- Under deregulated markets, states can mandate green power marketers' access to electricity customers, which would otherwise involve high transaction costs to the marketers.

In addition to fostering green power programs, states can ensure that they complement other policies already in place, such as public benefits funds (PBFs) or RPSs.

Green power programs have existed for approximately 10 years and have contributed to development of more than 2,200 megawatts (MW) of new renewable capacity. Biomass has been the second most popular resource, after wind, to serve renewable demand.

- **Renewable Fuel Standard (RFS)**. U.S. EPA, under EISA, is responsible for revising and implementing regulations to ensure that a certain percentage of transportation fuel be renewable. The federal Renewable Fuel Standard program will increase the volume of renewable fuel required to be blended into gasoline from 9 billion gallons in 2008 to 36 billion gallons by 2022.[4] States may also enact their own RFSs in addition to the federal program. As of August 2008, 12 states had an RFS in place (Pew Center on Global Climate Change, 2008).

- **Low Carbon Fuel Standard (LCFS)**. An LCFS for transportation fuels is a policy to encourage utilization of low-carbon fuels (measured on a full life-cycle basis) to reduce GHG emissions from the transportation sector.

  In 2007, the Governor of California signed an executive order directing the state's Secretary of Environmental Protection to coordinate the development of an LCFS, which will be the first and only in the United States. The California Air Resources Board released a draft of the standard in March 2009, which if implemented would start in 2011 and require fuel providers to ensure that the mix of fuel they sell into the California market meets, on average, a declining standard for GHG emissions (measured in CO2-equivalent grams per unit of fuel energy sold). By 2020 the standard would reduce the carbon intensity of California's passenger vehicle fuels by at least 10 percent and reduce GHG emissions from the transportation sector by about 16 million metric tons (almost 10 percent of the total GHG emission reductions needed to achieve the State's mandate of reducing GHG emissions to 1990 levels by 2020). The proposed standard is designed to be compatible with market-based compliance mechanisms (U.S. EPA, 2008b and California Environmental Protection Agency, 2009).

» **For more information on California's pending LCFS, see *www.energy.ca.gov/low_carbon_fuel_standard/*.**

- **High Tipping Fees**. The availability of urban wood residues is largely governed by the size of tipping fees. Where such fees are high (partly due to the lack of land for landfills), recycling is often higher. Also, high tipping fees provide economic incentives to utilize these resources (U.S. DOE, 2005).

5.2 FAVORABLE REGULATORY DEVELOPMENT

In some circumstances, bioenergy developers will experience time delays as they go through the process of obtaining required utility interconnection, environmental compliance, and construction permits. The prospect of significant time delays for some projects can contribute to investor risk. States can help reduce this risk by streamlining and standardizing regulatory and permitting processes for bioenergy producers.

Example

BIOENERGY ONE STOP SHOPS

The Georgia Center for Innovation in Agribusiness is working to promote production and use of renewable energy and biofuels in Georgia by conducting One Stop Shops that bring together prescreened businesses and representatives from more than 20 state and federal agencies. These working meetings give companies the opportunity to present and discuss ideas for bioenergy projects and obtain the permitting and contact information they need to get their ideas off the ground. The center aims to help businesses through the permitting process in 90 days while creating networks connecting business, industry, research, and government. To date, 14 One Stop Shop meetings have been conducted, with 85 companies presenting ideas. As a result of these meetings, 23 bioenergy projects have been launched or planned for implementation by 2015.

For more information, visit *http://energy.georgiainnovation.org/services*.

4 The new RFS program regulations are being developed in collaboration with refiners, renewable fuel producers, and many other stakeholders (see www.epa.gov/oms/renewablefuels/index.htm).

EPA's Environmental Technology Verification program provides emissions verification for various technologies, including biomass cofiring and other new clean energy technologies. Use of emissions data from verification studies can help speed the permitting process for new facilities.

Visit *www.epa.gov/etv/* to see what verification reports are available.

For biofuels producers and distributors, one step that states can take is to adopt ASTM standards for blending. There is no federal requirement in this area, so states have often had different standards. A more consistent market allowing preblended fuels to be sold across states could reduce distribution costs (Schultz, 2008).

Example

STATE GRANT PROGRAMS: PENNSYLVANIA ENERGY DEVELOPMENT AUTHORITY

Several states provide funding and financial incentives, such as grants, loans, and loan guarantees, to drive investment in renewable energy, including bioenergy. These offerings are not only stimulating the nation's renewable energy markets, but are helping to reduce air and water pollution, promote economic development and job creation, and improve energy security. Pennsylvania is among the states now offering grant funding for bioenergy research and production.

Every year, the Pennsylvania Energy Development Authority (PEDA) competitively awards millions of dollars in grants to help finance clean, advanced energy projects. Energy projects eligible to receive funding include biomass, wind, solar, fuel cells, and other energy sources. For-profit businesses, local governments, and nonprofit organizations, as well as businesses interested in locating their advanced energy operations in Pennsylvania, have been invited to apply for funding in the past. Applications to receive funding are evaluated based on numerous factors, such as a project's cost-effectiveness, technical feasibility, and economic and environmental benefits. The extent to which the project promotes use and development of the state's indigenous energy resources, such as biomass, and improves energy diversity and security are also considered in the evaluation process.

From 2004 to 2007, Pennsylvania awarded $6 million in grants to 13 different bioenergy projects. Among the recipients of funding were a school district using biomass to heat school buildings, several biodiesel producers, a major university conducting applied research, and several LFG energy projects.

To learn more about the grant program, visit PEDA's Web site at *www.depweb.state.pa.us/enintech/cwp/view.asp?a=1415&q=504241*.

Source: DSIRE

5.3 ENVIRONMENTAL REVENUE STREAMS

Bioenergy has a number of potential environmental benefits over other forms of energy, which in some cases can be monetized (for more information on these potential benefits, see Chapter 3, Benefits and Challenges of Bioenergy*)*. States can offer environmental revenue streams (ERS), such as renewable energy certificates (RECs) or emission allowance guarantees that reward biomass technologies for their environmental attributes.

Some states, for example, allow renewable energy producers to participate in the emissions allowance market for NO_x. The sale of these allowances can provide bioenergy producers with an additional source of revenue. Further, if CO_2 is regulated through a cap-and-trade system, biopower and other bioenergy sources might obtain cash flow through the associated carbon market. These additional sources of revenue can significantly reduce risk for potential lenders and improve potential investment returns.

For more information on environmental revenue streams, see EPA's CHP Partnership paper *Environmental Revenue Streams for Combined Heat and Power* at *www.epa.gov/chp/documents/ers_program_details.pdf*.

CO_2 OFFSETS: ENVIRONMENTAL REVENUE STREAMS FOR BIOENERGY PROJECTS

Separate from CO_2 cap-and-trade programs, several states regulate CO_2 emissions from particular sources. To help regulated sources comply cost effectively, these states allow sale of CO_2 emission offset credits. Projects that reduce CO_2 or other GHG emissions at one location generate CO_2 credits that can be sold to offset emissions at another location. In states such as Massachusetts, Oregon, and Washington, biomass CHP projects can be used to create offsets.

Source: U.S. EPA, 2008

5.4 DIRECT INVESTMENT/ FINANCING AND INCENTIVES

States can substantially reduce investor risk by providing funding and financial incentives for bioenergy production. These offerings increase the likelihood of a market for bioenergy by reducing energy costs—and, therefore, the competitiveness of bioenergy with other energy sources—and improving returns for potential investors.

Numerous states offer direct incentives to bioenergy project developers in various forms; more incentives are available for biopower production than for biofuels (see Tables 5-1 and 5-2). Low interest rate loans, bond programs, rebates, grants, production incentives, and tax incentives (deductions, exemptions, and credits) are among the different types of incentives states have made available for bioenergy production. The effectiveness of incentive programs varies greatly, as tracked by NREL's State Clean Energy Policies Analysis Project.

» **For more information, see *www.nrel.gov/applying_technologies/scepa.html*.**

For municipal projects—including municipal use of urban wood waste and methane capture and use at municipal landfills and wastewater treatment plants—municipal bonds, bank loans, and/or lease purchase agreements may be available.

Some common state approaches to providing incentives include:

- **Public Benefit Funds (PBFs)**. PBFs, also known as system benefits charges (SBC) or clean energy funds, are typically created by levying a small fee or surcharge on electricity rates paid by customers (e.g., for renewable energy PBFs, this fee is approximately 0.01 to 0.10 mills per kWh). To date, PBFs have been used primarily to fund energy efficiency and low-income assistance programs; more recently they have supported clean energy supply (i.e., renewable energy, including bioenergy, and CHP).

» **For more information about PBF benefits, design elements, interaction with state and federal programs, implementation and evaluation, and case studies, see EPA's Clean Energy-Environment Guide to Action at *www.epa.gov/cleanenergy/energy-programs/state-and-local/state-best-practices.html*.**

- **Financial Incentives**. Financial incentives, including tax incentives, grants, and loans, can play a key role in reducing investor risks and promoting bioenergy development.
  - ***State tax incentives*** for renewable energy can take the form of personal or corporate income tax credits, tax reductions or exemptions, and tax deductions (e.g., for construction programs). Tax incentives aim to spur innovation by the private sector. State tax incentives for renewable energy are a fairly common policy tool. While state tax incentives tend to be

Example

INCENTIVES FOR BIOMASS IN OREGON

The state of Oregon has developed a suite of financial incentives to promote the use of biomass for bioenergy production. Two of these include:

Business Energy Tax Credit. Offers a 50 percent tax credit on eligible project costs up to $20 million for a variety of projects, including two categories that may apply to biomass projects—high efficiency combined heat and power (CHP) and renewable energy generation. The credit can be taken as 10 percent annually over five years, or a project owner can transfer the credit to a pass-through partner in return for a lump sum payment at the completion of the project. For more information, visit: *www.oregon.gov/ENERGY/CONS/BUS/BETC.shtml*.

Energy Trust of Oregon Grants. Charged by the Oregon Public Utility Commission with investing in cost-effective energy conservation, renewable energy resources, and energy market transformation in Oregon, the Energy Trust offers millions of dollars annually in grants for innovative commercial applications of renewable energy technology. Incentive levels are based on a project's above-market costs. For more information, visit: *www.energytrust.org/grants/up/index.html*.

Example

BIOFUEL TAX INCENTIVES IN INDIANA

The state of Indiana has developed a comprehensive set of incentives to promote biofuels within its borders. Between 2005 and 2009, $16 million in tax incentives were used to kick-start the ethanol industry—resulting in 10 new ethanol production facilities in the state along with several biodiesel plants to make soybean-based fuel. These incentives target different aspects of biofuel production and distribution, and include tax credits for:

- **Ethanol production**. Ethanol producers are entitled to a credit of $0.125 per gallon of ethanol produced, including cellulosic ethanol. The maximum credit that may be claimed by a single producer depends on the volume of grain ethanol produced.
- **Ethanol retail**. E85 retailers are allowed to deduct $0.18 from the required state gross retail tax for every gallon of E85 sold during reporting periods ending before July 1, 2020.
- **Biodiesel production**. Biodiesel producers are entitled to a credit of $1.00 per gallon of biodiesel produced. The total amount of credits granted to a single taxpayer may not exceed $3 million for all taxable years, but may be increased to $5 million with prior approval by the Indiana Economic Development Corporation.*
- **Biodiesel blending**. Biodiesel blenders are entitled to a credit of $0.02 per gallon of blended biodiesel produced at a facility located in Indiana. The total amount of credits granted to a single taxpayer may not exceed $3 million for all taxable years.*
- **Biodiesel retail**. Through December 31, 2010, a taxpayer that is a fuel retailer and distributes blended biodiesel for retail purposes is entitled to a credit of $0.01 per gallon of blended biodiesel distributed.*

*This tax credit is contingent on funding, which as of July 2009 was not available.

Source: U.S. DOE, 2009

TABLE 5-1. SUMMARY OF STATE FINANCIAL INCENTIVES FOR BIOMASS TECHNOLOGIES

INCENTIVE TYPE	NUMBER OF INCENTIVES AVAILABLE	STATES OFFERING INCENTIVES
State Grant Program	25	Alabama, Alaska, Connecticut (x2), Delaware, District of Columbia, Florida, Illinois, Indiana, Iowa, Maine, Massachusetts (x2), Michigan (x3), New York, North Carolina, Ohio, Pennsylvania (x2), Rhode Island, South Carolina, Vermont, Wisconsin
State Loan Program	28	Alabama, Alaska, California, Connecticut, Hawaii, Idaho, Iowa (x2), Maine, Massachusetts, Minnesota (x3), Mississippi, Missouri, Montana, Nebraska, New Hampshire, New York (x2), North Carolina, Oklahoma (x2), Oregon, Rhode Island, South Carolina, Tennessee, Vermont
Property Tax Exemption	21	Arizona, Colorado, Connecticut, Iowa, Kansas, Maryland, Michigan, Montana (x3), Nevada (x3), New Jersey, New York, Ohio, Oregon, Rhode Island, South Dakota, Texas, Vermont
Sales Tax Exemption	10	Georgia, Idaho, Kentucky, Maryland, New Mexico, Ohio, Utah, Vermont, Washington, Wyoming
Corporate Tax Credit	13	Florida, Georgia, Iowa, Kentucky, Maryland, Missouri, Montana, New Mexico, North Carolina, North Dakota, Oregon, South Carolina, Utah
Production Incentive	9	California, Connecticut, Minnesota, New York, North Carolina, South Carolina, Vermont, Washington
Personal Tax Credit	8	Iowa, Maryland, Montana (x2), New Mexico, North Carolina, North Dakota, Oregon, Utah
Personal Deduction	4	Alabama, Arizona, Idaho, Massachusetts
State Rebate Program	2	New Jersey, Wisconsin
Industry Recruitment	14	Colorado, Connecticut, Hawaii, Illinois, Massachusetts (x2), Michigan (x2), Montana (x2), New Mexico, Oregon, Wisconsin (x2)
Corporate Tax Exemption	1	Ohio
Corporate Deduction	1	Massachusetts
Excise Tax Incentive	1	Iowa
State Bond Program	2	Idaho, New Mexico
TOTAL INCENTIVES	**139**	

Source: DSIRE, January 26, 2009

smaller than federal incentives, they are often additive and can become significant considerations when making purchase and investment decisions.

- ***Grants, buy-downs, and generation incentives*** support development of energy efficiency and clean generation technologies. For renewable energy, state grants cover a broad range of activities and frequently address issues beyond system installation costs. To stimulate market activity, state grants can cover research and development, business and infrastructure development, system demonstration, feasibility studies, and system rebates. In contrast to incentives that help finance initial capital costs (e.g., rebates and state sales tax exemptions), states also provide generation incentives on the basis of actual electricity generated. In their most straightforward form, generation incentives are paid on a kilowatt-hour basis.
- ***State loan programs*** provide low-interest loans to promote development of clean energy. One common approach is a revolving loan fund. This type of fund is designed to be self-supporting. States create a pool of capital when the program is launched. This capital

TABLE 5-2. SUMMARY OF STATE INCENTIVES FOR ALTERNATIVE FUELS/ALTERNATIVE-FUEL VEHICLES

INCENTIVE TYPE	NUMBER OF INCENTIVES AVAILABLE	STATES OFFERING INCENTIVES
State Grant Program	42	Arizona, Arkansas, California, Colorado, Connecticut (x2), Florida, Georgia, Idaho, Illinois (x3), Indiana (x3), Iowa (x3), Louisiana, Michigan (x2) Minnesota, New Hampshire, New Mexico, North Carolina (x3), Ohio (x3), Pennsylvania (x2), Tennessee (x3), Texas (x4), Utah, Virginia, Washington
State Loan Program	16	California, Iowa (x3), Maine, Nebraska, North Dakota, Ohio, Oklahoma (x2), Oregon, Rhode Island, Tennessee, Utah, Virginia, Washington
Property Tax Exemption	1	Montana
State Bond Program Exemption	1	North Carolina
Production Incentive	15	California, Colorado, Florida, Hawaii, Kansas, Minnesota, Mississippi, Missouri (x2), Montana (x2), North Dakota, Oregon, South Dakota, Tennessee
Retail Incentive	1	South Carolina
Use Incentive	1	Indiana
Excise Tax Incentive	4	Arkansas, California, Georgia, North Dakota
Rebate	4	Illinois, Michigan, New Jersey (x2)
Tax Credit	60	Colorado, Florida, Georgia, Hawaii, Idaho, Indiana (x6), Iowa (x4), Kansas (x2), Kentucky (x4), Louisiana, Maine (x2), Maryland (x2), Michigan (x2), Missouri, Montana (x3), Nebraska, New Mexico (x2), New York (x2), North Carolina (x4), North Dakota (x3), Ohio, Oklahoma (x3), Oregon (x3), Pennsylvania, South Carolina (x5), South Dakota, Vermont, Virginia, Wisconsin, Wyoming
Tax Deduction	2	Idaho, Washington
Tax Exemption	25	Delaware, District of Columbia, Florida (x2), Georgia, Hawaii, Illinois (x2), Indiana, Louisiana, Massachusetts, Michigan, Missouri, Nebraska, New Mexico, North Carolina (x2), North Dakota, Oklahoma, Oregon, Rhode Island, Texas, Washington (x2), Wisconsin
Tax Reduction	11	Alaska, Arizona, Hawaii, Kansas, Kentucky, Maine, Michigan, Minnesota, Montana, New York, South Dakota
Tax Refund	5	Kentucky, Montana, Pennsylvania, South Dakota, Wisconsin
TOTAL INCENTIVES	**188**	

Source: U.S. DOE, 2008

then "revolves" over a multiyear period, as payments from borrowers are returned to the pool and lent anew to other borrowers. Revolving loan funds can be created from several sources, including PBFs, utility program funds, state general revenues, or federal programs. Loan funds are typically created by state legislatures and administered by state energy offices.

- **Biofuels Incentives.** Many states have incentives to help promote development of biofuels. These incentives can include exemptions from state gasoline excise taxes, direct production payments, state RFSs, and price supports. A current list of state ethanol incentives can be found on the RFA Web site at *www.ethanolrfa.org/policy/actions/state/*.

5.5 RESEARCH, DEVELOPMENT, AND DEMONSTRATION

Lack of confidence in the less common biomass conversion technologies, such as gasification, generally will discourage lending and investment in bioenergy. Research, development, and demonstration projects will help not only to advance the capabilities of emerging technologies, but will increase investor confidence and therefore facilitate bioenergy developers' access to capital.

Example

FLORIDA'S RENEWABLE ENERGY AND ENERGY-EFFICIENT TECHNOLOGIES GRANTS PROGRAM

Since 2006, Florida's Renewable Energy and Energy-Efficient Technologies Grants Program has provided more than $27 million in matching grants to support a variety of renewable energy projects. Nonprofit organizations, as well as Florida municipalities and county governments, state agencies, for-profit businesses, universities and colleges, and utilities, are eligible to receive funding. Numerous bioenergy projects have benefited from the program in recent years.

One of these projects includes a field demonstration of a power, refrigeration, heat, and a fresh water plant that is capable of running on a variety of biomass-derived fuels—including crop and forest wastes, energy crops, and municipal wastes, in addition to hydrogen and conventional fuels. Located at the University of Florida Energy Research Park, the plant uses the university's patented PoWER technology and is designed to provide essentials such as fresh water, refrigeration, and electricity even during grid outages that can occur due to hurricanes and other emergencies.

To learn more about the program, as well as the renewable energy projects that have received funding under this program, visit *www.floridaenergy.org/energy/energyact/grants.htm*.

Sources: DSIRE

5.6 INFORMATION SHARING

Potential lenders and investors will not necessarily be aware of the financial incentives offered in each state for bioenergy development. States can facilitate financing of bioenergy projects by providing information about financing sources. This information will help developers, investors, and lenders take advantage of revenue streams as well as any federal and municipal financing options.

In addition, states can develop their own outreach programs that educate consumers, potential markets, and regulators about the benefits of bioenergy and how it will meet state goals. Additional options are described in Section 5.7—Resources for Detailed Information.

Some examples of outreach efforts that can be used by states include:

- ***Wood Stove Changeout Campaign***. U.S. EPA offers resources to assist states and local governments with successful implementation of a Wood Stove Changeout Campaign, including how to identify potential partners, identify sources of funding, develop a project plan, implement the campaign, and measure success. States provide information and incentives (e.g., rebates or discounts) to encourage residents to replace their old, conventional wood stoves with EPA-certified wood-burning appliances that burn more cleanly and efficiently. See ***www.epa.gov/woodstoves/how-to-guide.html***.
- ***Southern Forest Research Partnership materials***. The Southern Forest Research Partnership offers numerous publications, presentations, links, images, case studies, activities, videos, and other educational tools that can be used to share woody biomass information with natural resource management and extension professionals as well as community planning and development professionals. The *Sustainable Forestry for Bioenergy and Bio-based Products Training Curriculum Notebook* is a comprehensive training resource, which includes a trainer's introduction, seven modules, fact sheets, a glossary, evaluation resources, example activities, and a supplemental materials list. See ***www.forestbioenergy.net/training-materials***.
- ***It All Adds Up To Cleaner Air Resources Toolkit***. While not explicitly designed for bioenergy, this U.S. Department of Transportation step-by-step guide to implementing a public outreach program provides many tips that would be appropriate for any outreach campaign. See ***http://www.italladdsup.gov/tools/how_to.asp***.

5.6.1 NATIONAL BIOMASS STATE AND REGIONAL PARTNERSHIPS

States can also participate in regional partnerships to share best practices. U.S. DOE's Biomass Program works with the National Biomass State and Regional Partnerships, listed below. Each organization provides leadership in its region with regard to policies and technical issues to advance the use of biomass. Contact information is provided on the program Web sites.

Great Lakes Regional Biomass Energy Program
(Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin) *www.cglg.org/biomass*

Northeast Regional Biomass Energy Program
(Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont) *www.nrbp.org/*

Pacific Regional Biomass Energy Program
(Alaska, Hawaii, Idaho, Oregon, Montana, Washington) *www.pacificbiomass.org*

Southern State Energy Board
(Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia, Puerto Rico, U.S. Virgin Islands) *www.sseb.org/*

Southeast Regional Biomass Energy Program
(Alabama, Arkansas, D.C., Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Puerto Rico, South Carolina, Tennessee, Virgin Islands, Virginia, West Virginia) *www.serbep.org/*

Western Regional Energy Program
(Arizona, California, Colorado, Kansas, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, Wyoming) *www.westgov.org/wga/initiatives/biomass/*

5.7 RESOURCES FOR DETAILED INFORMATION

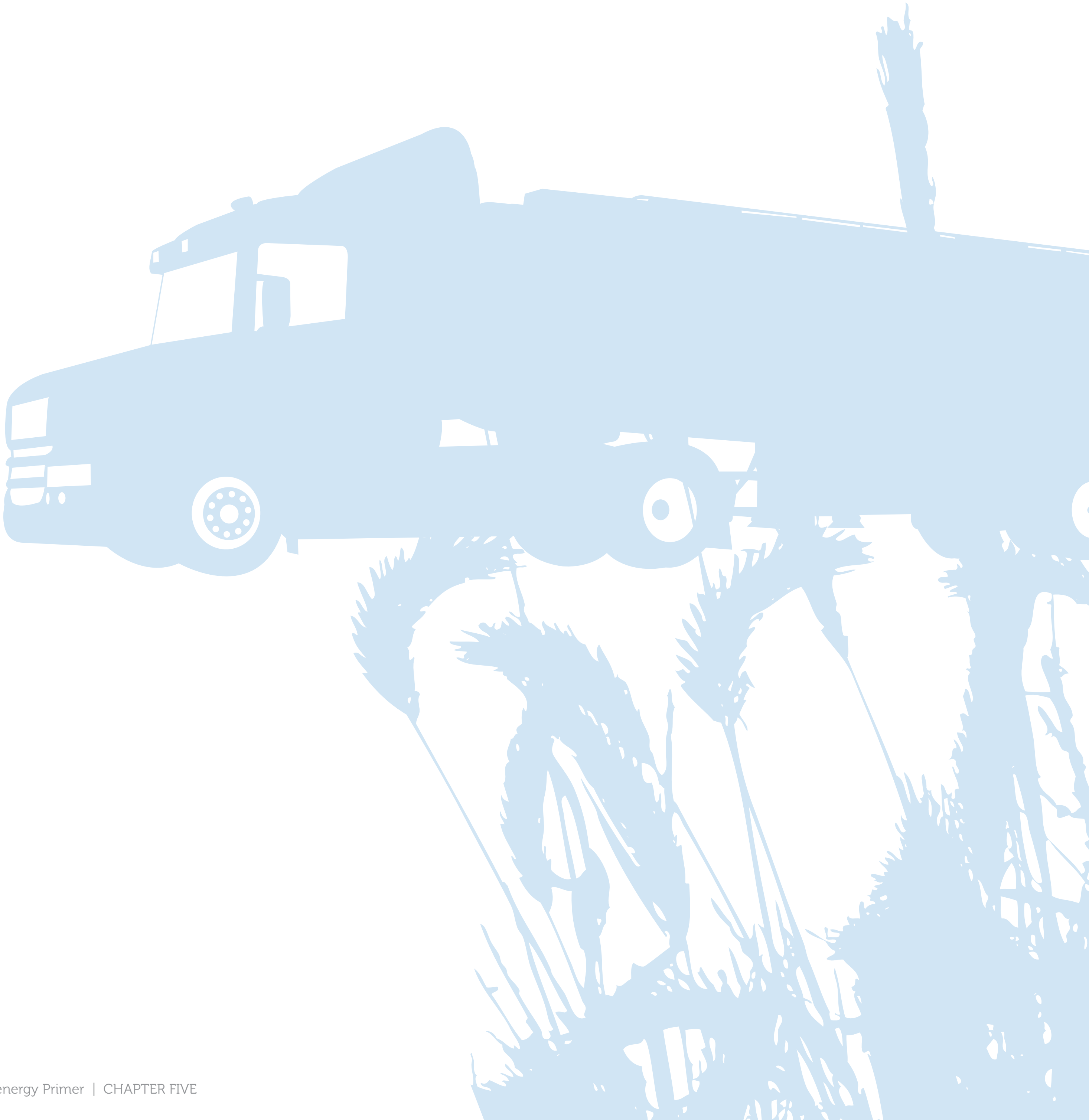
Resource	Description	URL
Bioenergy		
Capturing the Full Potential of Bioenergy: A Model for Regional Bioenergy Initiatives, GEN Publishing, Inc., 2007.	Advances a step-by-step approach for advancing bioenergy.	*www.liebertonline.com/doi/abs/10.1089/ind.2007.3.120*
Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States, U.S. EPA, 2006.	This Web site and guide present 16 policies that states use to advance clean energy.	*www.epa.gov/cleanrgy/stateandlocal/guidetoaction.htm*
Clean Energy Lead by Example Guide, U.S. EPA, 2009.	Describes proven strategies, resources, and tools to help states save money and reduce greenhouse gas emissions by adopting clean energy practices in their facilities, operations, and vehicle fleets.	*www.epa.gov/cleanenergy/documents/epa_lbe.pdf*
Database of State Incentives for Renewable Energy (DSIRE).	Searchable database of incentives relevant to bioenergy, by state. Select a renewable energy search, by technology, for biomass, CHP, and/or landfill gas. The database is updated routinely.	*www.dsireusa.org/*
State Policies for Promoting the Next Generation of Biomass Technologies, Great Plains Institute, November 22, 2006.	Summarizes recommendations on state policies to advance biomass.	*www.ef.org/documents/BWG_State_Policy_Menu_Final_v3.pdf*
State Incentives and Resources Search, U.S. DOE.	This Web page includes state energy information for biomass, other renewable energy, and fossil energy.	*www1.eere.energy.gov/industry/about/state_activities/incentive_search.asp*

Resource	Description	URL
Developing State Policies Supportive of Bioenergy Development, Southern States Energy Board, 2002.	Analyzes policy options to advance bioenergy, based on regional experiences in the Southeast.	*www.osti.gov/bridge/servlets/purl/828971-Pbx12e/native/828971.pdf*
Environment and Energy Study Institute (EESI).	This Web site includes information on bioenergy and federal and state incentives.	*www.eesi.org/Sustainable_Biomass_Energy_Program*
It All Adds Up to Cleaner Air Resources Toolkit, U.S. Department of Transportation.	While not explicitly designed for bioenergy, this step-by-step guide to implementing a public outreach program provides many tips that would be appropriate to any outreach campaign.	*www.italladdsup.gov/tools/how_to.asp*
Southern Forest Research Partnership.	Offers numerous publications, presentations, links, images, case studies, activities, videos, and other educational tools that can be used to share woody biomass information with natural resource management and extension professionals as well as community planning and development professionals.	*www.forestbioenergy.net/training-materials*
State Woody Biomass Utilization Policies, University of Minnesota, Department of Forest Resources, Staff Paper 199. Becker, D.R., and C. Lee. 2008.	A comprehensive database of woody biomass legislation for each state in the United States.	*www.forestry.umn.edu/publications/staffpapers/Staffpaper199.pdf*
Biopower/Bioheat		
Green-e Certification Process.	A voluntary market for renewable energy certificates exists, and some kinds of biopower generation are eligible for Green-e certification. Eligible sources must go through the certification process to be able to sell certified products.	*www.green-e.org/docs/Appendix_D-Green-e_National_Standard.pdf* *and www.green-e.org/getcert_re_6steps.shtml#rec*
State Energy Program.	This collaboration of DOE and the states provides joint funding for state formula grant projects and local energy efficiency and renewable energy projects.	*http://apps1.eere.energy.gov/state_energy_program/*
State Technologies Advancement Collaborative Program, U.S. DOE, National Association of State Energy Officials, Association of State Energy Research and Technology Transfer Institutions.	This collaboration provides funding for state energy efficiency and renewable energy projects.	*www.stacenergy.org*
Biofuels/Bioproducts		
Alternative Fuels Data Center: All State Incentives and Laws, U.S. DOE, NREL.	The data center is a comprehensive clearinghouse of data, publications, tools, and information related to advanced transportation technologies.	*www.afdc.energy.gov/afdc/data/methodology.html*
Funding Database – Biomass/Biogas, U.S. EPA.	This database of financial and regulatory incentives at the state level is updated monthly.	*www.epa.gov/chp/funding/bio.html*
Understanding and Informing the Policy Environment: State-Level Renewable Fuels Standards, NREL, January 2007.	Summary and analysis of state actions on renewable fuels standards.	*www.nrel.gov/docs/fy07osti/41075.pdf*

Resource	Description	URL
Funding Landfill Gas Energy Projects: State, Federal, and Foundation Resources, U.S. EPA.	This guide from the Landfill Methane Outreach Program details potential sources of funding for landfill gas projects.	*www.epa.gov/lmop/res/guide/index.htm*
State Examples		
Arkansas	State-Specific Financing Information	*http://arkansasenergy.org/solar-wind-bioenergy/bioenergy.aspx*
Florida	State-Specific Financing Information	*www.floridafarmtofuel.com/Downloads/FTF%20Grant%20Agreement%20Contract%20092507.pdf*
Michigan	State-Specific Financing Information	*http://michigan.gov/documents/cis/CIS_EO_Funding_Opportunities_192768_7.pdf*
Montana	State-Specific Financing Information	*www.deq.state.mt.us/Energy/bioenergy/Biodiesel_Production_Educ_Presentations/Combined_Biodiesel_Ethanol_Govt_Incentives_Montana_Jan07_bshh.pdf*
Washington	State-Specific Financing Information	*http://agr.wa.gov/Bioenergy/*

5.8 REFERENCES

- **California Environmental Protection Agency**, 2009. *Proposed Regulation to Implement the Low Carbon Fuel Standard* (Vol. 1). Sacramento, CA, March 5, 2009. *www.arb.ca.gov/fuels/lcfs/lcfs.htm*.
- **DSIRE (Database of State Incentives for Renewables & Efficiency)**. North Carolina Solar Center, Raleigh, NC. *www.dsireusa.org*.
- **Pew Center on Global Climate Change**, 2008. *Mandates and Incentives Promoting Biofuels*. Pew Center on Global Climate Change, Arlington, Virginia, August 5, 2008. *http://pewclimate.org/what_s_being_done/in_the_states/map_ethanol.cfm*.
- **U.S. DOE (Department of Energy)**, 2008. Alternative Fuels Data Center. Washington, DC, December 29, 2008. *http://www.afdc.energy.gov/afdc/incentives_laws.html*.
- **U.S. DOE**, 2009. Alternative Fuels and Advanced Vehicles Data Center. Washington, DC, 2009. *www.indystar.com/article/20081116/BUSINESS/811160391*; *www.afdc.energy.gov/afdc/progs/view_all.php/IN/0*; *www.afdc.energy.gov/afdc/progs/ind_state.php/IN/E85*; *www.afdc.energy.gov/afdc/progs/ind_state.php/IN/BD*.
- **U.S. EPA (Environmental Protection Agency)**, 2008a. ***Environmental Revenue Streams for Combined Heat and Power***. Combined Heat and Power Partnership. U.S. EPA, Washington, DC, December 2008. *www.epa.gov/chp/documents/ers_program_details.pdf*.
- **U.S. EPA**, 2008b. ***State and Regional Climate Policy Maps***. U.S. EPA, Washington, DC, May, 2008. *http://epa.gov/climatechange/wycd/stateandlocalgov/state_actionslist.html*.



APPENDIX A

Resources and Tools for States

The resources for detailed information that are included at the end of each chapter are also compiled here to serve as a comprehensive snapshot of key reports, tools, and guidance documents.

APPENDIX A CONTENTS

A.1 BIOMASS FEEDSTOCKS AND CONVERSION TECHNOLOGIES

Resource	Description	URL
Bioenergy		
Woody Biomass Utilization, U.S. Forest Service and Bureau of Land Management.	This U.S. Forest Service and Bureau of Land Management Web site provides links to a variety of resources and reports on woody biomass utilization, including tools and references specifically targeted at state governments.	*www.forestsandrangelands.gov/Woody_Biomass/index.shtml*
BioWeb, Sun Grant Initiative.	An online catalog of a broad range of resources on bioenergy, including descriptions of biomass resources, biofuels, and bioproducts; explanations of conversion technologies; and summaries of relevant policies. The resources are searchable by both topic and level of detail of information provided. The catalog is a product of the Sun Grant Initiative, a national network of land-grant universities and federally funded laboratories working together to further establish a bio-based economy.	*http://bioweb.sungrant.org/*
Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, U.S. DOE, USDA, 2005.	Describes issues associated with reaching the goal of 1 billion tons of annual biomass production (see especially pp. 34–37).	*www.osti.gov/bridge*
Biomass Energy Data Book, U.S. DOE, September 2006.	Provides a compilation of biomass-related statistical data.	*http://cta.ornl.gov/bedb/index.shtml*
Biomass Feedstock Composition and Property Database, U.S. DOE.	Provides results on chemical composition and physical properties from analyses of more than 150 samples of potential bioenergy feedstocks, including corn stover; wheat straw, bagasse, switchgrass, and other grasses; and poplars and other fast-growing trees.	*www1.eere.energy.gov/biomass/feedstock_databases.html*
A Geographic Perspective on the Current Biomass Resource Availability in the United States, Milbrandt, A., 2005.	Describes the availability of the various types of biomass on a county-by-county basis.	*www.nrel.gov/docs/fy06osti/39181.pdf*
Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology, Kent, 2007.	Detailed, comprehensive, fairly technical explanation of the range of biomass conversion technologies.	
Biopower/Bioheat		
Biomass Combined Heat and Power Catalog of Technologies, U.S. EPA, September 2007.	Detailed technology characterization of biomass CHP systems, including technical and economic characterization of biomass resources, biomass preparation, energy conversion technologies, power production systems, and complete integrated systems. Includes extensive discussion of biomass feedstocks.	*www.epa.gov/chp/documents/biomass_chp_catalog.pdf*
Combined Heat and Power Market Potential for Opportunity Fuels, U.S. DOE, Resource Dynamics Corporation, August 2004.	Determines the best "opportunity fuels" for distributed energy sources and CHP applications.	*www.eere.energy.gov/de/pdfs/chp_opportunityfuels.pdf*

Resource	Description	URL
Biofuels/Bioproducts		
Bioenergy Conversion Technology Characteristics, Western Governors' Association, September 2008.	Investigates the biofuel conversion technologies that are currently available, as well as technologies currently under development that are developed enough to be potentially available on a commercial basis circa 2015.	*www.westgov.org/wga/initiatives/transfuels/Task%202.pdf*
A National Laboratory Market and Technology Assessment of the 30x30 Scenario, NREL, March 2007.	Draft assessment of the market drivers and technology needs to achieve the goal of supplying 30 percent of 2004 motor gasoline fuel demand with biofuels by 2030.	
From Biomass to BioFuels: NREL Leads the Way, NREL, August 2006.	Provides an overview of the world of biofuels, including the maturity levels of various biofuels, how they are produced, and the U.S. potential for biofuels.	*www.nrel.gov/biomass/pdfs/39436.pdf*
Research Advances Cellulosic Ethanol: NREL Leads the Way, NREL, March 2007.	Highlights some of NREL's most recent advances in cellulosic ethanol production.	*www.nrel.gov/biomass/pdfs/40742.pdf*

A.2 BENEFITS OF BIOENERGY (ENVIRONMENTAL, ECONOMIC, ENERGY)

Resource	Description	URL
Bioenergy		
Economic Impacts of Bioenergy Production and Use, U.S. DOE, SSEB Southeast Biomass State and Regional Partnership, October 2005.	Summarizes the benefits of bioenergy production in the U.S., including job creation, reduced demand for fossil fuels, and expanded tax bases.	*www.vienergy.org/Economics.pdf*
State Energy Alternatives Web Site, U.S. DOE, National Conference of State Legislatures.	Provides information on state-specific biomass resources, policies, and status as well as current biofuels and biopower technology information.	*http://apps1.eere.energy.gov/states/*
An Assessment of Biomass Harvesting Guidelines, Evans and Perschel, Forest Guild, 2009.	Presents an assessment of existing biomass harvesting guidelines and provides recommendations for the development of future guidelines.	*www.forestguild.org/publications/research/2009/biomass_guidelines.pdf*
Planning for Disaster Debris, U.S. EPA, 2008.	Provides information and examples for developing a disaster debris plan that will help a community identify options for collecting, recycling, and disposing of debris in the event of a natural disaster.	*www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/disaster.htm*
Biopower/Bioheat		
Biomass Power and Conventional Fossil Systems with and without CO_2 Sequestration—Comparing the Energy Balance, Greenhouse Gas Emissions, and Economics, NREL, January 2004.	Provides a comparative analysis of a number of different biopower, natural gas, and coal technologies.	*www.nrel.gov/docs/fy04osti/32575.pdf*
Economic Impacts Resulting from Co-Firing Biomass Feedstocks in Southeastern U.S. Coal-Fired Power Plants, Presentation by Burton English et al., University of Tennessee.	Summarizes the economic impacts in eight southeastern states from using biomass to co-fire power plants that traditionally have only used coal for fuel.	*www.farmfoundation.org/projects/documents/english-cofire.pptprojects/documents/english-cofire.ppt*
Green Power Equivalency Calculator, U.S. EPA.	Allows any bioenergy user to communicate to internal and external audiences the environmental impact of purchasing or directly using green power in place of fossil fuel derived energy by calculating the avoided carbon dioxide (CO2) emissions. Results can be converted into an equivalent number of passenger cars, gallons of gasoline, barrels of oil, or American households' electricity use.	*www.epa.gov/grnpower/pubs/calculator.htm*
Job Jolt: The Economic Impacts of Repowering the Midwest: The Clean Energy Development Plan for the Heartland, Regional Economics Applications Laboratory, November 2002.	Analyzes the economic and job creation benefits of implementing a clean energy plan in the 10-state Midwest region.	*www.michigan.gov/documents/nwlb/Job_Jolt_RepoweringMidwest_235553_7.pdf*

A.2 BENEFITS OF BIOENERGY (ENVIRONMENTAL, ECONOMIC, ENERGY) *(cont.)*

Resource	Description	URL
Biofuels/Bioproducts		
Alternative Fueling Station Locator, U.S. DOE.	Allows users to find alternative fuels stations near a specific location on a route, obtain counts of alternative fuels stations by state, view U.S. maps, and more. The following alternative fuels are included in the mapping application: compressed natural gas, E85, propane/liquefied petroleum gas, biodiesel, electricity, hydrogen, and liquefied natural gas.	*www.afdc.energy.gov/afdc/data/geographic.html*
Biomass Energy Data Book, ORNL, September 2008.	Describes a meta-analysis of energy balance analyses for ethanol, revealing the sources of differences among the different studies.	*http://cta.ornl.gov/bedb/pdf/Biomass_Energy_Data_Book.pdf*
Changing the Climate: Ethanol Industry Outlook 2008, Renewable Fuels Association (RFA), 2008.	Forecasts that 4 billion gallons of ethanol production capacity will come on line from 68 biorefineries being constructed in 2008 and beyond, increasing the 2007 figure by nearly 50%.	*www.ethanolrfa.org/objects/pdf/outlook/RFA_Outlook_2008.pdf*
Contribution of the Ethanol Industry to the Economy of the United States, RFA, 2007.	Finds that the industry spent $12.5 billion on raw materials, other inputs, and goods and services to produce about 6.5 billion gallons of ethanol in 2007. An additional $1.6 billion was spent to transport grain and other inputs to production facilities; ethanol from the plant to terminals where it is blended with gasoline; and co-products to end-users.	*www.ethanolrfa.org/objects/documents/576/economic_contribution_2006.pdf*
Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion, University of Tennessee, 2006.	Finds that producing 60 billion gallons of ethanol and 1.6 billion gallons of biodiesel from renewable resources by 2030 would likely result in development of a new industrial complex with nearly 35 million acres planted dedicated to energy crops.	*http://beag.ag.utk.edu/pp/Ethanolagimpacts.pdf*
Ethanol and the Local Community, RFA, 2002.	Summarizes possible effects of ethanol production on local economic development.	*www.ethanolrfa.org/objects/documents/120/ethanol_local_community.pdf*
Greener Fuels, Greener Vehicles: A State Resource Guide, National Governors' Association, 2008.	Discusses alternative transportation fuels and vehicle technologies.	*www.nga.org/Files/pdf/0802GREENERFUELS.PDF*
Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use, U.S. EPA, April 2007.	Provides a summary of GHG emissions from a variety of advanced fuel options.	*www.epa.gov/oms/renewablefuels/420f07035.htm*
New Analysis Shows Oil-Savings Potential of Ethanol Biofuels, National Resources Defense Council (NRDC), 2006.	Describes NRDC's meta-analysis of energy balance papers and its standardized methods.	*www.nrdc.org/media/pressreleases/060209a.asp*
A Rebuttal to "Ethanol Fuels: Energy, Economics and Environmental Impacts," National Corn Growers Association, 2002.	Refutes the contention in a previous article that more energy goes into producing ethanol than ethanol itself can actually provide, creating a negative energy balance.	*www.ethanolrfa.org/objects/documents/84/ethanolffuelsrebuttal.pdf*
Renewable Fuel Standard Program, U.S. EPA.	Describes efforts undertaken by U.S. EPA toward a National Renewable Fuels Standard under requirements of the Energy Policy Act of 2005. While these requirements are superseded by more recent legislation, links from this page provide useful background. In particular, the discussion of estimated costs summarizes the expected incremental costs of policies advancing ethanol.	*www.epa.gov/oms/renewablefuels/*

Resource	Description	URL
Regulatory Impact Analysis: Renewable Fuel Standard Program, U.S. EPA, 2007.	Examines proposed standards that would implement a renewable fuel program as required by the Energy Policy Act of 2005. It notes, however, that renewable fuel use is forecast to exceed the standards due to market forces anyway.	*www.epa.gov/OMS/renewablefuels/420r07004-sections.htm*
SmartWay Grow & Go Factsheet on Biodiesel, U.S. EPA, October 2006.	Describes how biodiesel is made, its benefits versus vegetable oil, performance, availability, affordability, and other characteristics.	*www.epa.gov/smartway/growandgo/documents/factsheet-biodiesel.htm*
SmartWay Grow & Go Factsheet on E85 and Flex Fuel Vehicles, U.S. EPA, October 2006.	Describes E85-fuel and flex-fuel vehicles, including their affordability and benefits.	*www.epa.gov/smartway/growandgo/documents/factsheet-e85.htm*
State-Level Workshops on Ethanol for Transportation: Final Report.	Summarizes a series of DOE-sponsored, state-level workshops exploring and encouraging construction of ethanol plants.	*www.nrel.gov/docs/fy04osti/35212.pdf*
TransAtlas Interactive Alternative Fuel Map, U.S. DOE.	Provides user-friendly Google Maps to display the locations of existing and planned alternative fueling stations, concentrations of different vehicle types, alternative fuel production facilities, roads, and political boundaries.	*www.afdc.energy.gov/afdc/data/geographic.html*
Analysis of Potential Causes of Consumer Food Price Inflation, RFA, 2007.	Asserts that the "marketing bill," not increased ethanol production, is responsible for rising food prices.	*www.ethanolrfa.org/resource/facts/food/documents/Informa_Renew_Fuels_Study_Dec_2007.pdf*
Ethanol Juggernaut Diverts Corn from Food to Fuel, Raloff, Janet, Science News, 2007.	Makes the case that ethanol is driving up food prices.	*www.sciencenews.org/view/generic/id/8179/title/Food_for_Thought__Ethanol_Juggernaut_Diverts_Corn_from_Food_to_Fuel*
Food versus Fuel in the United States, Institute for Agriculture and Trade Policy, 2007.	Finds that biofuel production is not diverting food from tables in the U.S. or abroad.	*www.iatp.org/iatp/publications.cfm?accountID=258&refID=100001*
U.S. Corn Growers: Producing Food and Fuel, National Corn Growers Association, 2006.	Provides the corn growers' perspective that producing food and fuel from corn is working out well, without undue impact on food prices.	*www.ncga.com/files/pdf/FoodandFuelPaper10-08.pdf*
Aggressive Use of Bioderived Products and Materials in the U.S. by 2010, A.D. Little, Inc., 2001.	The presentation and report summarize near-term opportunities to dramatically increase the use of biomass to make nonfuel products.	*www.p2pays.org/ref/40/39031.pdf*
Industrial Bioproducts: Today and Tomorrow, U.S. DOE, July 2003.	The report finds that a bioindustry could harness the energy and molecular building blocks of biomass (crops, trees, grasses, crop residues, forest residues, animal waste, and municipal solid waste) to create products now manufactured from petroleum, making us far less dependent on fossil fuels.	*www.brdisolutions.com/pdfs/BioProductsOpportunitiesReportFinal.pdf*
Preliminary Screening Technical and Economic Assessment of Synthesis Gas to Fuels and Chemicals with Emphasis on the Potential for Biomass-Derived Syngas, NREL, 2003.	Summarizes opportunities for biomass to be used to manufacture a variety of products beyond fuels alone.	*www.nrel.gov/docs/fy04osti/34929.pdf*

A.2 BENEFITS OF BIOENERGY (ENVIRONMENTAL, ECONOMIC, ENERGY) *(cont.)*

Resource	Description	URL
Environmental Life Cycle Implications of Fuel Oxygenate Production from California Biomass – Technical Report, NREL, 1999.	Looks at the costs and benefits of biomass-derived ethanol, ETBE, and E10 as fuel oxygenates across their life cycles.	*www-erd.llnl.gov/FuelsoftheFuture/pdf_files/lifecyclecalif.pdf*
Quantifying Cradle-to-Farm Gate Life-Cycle Impacts Associated with Fertilizer used for Corn, Soybean, and Stover Production, NREL, May 2005.	Documents the costs, such as eutrophication, and benefits of nitrate and phosphate fertilizers used in production of three crops.	*www1.eere.energy.gov/biomass/pdfs/37500.pdf*
Life Cycle Analysis of Ethanol from Corn Stover, NREL, 2002.	This comprehensive accounting of ethanol's flows to and from the environment focuses on ethanol produced from corn stover	*www.nrel.gov/docs/gen/fy02/31792.pdf*
Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus: Final Report, NREL, 1998.	Examines the relative costs and benefits of using biodiesel versus petroleum diesel in an urban bus.	*www.nrel.gov/docs/legosti/fy98/24089.pdf*
Life Cycle Assessment of Biodiesel versus Petroleum Diesel Fuel, Institute of Electrical and Electronics Engineers, 1996.	The proceedings of the 31st Intersociety Energy Conversion Engineering Conference, held August 11–16, 1996, in Washington, DC.	Accessible by subscription only
Life Cycle Assessment of Biomass-Derived Refinery Feedstocks for Reducing CO2, NREL, 1997.	Discusses the two processes for producing 1,4-butanediol. The first process is the conventional hydrocarbon feedstock-based approach, utilizing methane to produce formaldehyde, and acetylene with synthesis under conditions of heat and pressure. The second is a biomass-based feedstock approach where glucose derived from corn is fermented.	Not available online
Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant, NREL, 2001.	Reports on a cradle-to-grave analysis of all processes necessary for the operation of a coal-fired power plant that co-fires wood residue, including raw material extraction, feed preparation, transportation, and waste disposal and recycling.	Accessible by subscription only
Understanding Land Use Change and U.S. Ethanol Expansion, RFA, November 2008.	Discusses historical agricultural land use and crop utilization trends, explores the role of increased productivity, looks at the contributions of ethanol feed co-products, and examines global agricultural land use projections obtained from Informa Economics.	*www.ethanolrfa.org/objects/documents/2041/final_land_use_1110_w_execsumm.pdf*
National Biofuels Action Plan, Biomass Research and Development Board, October 2008.	Outlines areas where cooperation between federal agencies will help to evolve bio-based fuel production technologies into competitive solutions for meeting U.S. fuel demands. Seven key areas for action are identified: feedstock production; feedstock logistics; conversion of feedstock to fuel; distribution; end Use; sustainability; and Environment, Health, and Safety.	*www1.eere.energy.gov/biomass/pdfs/nbap.pdf*

A.3 ASSESSING POTENTIAL MARKETS FOR BIOMASS

Resource	Description	URL
Bioenergy		
Biomass Resource Assessment Tool, U.S. EPA and NREL.	Online mapping tool that takes various biomass resource datasets and maps them, allowing user queries and analysis. For example, users can select a point on the map and determine the quantity of feedstock within a certain radius, and the quantity of energy that could potentially be produced from that biomass.	*http://rpm.nrel.gov/biopower/biopower/launch*
Coordinated Resource Offering Protocol (CROP) Evaluations, U.S. Forest Service and Bureau of Land Management.	Provides the results of ten CROP evaluations that have been conducted for over 30 million acres of public forestlands potentially vulnerable to wildfires. The evaluations contain detailed resource-offering maps that illustrate the growing fuel load problem within major forest systems and quantify the biomass available for removal within five years.	*www.forestsandrangelands.gov/Woody_Biomass/supply/CROP/index.shtml*
USFS Forest Inventory Data Online (FIDO).	Provides access to the National Forest Inventory and Analysis databases. It can be used to generate tables and maps of forest statistics (including tree biomass) by running standard reports for specific states or counties and survey year, or customized reports based on criteria selected by the user.	*http://fiatools.fs.fed.us/fido/index.html*
Biomass Feedstocks, U.S. DOE.	U.S. DOE Biomass Program Web site	*www1.eere.energy.gov/biomass/biomass_feedstocks.html*
Dynamic Maps, GIS Data, and Analysis Tools, NREL.	Provides county-level biomass resource maps. The feedstock categories include crop residues, forest residues, primary mill residues, secondary mill residues, urban wood waste, methane emissions from landfills, methane emissions from manure management, methane emissions from wastewater treatment plants, and dedicated energy crops. The maps are derived from data contained in a report, Geographic Perspective on the Current Biomass Resource Availability in the United States (described below). Note that these maps present technical biomass resource data. The economic biomass resource availability will most likely be somewhat less than what is presented in the maps.	*www.nrel.gov/gis/biomass.html*
Geographic Perspective on the Current Biomass Resource Availability in the United States, NREL, 2006.	Provides the basis for the maps and data presented in NREL's Dynamic Maps, GIS Data, and Analysis Tools Web site described above. The report provides a geographic analysis of biomass resource potential at the county level, and can give state officials a sense of the major biomass resources available within their state and their technical potential relative to other states.	*www.nrel.gov/docs/fy06osti/39181.pdf*
State Assessment for Biomass Resources (SABRE), U.S. DOE.	Provides detailed information on biomass resources and utilization throughout the United States. It features state-specific information on conventional fuel and biofuel use, ethanol and biodiesel stations and production plants, and biofuel production capacities. In addition, it offers state-by-state snapshots of available feedstocks, data on potential production capacities, and projections on the future use of biofuels.	*www.afdc.energy.gov/afdc/sabre/index.php*

Resource	Description	URL
State Woody Biomass Utilization Policies, University of Minnesota, Department of Forest Resources, Staff Paper 199. Becker, D.R., and C. Lee. 2008.	Documents information on state policies to facilitate comparison of the types of approaches used in certain areas, policy structures and incentives employed, program administration, and relationships to complementary local and federal actions.	*www.forestry.umn.edu/publications/staffpapers/Staffpaper199.pdf*
Biopower/Bioheat		
Initial Market Assessment for Small-Scale Biomass-Based CHP. National Renewable Energy Laboratory, NREL, January 2008.	Examines the energy generation market opportunities for biomass CHP applications smaller than 20 MW. Using relevant literature and expert opinion, the paper provides an overview of the benefits of and challenges for biomass CHP in terms of policy and economic drivers, and identifies primary characteristics of potential markets.	*www.nrel.gov/docs/fy08osti/42046.pdf*
Green Power Marketing in the United States: A Status Report, NREL.	Documents green power marketing activities and trends in voluntary markets in the United States.	*http://apps3.eere.energy.gov/greenpower/resources/pdfs/38994.pdf*
U.S. EPA's Landfill Methane Outreach Program (LMOP).	Promotes the use of landfill gas as a renewable, green energy source. Its Web site contains general information, tools, and links to databases containing specific landfill data.	*www.epa.gov/lmop/*
U.S. EPA's Landfill Methane Outreach Program (LMOP) Landfill Database.	Provides a nationwide listing of operational and under-construction LFG energy projects; candidate municipal solid waste landfills having LFG energy potential; and information on additional landfills that could represent LFG energy opportunities. The database can be accessed as a series of downloadable Excel spreadsheets, which are updated and posted to the Web site each month. The information contained in the LMOP database is compiled from a variety of sources, including annual voluntary submissions by LMOP partners and industry publications.	*www.epa.gov/lmop/proj/index.htm*
Landfill Gas Energy Project Development Handbook, U.S. EPA Landfill Methane Outreach Program.	Provides landfill gas energy project development guidance, with individual chapters on the basics of landfill gas energy, gas modeling, technology options, economic analysis and financing, contract and permitting considerations, and selection of project partners.	*www.epa.gov/lmop/res/handbook.htm*
Market Opportunities for Biogas Recovery Systems, U.S. EPA AgStar.	Assesses the market potential for biogas energy projects at swine and dairy farms in the United States. For the top ten swine and dairy states, the guide characterizes the sizes and types of operations where biogas projects are technically feasible, along with estimates of potential methane production, electricity generation, and greenhouse gas emission reductions.	*www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf*
U.S. EPA's Combined Heat and Power (CHP) Partnership.	Promotes the use of biomass-fueled CHP and the use of biogas at wastewater treatment facilities.	*www.epa.gov/chp*

Resource	Description	URL
Biofuels/Bioproducts		
State Assessment for Biomass Resources, U.S. DOE.	Provides detailed information on biomass resources and utilization throughout the United States. It features state-specific information on conventional fuel and biofuel use, ethanol and biodiesel stations and production plants, and biofuel production capacities. It offers state-by-state snapshots of available feedstocks, data on potential production capacities, and projections on the future use of biofuels. The site is particularly useful for states interested in evaluating resource potential for producing biofuels.	*www.afdc.energy.gov/afdc/sabre/index.php*
Environmental Laws Applicable to Construction and Operation of Ethanol Plants, U.S. EPA.	This compliance assistance manual, issued by EPA Region 7, serves as a road map of information on federal environmental programs and federal and state agency roles applicable to the construction, modification, and operation of ethanol plants.	*www.epa.gov/region07/priorities/agriculture/ethanol_plants_manual.pdf*
Environmental Laws Applicable to Construction and Operation of Biodiesel Production Facilities, U.S. EPA.	This compliance assistance manual, issued by EPA Region 7, serves as a road map of information on federal environmental programs and federal, state, and local agency roles applicable to designing, building, and operating biodiesel manufacturing facilities.	*www.epa.gov/region07/priorities/agriculture/biodiesel_manual.pdf*
State Examples		
California	***An Assessment of Biomass Resources in California***, 2007, provides an updated biomass inventory for the state along with an assessment of potential growth in biomass resources and power generation that could help to satisfy the state renewable portfolio standard (RPS).	*http://biomass.ucdavis.edu/materials/reports%20and%20publications/2008/CBC_Biomass_Resources_2007.pdf*
Georgia	***Biomass Wood Resource Assessment on a County-by-County Basis for the State of Georgia*** provides a biomass wood resource assessment on a county-level basis for Georgia.	*www.gfc.state.ga.us/ForestMarketing/documents/BiomassWRACountybyCountyGA05.pdf*
Hawaii	***Biomass and Bioenergy Resource Assessment: State of Hawaii*** provides an assessment of current and potential biomass and bioenergy resources for the state. Includes animal wastes, forest products residues, agricultural residues, and urban wastes.	*www.hawaii.gov/dbedt/info/energy/publications/biomass-assessment.pdf*
Mississippi	***Mississippi Institute for Forest Inventory Dynamic Report Generator*** provides a continuous, statewide forest resource inventory necessary for the sustainable forest-based economy. The inventory information is derived from sampling estimation techniques with a presumed precision of +/- 15% sampling error with 95 percent confidence.	*www.mifi.ms.gov/*
South Carolina	***Potential for Biomass Energy Development in South Carolina*** quantifies the amount of forestry and agricultural biomass available for energy production on a sustainable basis in South Carolina. Also includes an analysis of the economic impacts of transferring out-of-state costs for coal to in-state family forest landowners and biomass processors.	*www.scbiomass.org/Publications/Potential%20Biomass%20Energy%20in%20SC.pdf*

Resource	Description	URL
Oregon	***Biomass Energy and Biofuels from Oregon's Forests*** assesses the statewide potential for production of electricity and biofuels from woody biomass, including the available wood supply and the environmental, energy, forest health, and economic effects. Reviews and summarizes efforts underway to promote electric energy and biofuels from woody biomass, and identifies gaps in existing efforts. Assesses constraints and challenges to the development of biomass energy and biofuels from Oregon forests, including economic, environmental, legal, policy, infrastructure, and other barriers and develops recommendations on how to overcome these barriers.	*www.oregonforests.org/assets/uploads/Biomass_Full_Report.pdf*
Northeastern states (CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT)	***Securing a Place for Biomass in the Northeast United States: A Review of Renewable Energy and Related Policies*** provides a biomass feedstock assessment for northeastern states.	*www.nrbp.org/pdfs/nrbp_final_report.pdf*
Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, OK, ND, SD, NE, KS, AK, HI)	The ***Western Bioenergy Assessment*** includes a series of technical reports produced for the Western Governors' Association. These reports extensively evaluate biomass resources in the western states, biofuel conversion technologies, spatial analysis and supply curve development, and deployment scenarios and potential policy interactions.	*www.westgov.org/wga/initiatives/transfuels/index.html*
Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, OK, ND, SD, NE, KS, AK, HI)	The ***Western Governors' Association Transportation Fuels for the Future Initiative*** provides seven working group reports and a final report analyzing the potential for the development of alternative fuels and vehicle fuel efficiency in the West.	*www.westgov.org/wga/initiatives/transfuels/index.html*
Western states (WA, OR, ID, MT, WY, CO, NM, AZ, UT, NV, CA, TX, ND, SD, NE, KS, AK, HI)	***Biomass Task Force Report*** focuses on the use of biomass resources for the production of electricity as part of an overall effort of the Western Governors' Association to increase the contribution of clean and renewable energy in the region.	*www.westgov.org/wga/initiatives/cdeac/Biomass-full.pdf*

A.4 TOOLS TO HELP ESTIMATE ECONOMIC, ENERGY, AND/OR ENVIRONMENTAL BENEFITS

Resource	Description	URL
Tools for Evaluating Benefits		
AirCRED, Argonne National Laboratory, August 2007.	This tool is used to support local air emission reductions claims associated with alternative-fuel vehicles within the State Implementation Planning process.	*www.transportation.anl.gov/modeling_simulation/AirCred/index.html*
Biomass Technology Analysis Models and Tools.	Web sites of models and tools that demonstrate biomass technologies and uses, and can be used in life-cycle assessments. Most tools can be applied on a global, regional, local, or project basis.	*www.nrel.gov/analysis/analysis_tools_tech_bio.html*
Biomass Feedstock Composition and Property Database.	Provides data results from analysis of more than 150 samples of potential biofuels feedstocks, including corn stover, wheat straw, bagasse, switchgrass and other grasses, and poplars and other fast-growing trees.	*www1.eere.energy.gov/biomass/feedstock_databases.html*
CHP Emissions Calculator, U.S. EPA.	Enables a quick and easy analysis of the criteria air pollutant and GHG emission reductions from incorporating CHP designs into plants and production facilities. It also translates these reductions into "cars" and "trees" to convey their value to a nontechnical audience.	*www.epa.gov/chp/basic/calculator.html*
Clean Air Climate Protection Software, ICLEI and NACAA.	Helps local governments create greenhouse gas inventories, quantify the benefits of reduction measures, and formulate local climate action plans.	*www.cacpsoftware.org/*
Emissions & Generation Resource Integrated Database (EGRID), U.S. EPA.	Provides a comprehensive database of electric-sector emissions at the plant, state, and regional levels. These can be compared to emissions from biopower to estimate emissions' effects.	*www.epa.gov/cleanrgy/egrid/index.htm*
Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, Argonne National Laboratory, August 2007.	Includes full fuel-cycle and vehicle-cycle emissions and energy estimation capability. While not a full life-cycle assessment tool, it allows estimation of upstream emissions and energy effects. For some state policy questions, it may provide sufficient analytic detail on its own. For decisions with greater financial implications, it may be most appropriate to use for initial screening to support development of a more detailed study. States may wish to use GREET directly or to consider analyses that have been done using this tool.	*www.transportation.anl.gov/modeling_simulation/GREET/*
Job and Economic Development Impact (JEDI) Models.	Easy-to-use, spreadsheet-based tools that analyze the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels.	*www.nrel.gov/analysis/jedi*
Power Profiler, U.S. EPA.	Provides a quick estimate of electricity emissions rates by location, which could be compared to emissions from biopower to estimate emissions effects.	*www.epa.gov/grnpower/buygp/powerprofiler.htm*
Standard Biomass Analytical Procedures.	Provides tested and accepted methods for performing analyses commonly used in biofuels research.	*www1.eere.energy.gov/biomass/analytical_procedures.html*
Theoretical Ethanol Yield Calculator.	Calculates the theoretical ethanol yield of a particular biomass feedstock based on its sugar content.	*www1.eere.energy.gov/biomass/ethanol_yield_calculator.html*
Thermodynamic Data for Biomass Conversion and Waste Incineration, NREL, National Bureau of Standards.	Provides heat of combustion and other useful data for biopower and biofuels research on a wide range of biomass and non-biomass materials.	*www1.eere.energy.gov/biomass/pdfs/2839.pdf*

A.5 FINANCING BIOENERGY PROJECTS

Resource	Description	URL
Bioenergy		
Capturing the Full Potential of Bioenergy: A Model for Regional Bioenergy Initiatives, GEN Publishing, Inc., 2007.	Advances a step-by-step approach for advancing bioenergy.	*www.liebertonline.com/doi/abs/10.1089/ind.2007.3.120*
Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States, U.S. EPA, 2006.	This Web site and guide present 16 policies that states use to advance clean energy.	*www.epa.gov/cleanrgy/stateandlocal/guidetoaction.htm*
Clean Energy Lead by Example Guide, U.S. EPA, 2009.	Describes proven strategies, resources, and tools to help states save money and reduce greenhouse gas emissions by adopting clean energy practices in their facilities, operations, and vehicle fleets.	*www.epa.gov/cleanenergy/documents/epa_lbe.pdf*
Database of State Incentives for Renewable Energy (DSIRE).	Searchable database of incentives relevant to bioenergy, by state. Select a renewable energy search, by technology, for biomass, CHP, and/or landfill gas. The database is updated routinely.	*www.dsireusa.org/*
State Policies for Promoting the Next Generation of Biomass Technologies, Great Plains Institute, November 22, 2006.	Summarizes recommendations on state policies to advance biomass.	*www.ef.org/documents/BWG_State_Policy_Menu_Final_v3.pdf*
State Incentives and Resources Search, U.S. DOE.	This Web page includes state energy information for biomass, other renewable energy, and fossil energy.	*www1.eere.energy.gov/industry/about/state_activities/incentive_search.asp*
Developing State Policies Supportive of Bioenergy Development, Southern States Energy Board, 2002.	Analyzes policy options to advance bioenergy, based on regional experiences in the Southeast.	*www.osti.gov/bridge/servlets/purl/828971-Pbx12e/native/828971.pdf*
Environment and Energy Study Institute (EESI).	This Web site includes information on bioenergy and federal and state incentives.	*www.eesi.org/Sustainable_Biomass_Energy_Program*
It All Adds Up to Cleaner Air Resources Toolkit, U.S. Department of Transportation.	While not explicitly designed for bioenergy, this step-by-step guide to implementing a public outreach program provides many tips that would be appropriate to any outreach campaign.	*www.italladdsup.gov/tools/how_to.asp*
Southern Forest Research Partnership.	Offers numerous publications, presentations, links, images, case studies, activities, videos, and other educational tools that can be used to share woody biomass information with natural resource management and extension professionals as well as community planning and development professionals.	*www.forestbioenergy.net/training-materials*
State Woody Biomass Utilization Policies, University of Minnesota, Department of Forest Resources, Staff Paper 199. Becker, D.R., and C. Lee. 2008.	A comprehensive database of woody biomass legislation for each state in the United States.	*www.forestry.umn.edu/publications/staffpapers/Staffpaper199.pdf*

Resource	Description	URL
Biopower/Bioheat		
Green-e Certification Process.	A voluntary market for renewable energy certificates exists, and some kinds of biopower generation are eligible for Green-e certification. Eligible sources must go through the certification process to be able to sell certified products.	*www.green-e.org/docs/Appendix_D-Green-e_National_Standard.pdf* and *www.green-e.org/getcert_re_6steps.shtml#rec*
State Energy Program.	This collaboration of DOE and the states provides joint funding for state formula grant projects and local energy efficiency and renewable energy projects.	*http://apps1.eere.energy.gov/state_energy_program/*
State Technologies Advancement Collaborative Program, U.S. DOE, National Association of State Energy Officials, Association of State Energy Research and Technology Transfer Institutions.	This collaboration provides funding for state energy efficiency and renewable energy projects.	*www.stacenergy.org*
Biofuels/Bioproducts		
Alternative Fuels Data Center: All State Incentives and Laws, U.S. DOE, NREL.	The data center is a comprehensive clearinghouse of data, publications, tools, and information related to advanced transportation technologies.	*www.afdc.energy.gov/afdc/data/methodology.html*
Funding Database – Biomass/Biogas, U.S. EPA.	This database of financial and regulatory incentives at the state level is updated monthly.	*www.epa.gov/chp/funding/bio.html*
Understanding and Informing the Policy Environment: State-Level Renewable Fuels Standards, NREL, January 2007.	Summary and analysis of state actions on renewable fuels standards.	*www.nrel.gov/docs/fy07osti/41075.pdf*
Funding Landfill Gas Energy Projects: State, Federal, and Foundation Resources, U.S. EPA.	This guide from the Landfill Methane Outreach Program details potential sources of funding for landfill gas projects.	*www.epa.gov/lmop/res/guide/index.htm*
State Examples		
Arkansas	State-Specific Financing Information	*http://arkansasenergy.org/solar-wind-bioenergy/bioenergy.aspx*
Florida	State-Specific Financing Information	*www.floridafarmtofuel.com/Downloads/FTF%20Grant%20Agreement%20Contract%20092507.pdf*
Michigan	State-Specific Financing Information	*http://michigan.gov/documents/cis/CIS_EO_Funding_Opportunities_192768_7.pdf*
Montana	State-Specific Financing Information	*www.deq.state.mt.us/Energy/bioenergy/Biodiesel_Production_Educ_Presentations/Combined_Biodiesel_Ethanol_Govt_Incentives_Montana_Jan07_bshh.pdf*
Washington	State-Specific Financing Information	*http://agr.wa.gov/Bioenergy/*

APPENDIX B

Glossary

A

- **agricultural residue**: Plant parts, primarily stalks and leaves, not removed from fields with the primary food or fiber product. Examples include corn stover (stalks, leaves, husks, and cobs), wheat straw, and rice straw.
- **algae**: Simple photosynthetic plants containing chlorophyll, often fast growing and able to live in freshwater, seawater, or damp oils. May be unicellular and microscopic or very large, as in the giant kelps.
- **anaerobic**: Living or active in an airless environment.
- **anaerobic digestion**: Degradation of organic matter by microbes in the absence of oxygen to produce methane and CO_2.

B

- **benzene**: Aromatic component of gasoline that is a known cancer-causing agent.
- **biodiesel**: Biodegradable transportation fuel used in diesel engines. Biodiesel is produced through transesterification of organically derived oils and fats. It may be used either as a replacement for or component of diesel fuel.
- **bioenergy**: Renewable energy produced from biomass.
- **biofuels**: Fuels for transportation made from biomass or its derivatives after processing. The major biofuels include ethanol and biodiesel.
- **biogas**: Gaseous mixture of CO_2 and methane produced by anaerobic digestion of organic matter.
- **biomass**: Any plant-derived organic matter. Biomass available for energy on a sustainable basis includes herbaceous and woody energy crops, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, and other waste materials, including some municipal wastes.
- **biopower**: Use of biomass to produce electricity and heat.
- **bioproducts**: Commercial or industrial products (other than food or feed) that are composed in whole or significant part of biomass.

C

- **carbohydrate**: Organic compounds made up of carbon, hydrogen, and oxygen and having approximately the formula $(CH_2O)_n$; includes cellulosics, starches, and sugars.
- **carbon dioxide**: (CO_2) Naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land use changes and other industrial processes. It is the principal anthropogenic GHG that affects the earth's radiative balance.
- **carbon monoxide**: (CO) Colorless, odorless, poisonous gas produced by incomplete combustion.
- **catalyst**: Substance that increases the rate of a chemical reaction without being consumed or produced by the reaction. Enzymes are catalysts for many biochemical reactions.
- **cellulase**: Family of enzymes that break down cellulose into glucose molecules.

- **cellulose**: Carbohydrate that is the principal constituent of wood and other biomass and forms the structural framework of the wood cells.
- **chips**: Small fragments of wood chopped or broken by mechanical equipment. Total tree chips include wood, bark, and foliage. Pulp chips or clean chips are free of bark and foliage.
- **cofiring**: Use of a mixture of two fuels within the same combustion chamber.
- **cogeneration**: Technology of producing electric energy and another form of useful energy (usually thermal) for industrial, commercial, or domestic heating or cooling purposes through sequential use of the energy source. Also called combined heat and power (CHP).
- **combustion**: Chemical reaction between a fuel and oxygen that produces heat (and usually light).
- **coproducts**: Resulting substances and materials that accompany production of a fuel product such as ethanol.
- **corn stover**: Refuse of a corn crop after the grain is harvested.
- **criteria pollutants**: Pollutants regulated under the federal NAAQS, which were established under the Clean Air Act. Criteria pollutants include CO, lead, nitrogen dioxide, PM (PM2.5, PM10), ground-level ozone, and SO_2.

D

- **digester**: Biochemical reactor in which anaerobic bacteria are used to decompose biomass or organic wastes into methane and CO_2.

E

- **E10**: Mixture of 10 percent ethanol and 90 percent gasoline based on volume.
- **E85**: Mixture of 85 percent ethanol and 15 percent gasoline based on volume.
- **effluent**: Liquid or gas discharged after processing activities, usually containing residues from such use. Also discharge from a chemical reactor.
- **energy crop**: Crop grown specifically for its fuel value. These include food crops such as corn and sugar cane, and nonfood crops such as poplar trees and switchgrass.
- **enzyme**: Protein or protein-based molecule that speeds up chemical reactions in living things. Enzymes act as catalysts for a single reaction, converting a specific set of reactants into specific products.
- **ester**: Compound formed from the reaction between an acid and an alcohol.
- **ethanol**: (CH_3CH_2OH) A colorless, flammable liquid produced by fermentation of sugars. Ethanol is used as a fuel oxygenate. Ethanol is the alcohol found in alcoholic beverages, but is denatured for fuel use.
- **eutrophic conditions**: In surface waters, conditions such as significant algae growth and subsequent oxygen depletion, which can be caused by excessive nutrients from fertilizers, pesticides, and herbicides. Some aquatic species cannot survive eutrophic conditions.

F

- **feedstock**: Any material used as a fuel directly or converted to another form of fuel or energy product.
- **fermentation**: Biochemical reaction that breaks down complex organic molecules (such as carbohydrates) into simpler materials (such as ethanol, CO_2, and water). Bacteria or yeasts can ferment sugars to ethanol.
- **fluidized bed**: Gasifier or combustor design in which feedstock particles are kept in suspension by a bed of solids kept in motion by a rising column of gas. The fluidized bed produces approximately isothermal conditions with high heat transfer between the particles and gases.
- **forestry residues**: Includes tops, limbs, and other woody material not removed in forest harvesting operations in commercial hardwood and softwood stands, as well as woody material resulting from forest management such as precommercial thinnings and removal of dead and dying trees.
- **fossil fuel**: Carbon or hydrocarbon fuel formed in the ground over millions of years from the remains of dead plants and animals. Oil, natural gas, and coal are fossil fuels.

G

- **gasification**: Any chemical or heat process used to convert a feedstock to a gaseous fuel.
- **greenhouse gas**: Gas—such as water vapor, CO_2, tropospheric ozone, methane, and low-level ozone—that contributes to the greenhouse effect.

H

- **hemicellulose**: Hemicellulose consists of short, highly branched chains of sugars. In contrast to cellulose, which is a polymer of only glucose, a hemicellulose is a polymer of five different sugars.
- **herbaceous plants**: Non-woody species of vegetation, usually of low lignin content, such as grasses.
- **herbaceous energy crops**: Perennial non-woody crops that are harvested annually, though they may take two to three years to reach full productivity. Examples include switchgrass (*Panicum virgatum*), reed canary grass (*Phalaris arundinacea*), miscanthus (*Miscanthus x giganteus*), and giant reed (*Arundo donax*).
- **hydrolysis**: Conversion, by reaction with water, of a complex substance into two or more smaller units, such as conversion of cellulose into glucose sugar units.

I

K

L

- **landfill gas**: Biogas produced from natural degradation of organic material in landfills. By volume, LFG is about 50 percent methane and 50 percent CO_2 and water vapor.
- **life-cycle analysis**: Assessment of the impacts from all stages of a product's development, from extraction of fuel for power to production, marketing, use, and disposal.
- **lignin**: Structural constituent of wood and other native plant material that encrusts the cell walls and cements the cells together.
- **lignocellulose**: Plant materials made up primarily of lignin, cellulose, and hemicellulose.

M

- **methane**: (CH_4) The major component of natural gas. It can be formed by anaerobic digestion of biomass or gasification of coal or biomass.
- **methanol (wood alcohol)**: (CH_3OH) Alcohol formed by catalytically combining carbon monoxide with hydrogen in a 1:2 ratio under high temperature and pressure.
- **microorganism**: Any microscopic organism such as yeast, bacteria, fungi, etc.
- **municipal solid waste**: Any organic matter, including sewage, industrial, and commercial wastes, from municipal waste collection systems. Municipal waste does not include agricultural and wood wastes or residues.

N

- **net energy balance**: Total amount of energy used over the full life cycle of a fuel, from feedstock production to end use.
- **nitrogen oxides**: (NO_X) Product of photochemical reactions of nitric oxide in ambient air, and the major component of photochemical smog.
- **nonrenewable resource**: One that cannot be replaced as it is used. Although fossil fuels, such as coal and oil, are in fact fossilized biomass resources, they form at such a slow rate that, in practice, they are nonrenewable.

O

- **opportunity fuels**: Biomass feedstocks derived from waste materials that would otherwise go unused or would be disposed of. Bioenergy production provides an opportunity to productively use these materials.
- **oxygenate**: Compound that contains oxygen in its molecular structure. Ethanol and biodiesel act as oxygenates when they are blended with conventional fuels. Oxygenated fuel improves combustion efficiency and reduces tailpipe emissions of CO.

P

- **particulates**: Fine liquid or solid particle, such as dust, smoke, mist, fumes, or smog, found in air or emissions.
- **petroleum**: Any substance composed of a complex blend of hydrocarbons derived from crude oil, including motor fuel, jet oil, lubricants, petroleum solvents, and used oil.
- **pyrolysis**: Breaking apart of complex molecules by heating in the absence of oxygen, producing solid, liquid, and gaseous fuels.

R

- **renewable energy resource**: Energy resources that can be replaced as they are used, including solar, wind, geothermal, hydro, and biomass. MSW is also considered a renewable energy resource.
- **residues, biomass**: By-products from processing all forms of biomass that have significant energy potential. For example, making solid wood products and pulp from logs produces bark, shavings, sawdust, and spent pulping liquors. Because these residues are already collected at the point of processing, they can be convenient and relatively inexpensive sources of biomass for energy.

S

- **silviculture**: Science and practice of growing trees for human use.
- **stover**: Dried stalks and leaves of a crop remaining after the grain has been harvested.
- **syngas**: Synthesis gas produced by the gasification process using biomass feedstock. Syngas can be burned in a boiler or engine to produce electricity or heat, and can be used to produce a liquid for biofuels production.

T

- **tar**: Liquid product of thermal processing of carbonaceous materials.
- **thermochemical conversion**: Use of heat to change substances chemically to produce energy products.
- **transesterification**: Chemical process that reacts an alcohol with triglycerides contained in vegetable oils and animal fats to produce biodiesel and glycerin.

U

V

- **volatile**: Solid or liquid material that easily vaporizes.

W

X

- **xylose**: ($C_5H_{10}O_5$) Five-carbon sugar that is a product of hydrolysis of xylan found in the hemicellulose fraction of biomass.

Z

- **zero net contribution**: Refers to a process that results in contribution of no additional carbon emissions to the atmosphere. For example, combustion of biomass feedstocks returns the same amount of CO_2 to the atmosphere that was absorbed during growth of the biomass, resulting in no additional CO_2 released into the air.

Source: Adapted from National Renewable Energy Laboratory (NREL) Glossary of Biomass Terms, www.nrel.gov/biomass/glossary.html

U.S. Environmental Protection Agency
Office of Atmospheric Programs
Climate Protection Partnerships Division
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www.epa.gov
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