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IEA Bioenergy Task 40

Sustainable International Bioenergy Trade: Securing Supply and Demand

Country Report 2014 — United States

January 2015

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CONTENTS

FIGURES

TABLES

ACRONYMS

BCAP	Biomass Crop Assistance Program
BDT	Billion dry tons (U.S. short ton)
bgy	Billion gallons per year
BRDI	Biomass Research and Development Initiative
CBI	Caribbean Basin Initiative
CCC	Commodity Credit Corporation
CO_{2e}	Carbon Dioxide Equivalent
D&D	Demonstration and Deployment
DOE	Department of Energy
DOT	Department of Transportation
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
EPA	Environmental Protection Agency
EPACT	Energy Policy Act
EU	European Union
FSA	Farm Service Agency (USDA)
GBEP	Global Bioenergy Partnership
GDP	Gross Domestic Product
IBRs	Integrated Biorefinery Projects
IEA	International Energy Agency
INL	Idaho National Laboratory
IRS	Internal Revenue Service
MDT	Million dry ton (U.S. short ton)
MTBE	Methyl Tertiary Butyl Ether
MYYP	Multi-Year Program Plan
NGPL	Natural Gas Plant Liquids
NREL	National Renewable Energy Laboratory
RD&D	Research, Development, and Demonstration
RFS	Renewable Fuels Standard
RGGI	Regional Greenhouse Gas Initiative
USDA	United States Department of Agriculture
WCI	Western Climate Initiative

STATE ABBREVIATIONS

AL	Alabama	MT	Montana
AK	Alaska	NE	Nebraska
AZ	Arizona	NV	Nevada
AR	Arkansas	NH	New Hampshire
CA	California	NJ	New Jersey
CO	Colorado	NM	New Mexico
CT	Connecticut	NY	New York
DE	Delaware	NC	North Carolina
FL	Florida	ND	North Dakota
GA	Georgia	OH	Ohio
HI	Hawaii	OK	Oklahoma
ID	Idaho	OR	Oregon
IL	Illinois	PA	Pennsylvania
IN	Indiana	RI	Rhode Island
IA	Iowa	SC	South Carolina
KS	Kansas	SD	South Dakota
KY	Kentucky	TN	Tennessee
LA	Louisiana	TX	Texas
ME	Maine	UT	Utah
MD	Maryland	VT	Vermont
MA	Massachusetts	VA	Virginia
MI	Michigan	WA	Washington
MN	Minnesota	WV	West Virginia
MS	Mississippi	WI	Wisconsin
MO	Missouri	WY	Wyoming

The “Lower 48 states” include all but Hawaii and Alaska.

CONVERSION FACTORS

1 acre = 0.404686 hectares = 4,046 m^2

To:	**TJ**	**Mtoe**	**MBtu**	**GWh**
From:	multiply by:			
Tera Joule (TJ)	1	2.388×10^{-5}	947.8	0.2778
Million tonnes of oil equivalent (Mtoe)	4.1868×10^{4}	1	3.968×10^{7}	11,630
Million British Thermal Units (MBtu)	1.0551×10^{-3}	2.52×10^{-8}	1	2.931×10^{-4}
Giga Watt hours (GWh)	3.6	8.6×10^{-5}	3,412	1

To:	**kg**	**tonne**	**ton**	
From:	multiply by:			
Metric tonne (tonne)	1,000	1	1.1023	
US short ton (ton)	907.2	0.9072	1	

To:	**gal**	**bbl**	**ft^3**	**l**	**m^3**
From:	multiply by:				
U.S. gallon (gal)	1	0.02381	0.1337	3.785	0.0038
Barrel (bbl)	42	1	5.615	159	0.159
Cubic foot (ft^3)	7.48	0.1781	1	28.3	0.0283
Liter (l)	0.2642	0.0063	0.0353	1	0.001

Source: International Energy Agency (IEA)
(http://www.iea.org/newsroomandevents/resources/conversiontables/)

1. GENERAL INTRODUCTION

1.1 Country Characteristics

The population of the United States (U.S.) as of 2010 was 318,892,103,[1] and the gross domestic product (GDP) was $16,800 billion.[2] The U.S. has a total land area of nearly 2.3 billion acres with an approximate breakdown of land use as follows:

- Forest land, 671million acres (30%)
- Grassland pasture and range land, 614 million acres (27%)
- Crop land, 408 million acres (14%)
- Special uses (primarily parks and wildlife areas), 313 million acres (14%)
- Miscellaneous other uses, 197 million acres (9%)
- Urban land, 61 million acres (3%).[3]

The most consistent trends in major uses of land (1945 to 2007) have been upwards in special-use areas and downwards in total grazing lands. Urban areas land increased from 1945 to 1997 but decreased from 1997 to 2007. The total amount of forest use area fluctuated over time. Forest-use area generally declined from 1949 to 1997 but increased by about 4.5% from 1997 to 2007. Total cropland area has declined over this 62-year period, but it has not done so consistently. Total cropland area increased in the late 1940s, declined from 1949 to 1964, increased from 1964 to 1978, and then declined again from 1978 to 2007.[3]

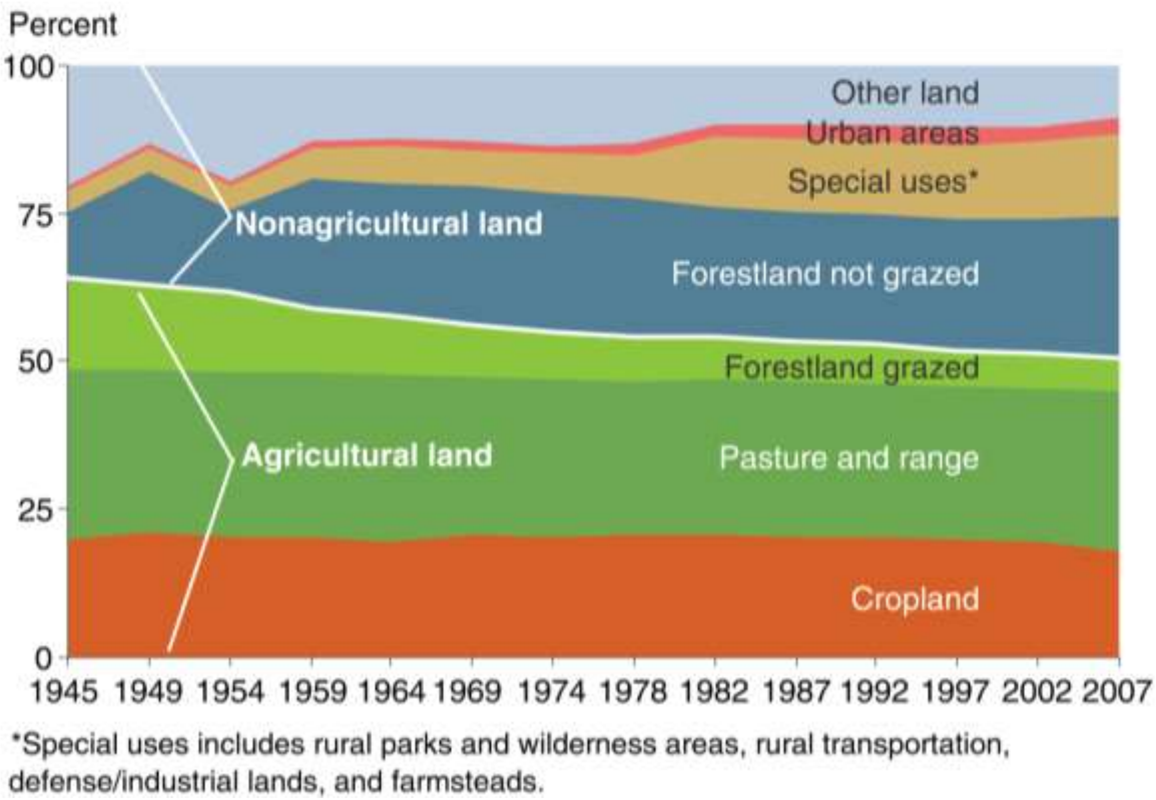

Figure 1. Development of major land uses in the U.S. between 1945-2007.[4]

1.2 Main Industries

Table 1 lists sales, receipts, and shipments for major U.S. industries. The top eight industries represent approximately 90% of the total economic expenditure in the United States. Within the main industries shown in Table 1, several sub-industries exist that have specific relevance to biomass. These industries are shown in Table 2.

Table 1. U.S. industries ranked by total economic expenditure (2007).[5]

Description	*Sales, Shipments, or Receipts ($1,000)*	*Total Economic Expenditure (%)*
Wholesale trade	603,922,7184	20.9%
Manufacturing	5,339,345,058	18.5%
Retail trade	3,932,027,444	13.6%
Wholesale trade	7,188,763,243	12.31%
Manufacturing	5,756,336,857	9.86%
Retail trade	4,228,053,136	7.24%
Merchant wholesalers, nondurable goods	3,600,582,851	6.17%
Finance and insurance	3,532,178,296	6.05%
Merchant wholesalers, durable goods	2,963,537,899	5.07%
Health care and social assistance	2,051,106,989	3.51%
Insurance carriers and related activities	1,754,090,457	3.00%
Professional, scientific, and technical services	1,543,690,338	2.64%
Information	1,231,918,569	2.11%
Credit intermediation and related activities	1,160,727,635	1.99%
Motor vehicle and parts dealers	870,864,925	1.49%
Hospitals	860,044,988	1.47%
Petroleum and coal products manufacturing	844,041,764	1.45%
Ambulatory health care services	842,840,985	1.44%
Chemical manufacturing	802,932,662	1.37%
Transportation equipment manufacturing	792,924,700	1.36%
Food manufacturing	747,642,168	1.28%

Transportation and warehousing (104)	743,620,690	1.27%
Administrative and support and waste management and remediation services	724,942,308	1.24%
Accommodation and food services	710,382,088	1.22%
General merchandise stores	641,281,967	1.10%
Administrative and support services	639,082,259	1.09%
Wholesale electronic markets and agents and brokers	624,642,493	1.07%
Food and beverage stores	619,825,728	1.06%
Other	12,920,315,181	22.13%

Table 2. U.S. industries with relevance to biomass.[6]

Industry/Sub Industry	*Relevance to Biomass*
Forestry, logging, fishing, hunting, trapping, and agricultural support activities	Biomass collection, harvesting, and other forest and agricultural services are resources whose byproducts are used to produce biofuels, bio-power, and bio-based products.
Electric power generation, transmission, and distribution	Biomass and Municipal Solid Waste are used for production of electric power.
Water, sewage, and other systems	Possible opportunity for anaerobic digestion.
Food manufacturing	Waste products from food manufacturing can be used for biofuels and bio-based products. Grain and oilseed milling would be obvious forms of food manufacturing that are relevant to biomass.
Paper manufacturing	Waste streams from paper manufacturing, such as black liquor, can be used to produce biofuels and biopower. Pulp, paper, and paperboard mills would be an example of a sub-industry of paper manufacturing that is relevant to biomass.
Petroleum and coal products manufacturing	Biomass inputs could be used for fuels blends and chemical production.
Pesticide, fertilizer, and other agricultural chemical manufacturing	Biomass could be used as an input to some of these chemical productions.
Plastics and rubber products manufacturing	Biomass can be an input for bio-based products and other alternatives to plastics, etc.
Wood product manufacturing	Waste products from wood manufacturing can be used for biofuels and biopower.
Farm Product Raw Material Wholesalers	This industry group comprises establishments primarily engaged in wholesaling agricultural products (except raw milk, live poultry, and fresh fruits and vegetables), such as grains, field beans, livestock, and other farm product raw materials (excluding seeds). Grain and field-bean wholesalers would be an example of a sub-industry of wholesale trade that is relevant to biomass.

1.3 CO_2 Reduction Requirements

The U.S. Environmental Protection Agency (EPA) reported that in 2012, U.S. greenhouse gas emissions totaled 6,526 million metric tonnes of carbon dioxide equivalents (CO_{2e}). Between 2011 and 2012, U.S. emissions decreased by 3.4 percent. Recent trends can be attributed to multiple factors including reduced emissions from electricity generation, improvements in fuel efficiency in vehicles with reductions in miles traveled, and year-to-year changes in the prevailing weather.[7]

1.4 Domestic Energy Production

The energy mix of the U.S. is dominated by fossil fuels, primarily natural gas and coal. Of the 81.8 quadrillion British Thermal Units (BTU) produced in the United States, 11% are produced from renewable energy, more than nuclear electric power (Table 3). Biomass makes up the largest fraction of renewable energy production, followed by hydroelectric power and wind (Table 3).

Table 3. Primary energy production ranked by source, 2014.[8]

Energy Type		*Quadrillion BTU*	*Production (%)*
Fossil Fuels	Coal	19.988	24.436%
	Natural Gas (dry)	24.889	30.428%
	Crude Oil	15.753	19.259%
	NGPL[a]	3.601	4.402%
		64.230	78.524%
Nuclear Electric Power		8.268	10.108%
Renewable Energy	Hydroelectric Power	2.561	3.131%
	Geothermal	0.221	0.270%
	Solar	0.307	0.375%
	Wind	1.595	1.951%
	Biomass	4.614	5.641%
		9.298	11.368%
Total		81.796	100.00

a. Natural gas plant liquids.

Domestic electricity production is primarily drawn from coal-fired boilers (37% of total production), followed by nuclear power (19% of total production). A total of 12% of U.S. electric power comes from renewable resources, primarily from hydroelectric (6.8% of total U.S. electricity production) and biomass (1.4% of total U.S. electricity production) (Table 4).

Table 4. Electrical production in the United States, 2012.[9]

Power Source	*Annual Production (Thousand MWh)*	*Annual Production (%)*
Coal	1,514,043	37.40%
Petroleum liquids	13,403	0.33%
Petroleum coke	9,787	0.24%
Natural Gas	1,225,894	30.29%
Other Gases	11,898	0.29%
Nuclear	769,331	19.01%
Hydroelectric conventional	276,240	6.82%

Wind	140,822	3.48%
Solar/PV	4,327	0.11%
Wood and Wood Derived	37,799	0.93%
Geothermal	15,562	0.38%
Other Biomass	19,823	0.49%
Hydroelectric Pumped Storage	-4,950	-0.12%
Other	13,787	0.34%
Total	4,047,765	100.00%

1.5 Domestic Energy Consumption

Natural gas and coal also dominate the U.S. primary energy consumption. Biomass continues to make up the largest form of renewable energy consumed, followed by hydroelectric power and wind (Table 5). The largest biomass fractions include woody biomass, followed by transport biofuels (mainly ethanol and biodiesel), and waste.

Table 5. Primary energy consumption by source, 2014.[10]

Energy Type		*Quadrillion BTU*	*Consumption (%)*
Fossil Fuels	Coal	18.084	18.52%
	Natural Gas	26.630	27.28%
	Petroleum	35.194	36.05%
		79.891	81.83%
Nuclear Electric Power		8.268	8.47%
Renewable Energy	Hydroelectric Power	2.561	2.62%
	Geothermal	0.221	0.23%
	Solar/PV	0.307	0.31%
	Wind	1.595	1.63%
	Biomass	4.613	4.73%
		9.298	9.52%
Total		97.635	100.00

The U.S. DOE tracks national energy consumption in four broad sectors: industrial, transportation, residential, and commercial. It is projected that the industrial sector will be the country's largest energy user by 2040, currently representing about 30% of the total consumption (Figure 2, Figure 3).

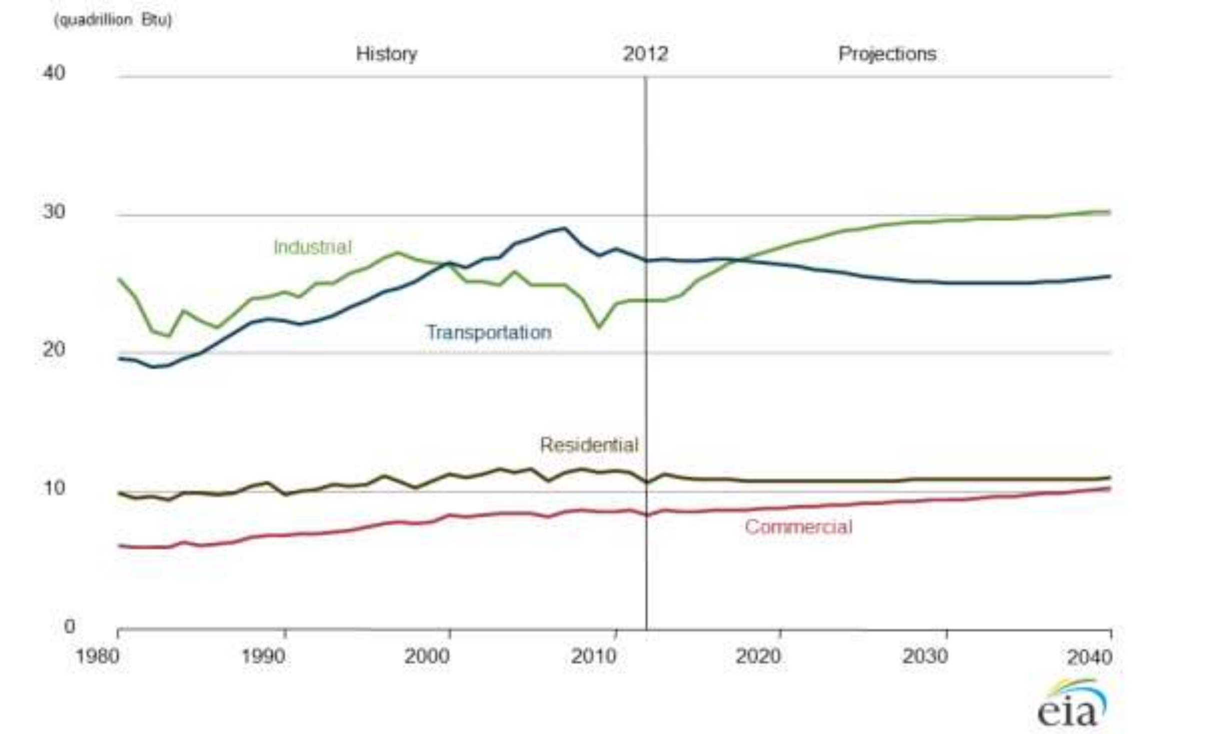

Figure 2. Delivered energy consumption by sector between 1980-2040.[11]

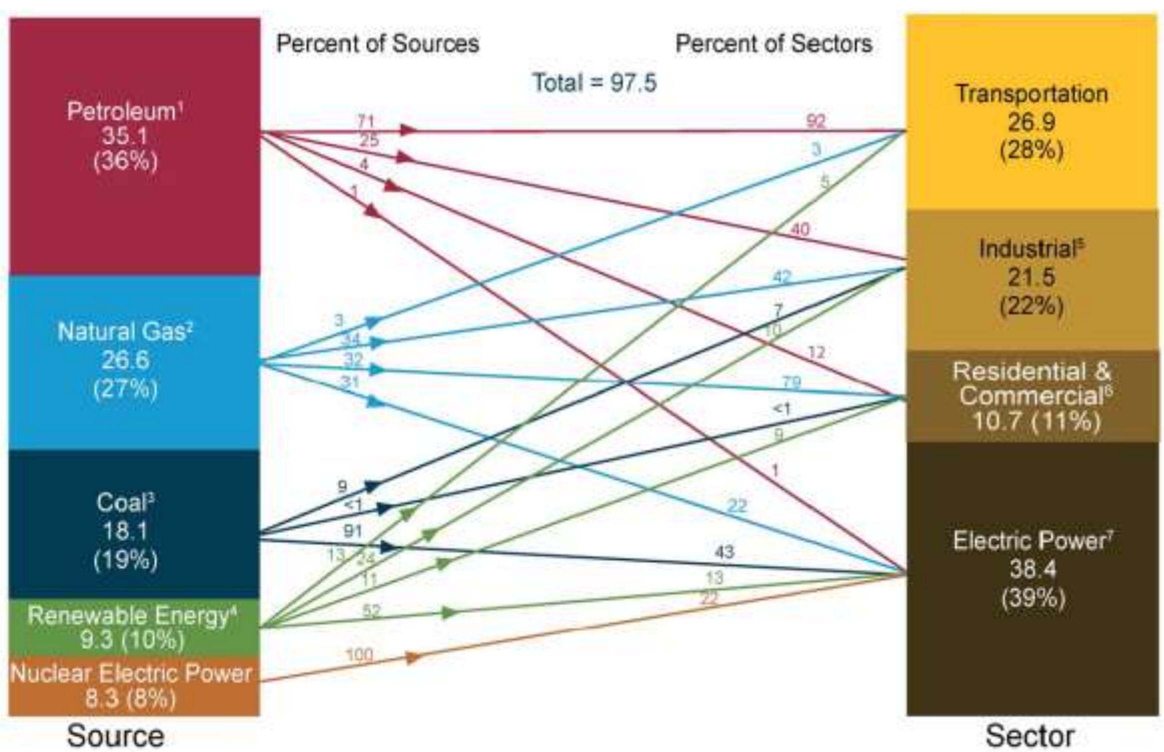

Figure 3. Primary energy consumption by source and sector, 2013 (Quadrillion Btu).[12]

1.5.1 Renewable Energy

Renewable energy resources including hydroelectric, wind, solar, geothermal, and biomass provided about 9.5% of the total energy consumed in the United States in 2013. Figure 4shows the renewable energy consumption and production over the years.

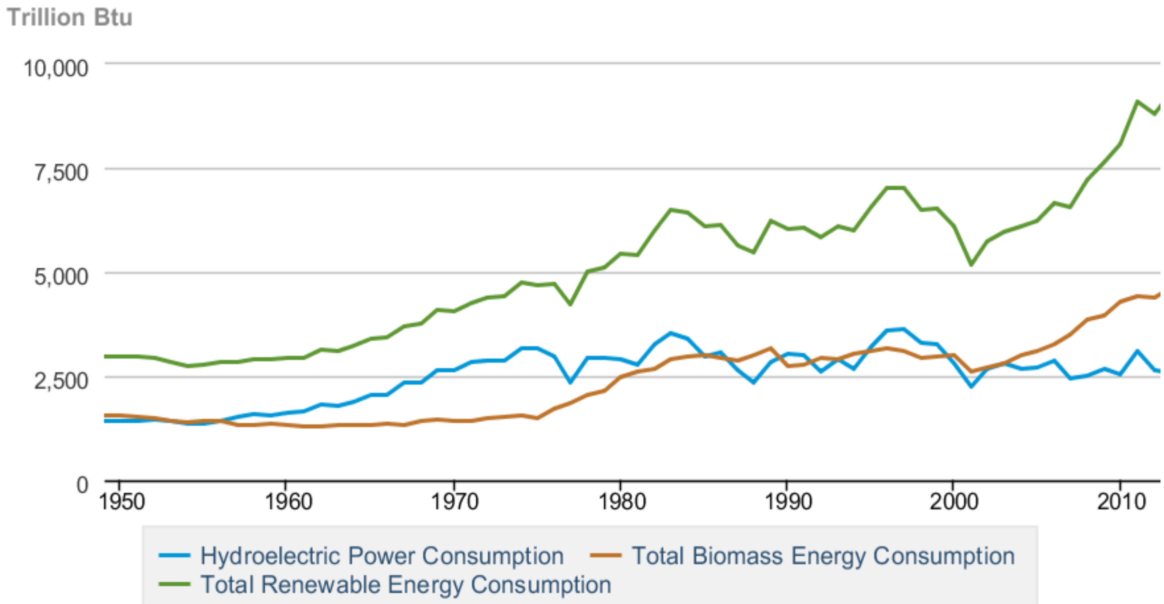

Figure 4. Renewable energy consumption and production by source[8]

1.5.2 Biofuels

From 2002 to 2013, biomass energy converted to biofuels grew by more than 500% due to a heavy increase in the production of fuel ethanol and biodiesel.[13] On average, 60% of the energy in the feedstock is converted to deliverable biofuels. The remainder becomes energy losses or coproducts, which are measured as energy consumed by the industrial sector. Most biofuels are consumed as blended transportation fuels—ethanol blended with motor gasoline or biodiesel blended with diesel fuel. Some biodiesel is used as heating oil. Recently the Department of Defense expressed interest to procure biofuels. [14] For the first time, the procurement requests military-specification diesel fuel and jet fuel that are blended with biofuels. The U.S. Navy's interest in biofuels is part of its goal to generate 50% of its energy from alternative sources by 2020: nuclear energy, electricity from renewable sources, and biofuels.

1.5.3 Petroleum

In 2013 the U.S. consumed 18.9 million barrels of petroleum a day [15] of which 8.84 million barrels accounted for use as motor gasoline. The transportation sector has the highest consumption rates, accounting for approximately 71% of the U.S. petroleum use in 2013. The U.S. has been import dependent with respect to crude oil for several decades (Figure 5 and Figure 6). By 2013, dependence on net petroleum imports was 33% (EIA, as above). Crude oil imports have dropped in recent years however due to an increase in local production (Figure 6and Figure 7). U.S. production of crude oil has dropped steadily since the 1970’s but recent advances in hydro-fracking lead to production increases to 7,462 thousand barrels per day in 2013.

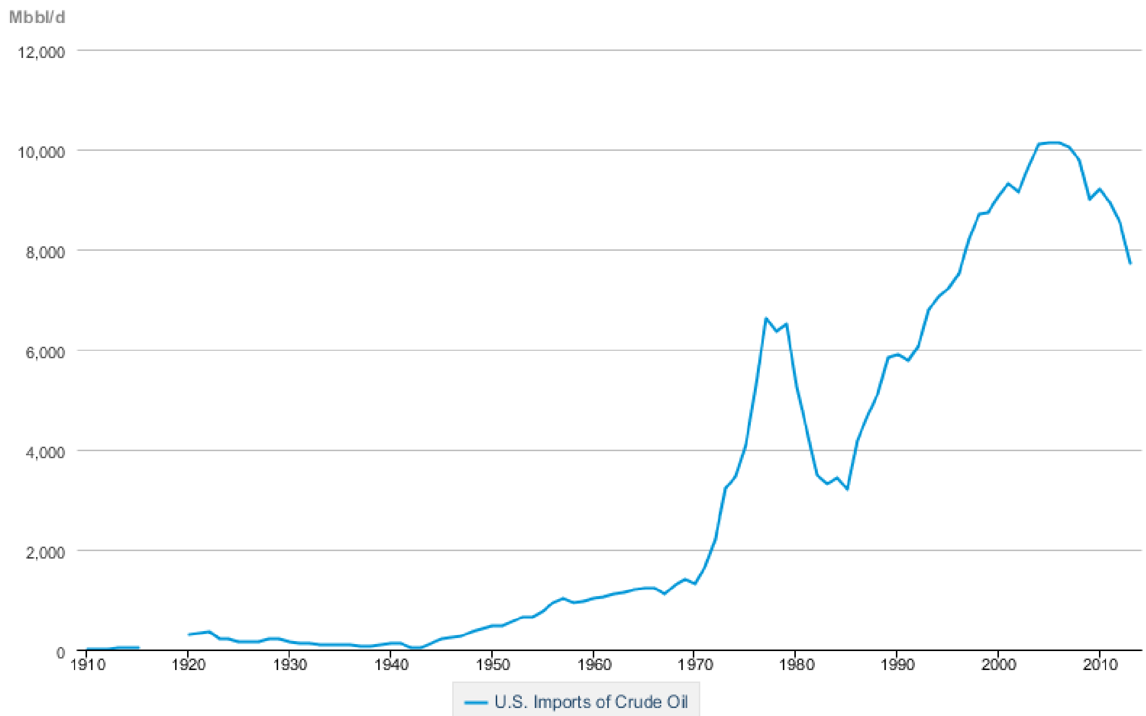

Figure 5. Historical U.S. crude oil imports by area of entry.[16]

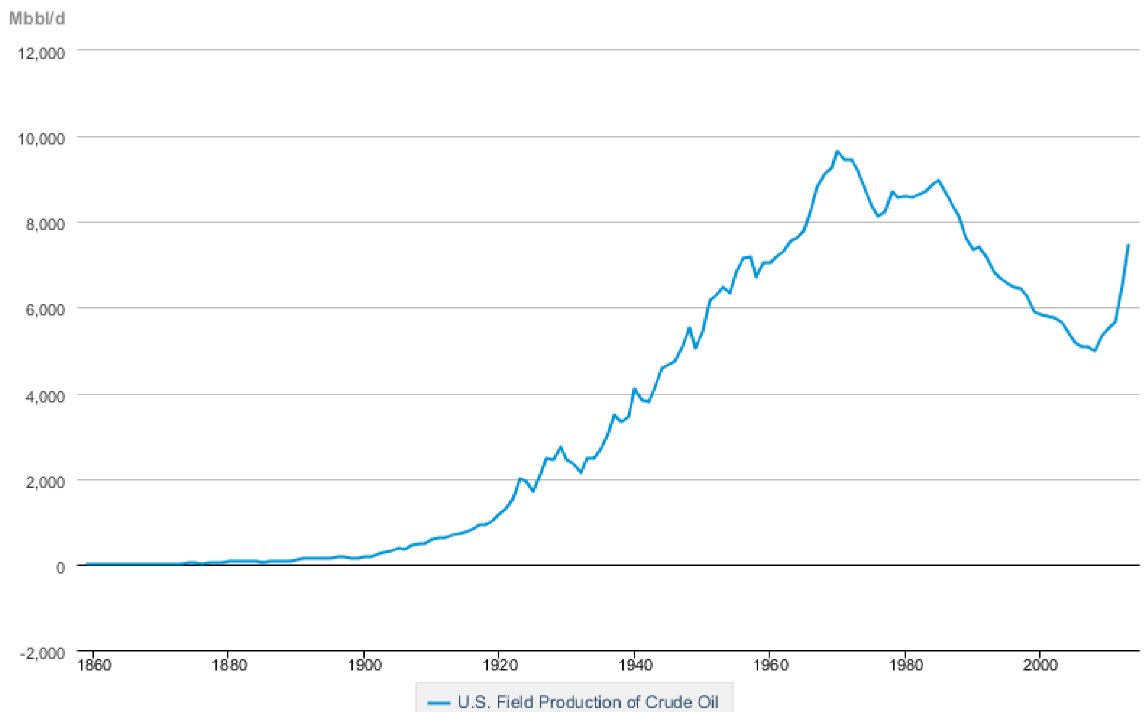

Figure 6. U.S. historical production of crude oil.[17]

1.5.4 Coal

The U.S. is self-sufficient with respect to coal.[18] It has several hundred years of supply at the current rate of consumption.[19,20] Up until 2008, U.S. coal production and consumption increased steadily. From 1950 through 2010, both coal production and coal consumption in the U.S. have more than doubled.[21] .

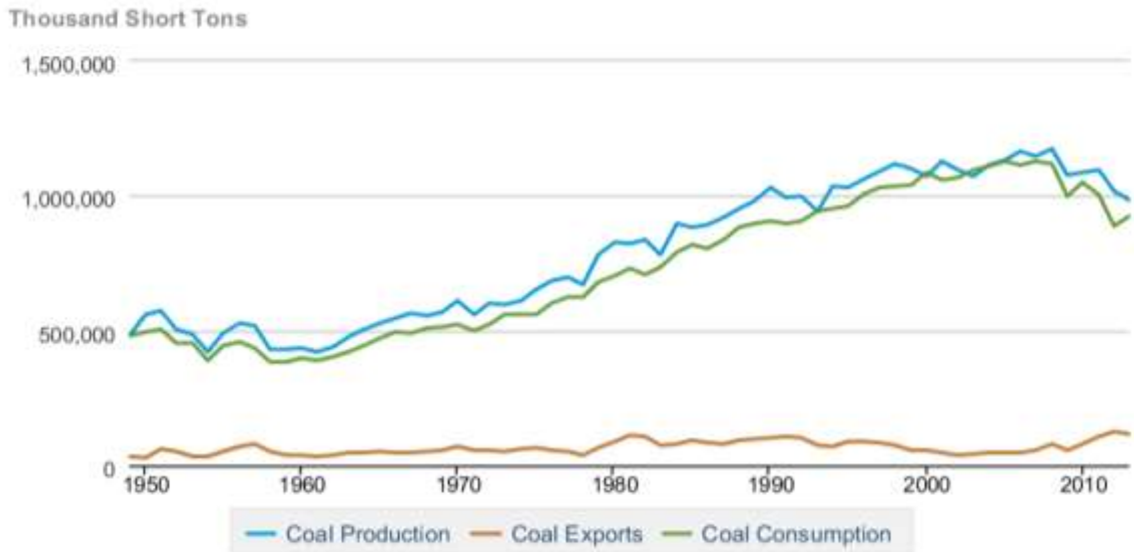

Figure 7. U.S. coal production, exports, and consumption from 1950-2012.[22]

1.6 Further Country-Specific Energy-Related Information

The U.S. population is growing at a rate of 0.75%.[23] The U.S. Census projects that this growth rate will slow over the coming decades to a projected population growth rate of 0.5% by 2050. However, this does not reflect the raw growth of the U.S., which is projected to reach 392 million people by 2050, assuming current rates of immigration and trends regarding birthrates. Figure 8 and Figure 9 correlates U.S. population and energy consumption, illustrating that while overall energy consumption in the U.S. has grown, the per capita energy consumption has actually slowed and leveled off in the past decade. The EIA projects a gradual decline in energy consumption per capita through 2030 due to improved technology, government mandates and initiatives, and continuing high oil prices. Total consumption will continue to rise slowly if current trends hold constant, while per capita consumption should go down over the next few decades.

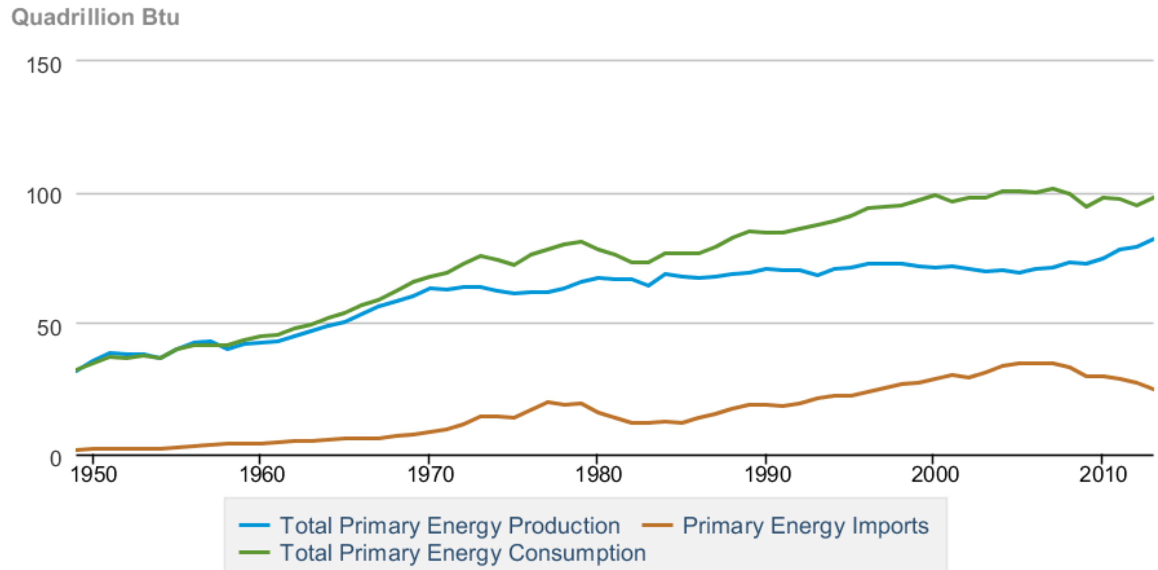

Figure 8. Primary energy overview.[24]

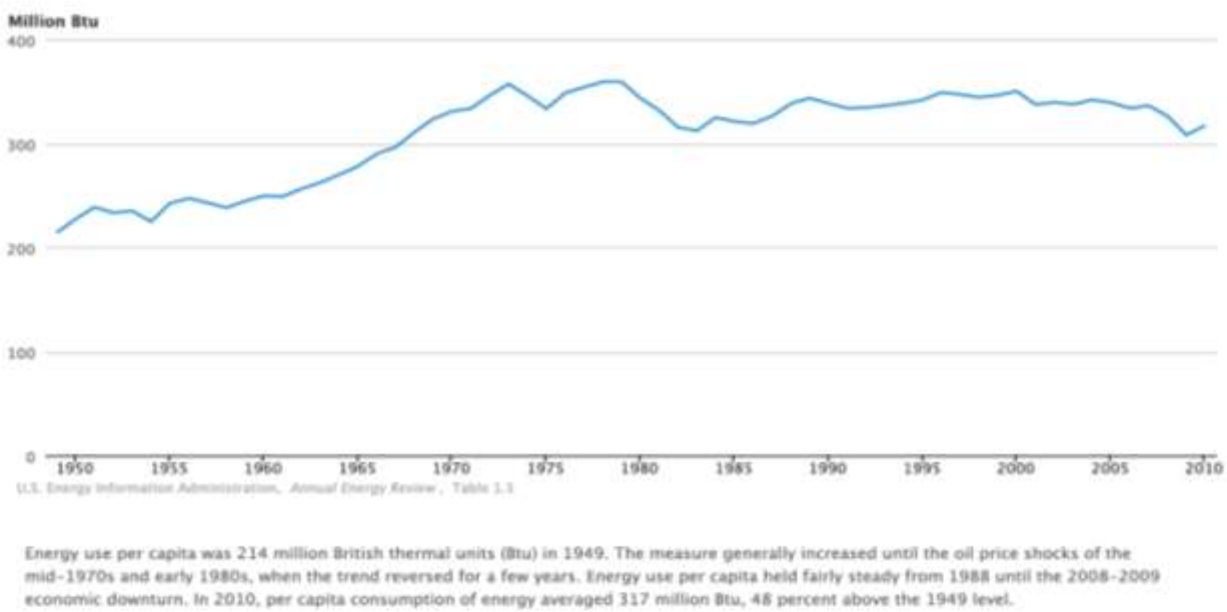

Figure 9. U.S. primary energy consumption per capita from 1949-2010.[25]

2. DOMESTIC BIOMASS RESOURCES, CURRENT USE, TRENDS

2.1 Domestic biomass resources

About half of the total US land base has some potential for growing biomass for bioenergy feedstocks while continuing to meet food, feed, and fiber demands. *The Billion-Ton Update*[26], released in 2011 by the U.S. Department of Energy, projects biomass potentials at a conservative baseline yield increase and a more optimistic yield increase driven by increased bioenergy industry demand.[27] Cropland and forestland have the potential to supply more than 1.1 billion dry ton (BDT) per year as projected from historical yield baselines, and between 1.3 to 1.6 BDT considering higher yield increases of 2% and 4%, respectively. Figure 10 show the projected resource potential for both baseline and high-yield scenarios based on grower/stumpage payments of $60 per dry ton.

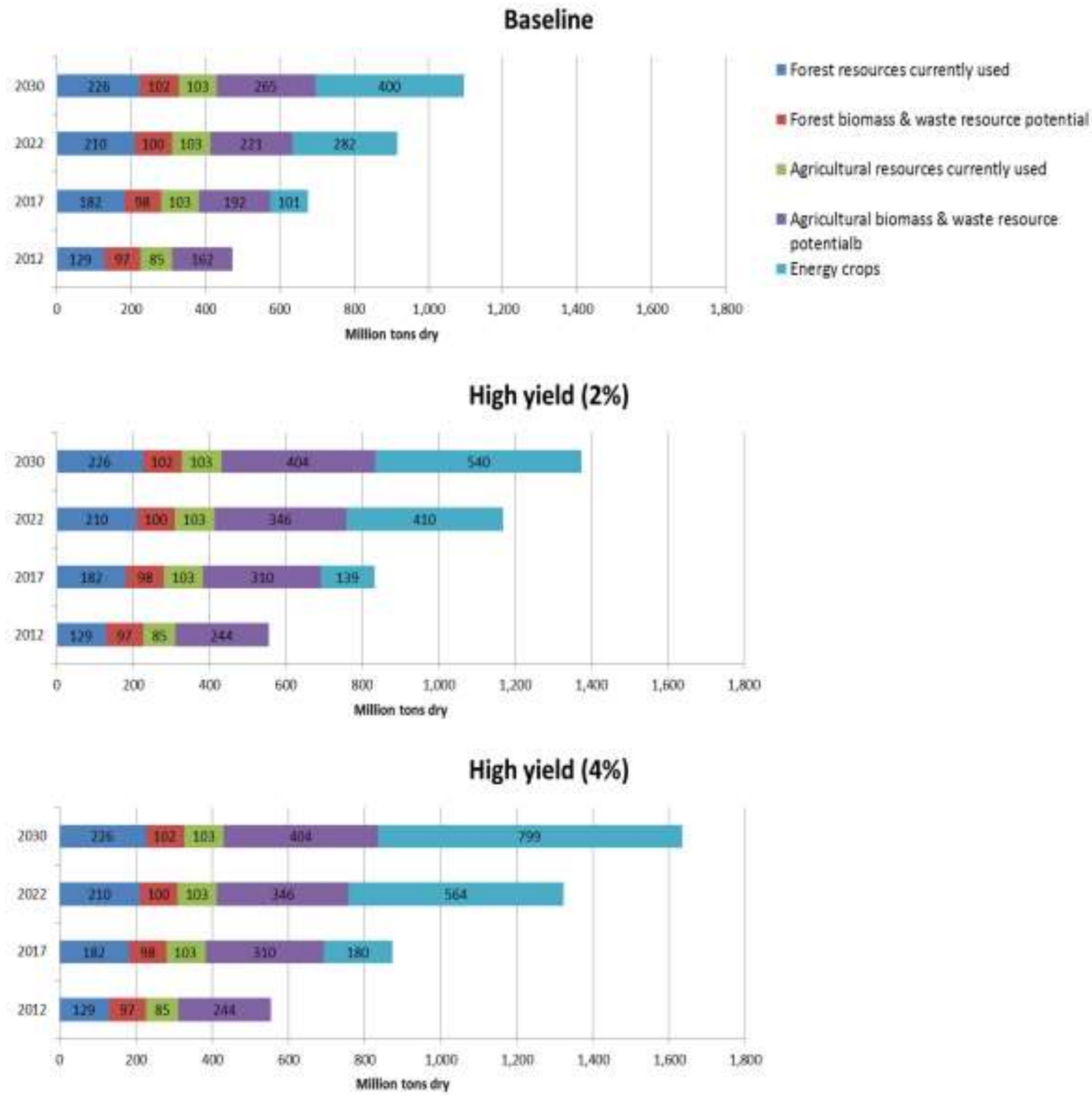

Figure 10. Summary of annual biomass resource potential from forest and agricultural resources under baseline, and high-yield scenario assumptions.

2.1.1 Forest Resources

At baseline yield increase assumptions and $60 per dry ton, the amount of biomass that can be removed sustainably from privately owned forestlands is currently about 90 MDT per year. Based on the assumptions and conditions outlined in this analysis, including expansion of biomass accessibility to Federal lands, the amount of forestland-derived biomass that can be sustainably produced is approximately 102 MDT per year[28] (Fig X). The 102 MDT potential availability from forest resources includes conventional pulpwood, urban wood wastes, mill residues, and forest residues.

Figure 11 shows a breakdown of forestland biomass resource availability at three different prices and four different time frames, projected from current industry practices and literature.

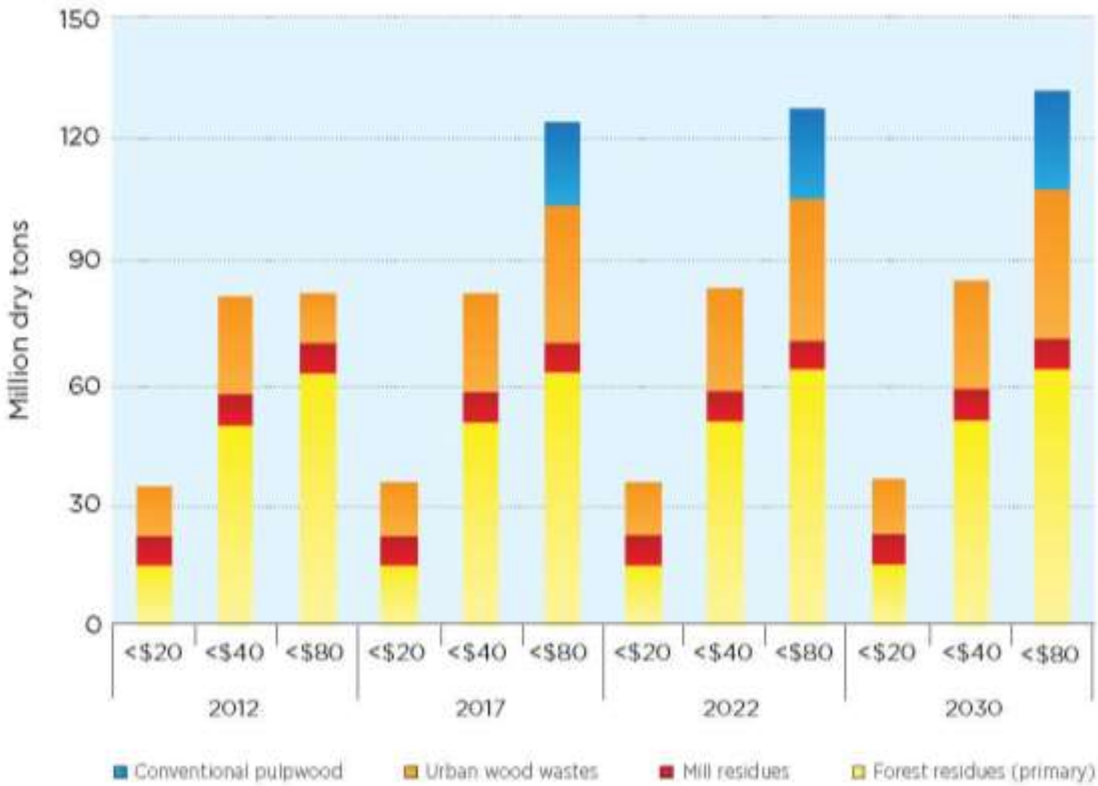

Figure 11. Estimated forestland biomass resource availability projected at $40, $50, and $60 per dry ton, projected from historical yield baselines.[29]

The spatial distribution of the biomass resources, as developed by US-DOE 2011[30], is publicly available in GIS-based tools and maps from U.S. national laboratories. The following maps are examples for forest residues. The data is partially made more regionally explicit, e.g., in the Sun Grant Initiative's regional atlases (e.g., for the U.S. South-East: http://biomassatlas.org/biowebgis).

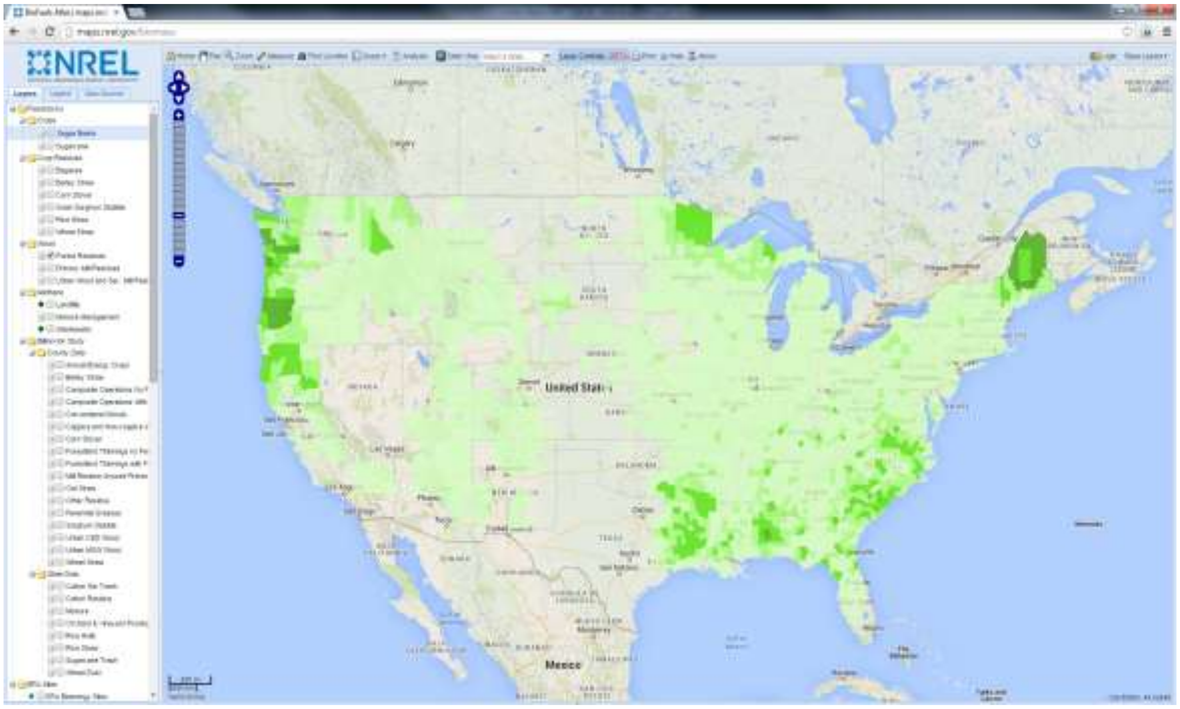

Figure 12. Forest residue potential in the continental United States[31.]

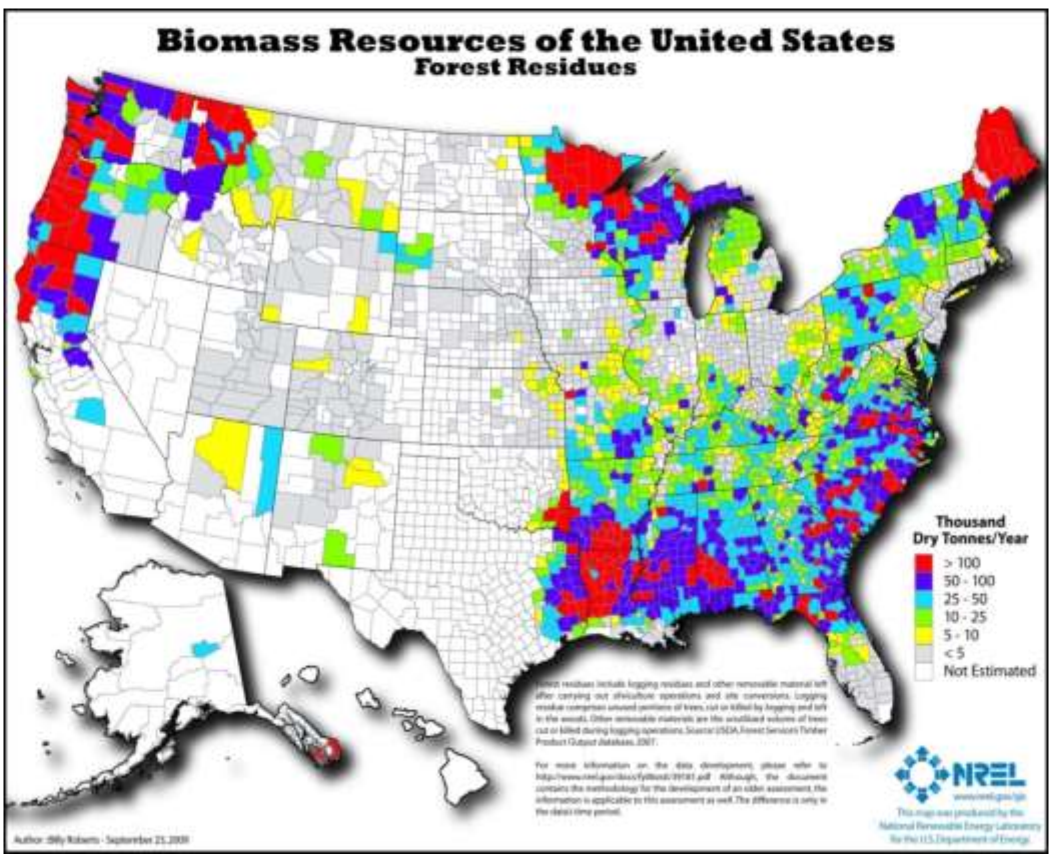

Figure 13. Forest residue potential in the continental United States32.

2.1.2 Agricultural Resources

At baseline yield increase assumptions and $60 per dry ton, the amount of biomass that can be removed sustainably from agricultural lands is currently about 247 MDT per year. This amount can be increased fivefold to nearly 1.1 to 1.3 BDT within 20 to 30 years through a combination of technology changes (e.g., higher crop yields and improved residue collection technology), adoption of no-till cultivation, and changes in land use to accommodate large-scale production of perennial energy crops. This high-yield scenario projection comprises 103 MDT of agricultural resources that are currently available, 404 MDT of agricultural biomass and waste resource potential, and 540 to 799 MDT of perennial energy crops.[33] Figure 14 shows a breakdown of agricultural biomass resource availability at three different prices and four different time frames, projected from historical yield baselines.

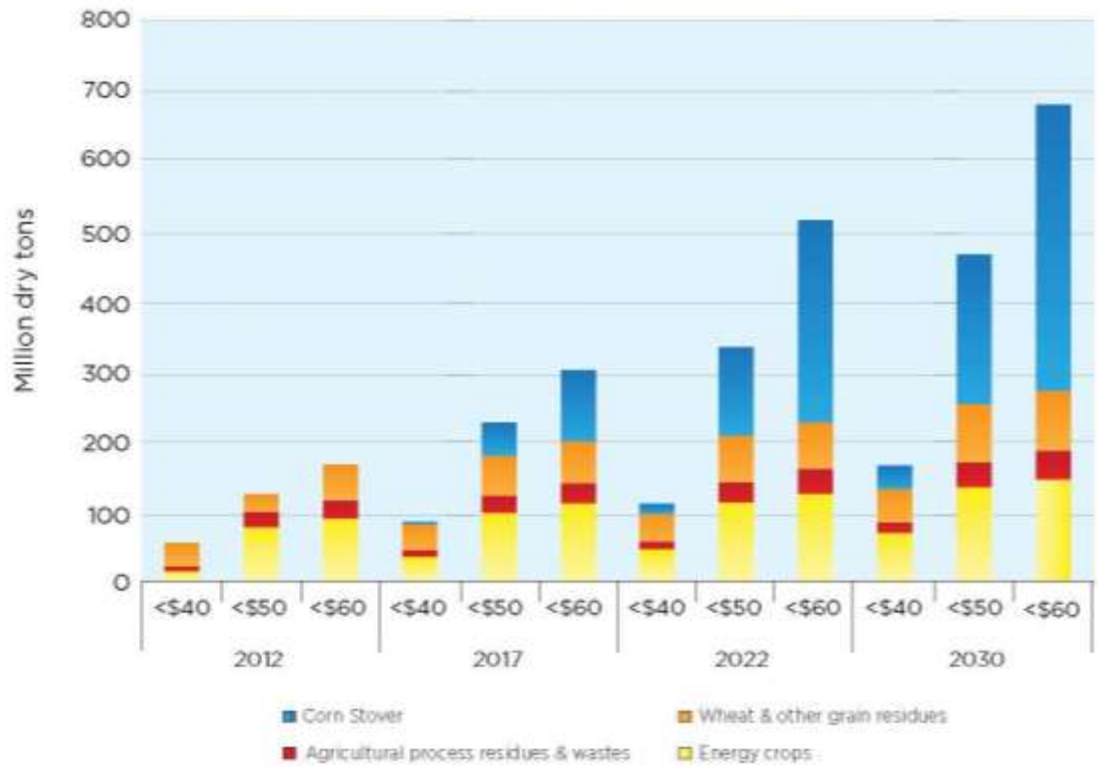

Figure 14. Estimated agricultural biomass resource availability projected at $40, $50, and $60 per dry ton, projected from historical yield baselines. High-yield projections (2 to 4% increases) are significantly higher.[34]

The Regional Feedstock Partnership was formed by the U.S. DOE, USDA, and Sun Grant initiative universities to address barriers associated with supplying a sustainable and reliable source of feedstock to a large-scale bioenergy industry. Figure 15 shows the 2010 energy crop field trial locations.[35]

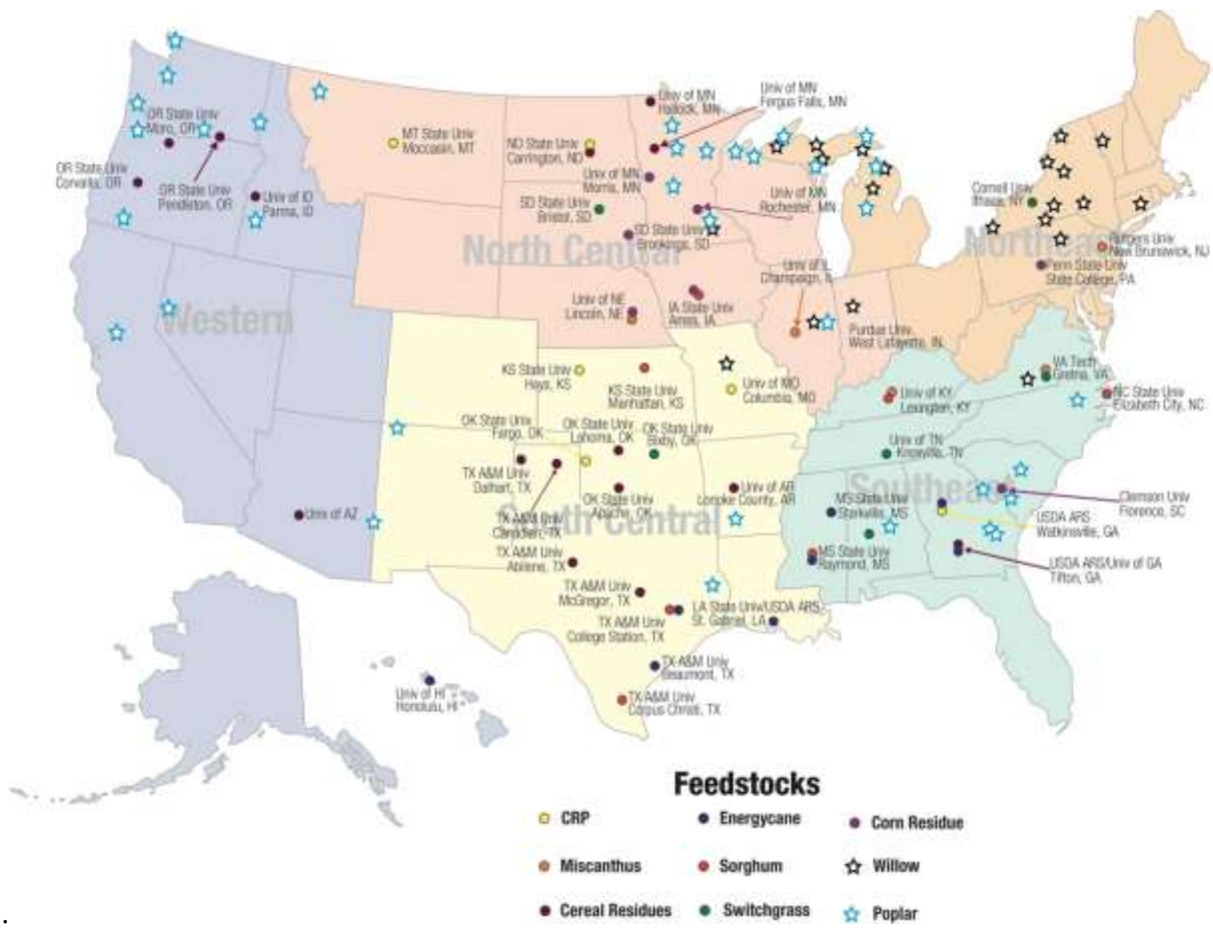

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Figure 15. Regional feedstock partnership development work underway: 2010 bioenergy crop trials (Updated May 2010).[36]

Corn stover provides the majority of crop residues currently available for biofuel production and accounts for 75% of total U.S. crop residues.[37] Most of the corn stover supply is concentrated in the Midwest region, including the states of Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, and South Dakota (Figure 16). Assuming a crop to residue ratio of 1:1[38], the U.S. corn stover production rose from around over 50 to close to 300 Million tons between 1950 and 2013 (Figure 17). This is largely due to productivity increases as the total area planted only rose by 20 Million acres across the same period (from 49 to 69 million acres). The partly drastic fluctuations in annual yields are related to inclement weather patterns, among others droughts (1980, 1983, 2012) and floods (1993).

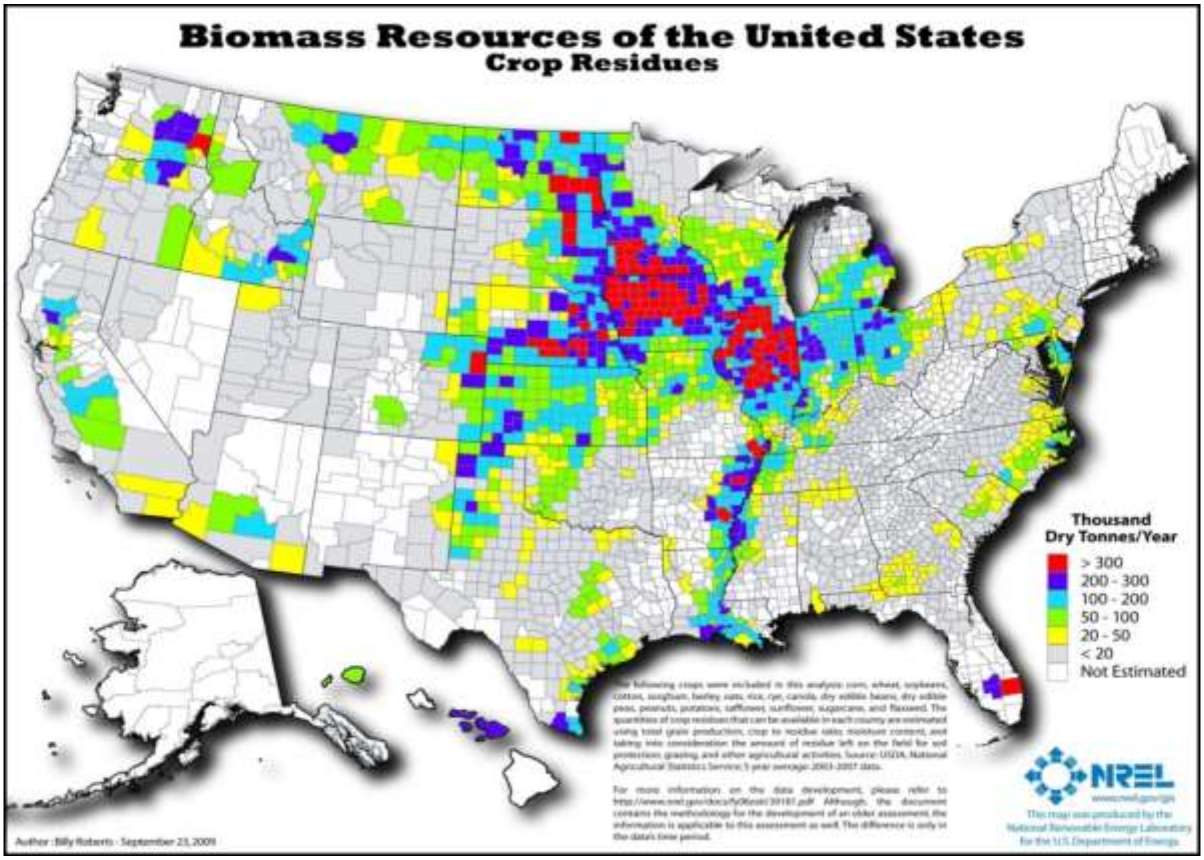

Figure 16. Corn stover potential in the continental United States. [39].

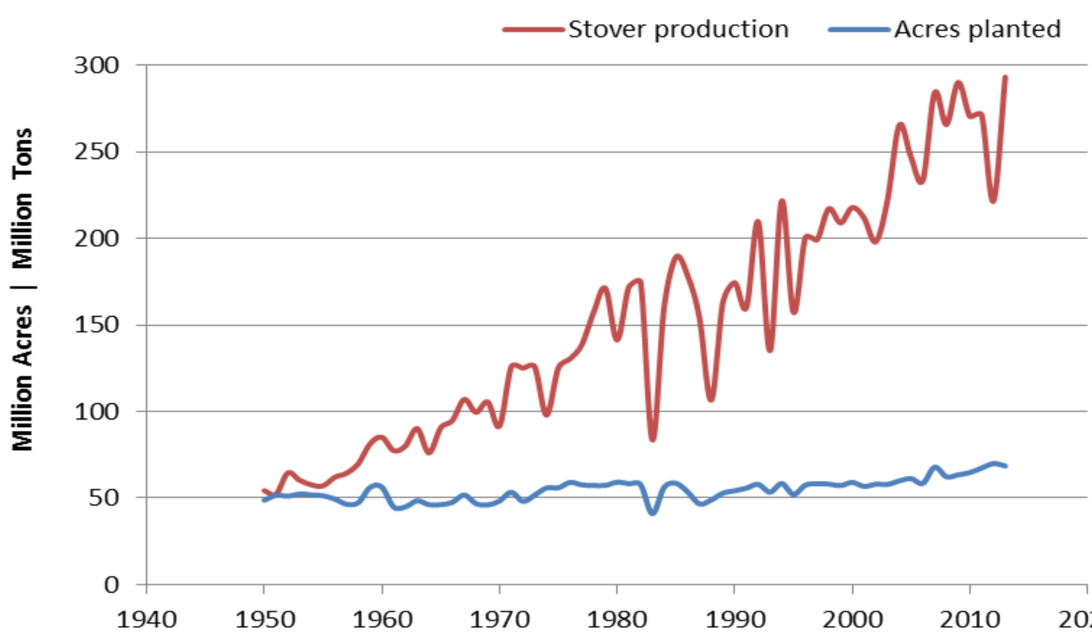

Figure 17. Corn stover production across the U.S. Midwest (including Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota) from 1950 to 2013. [40]

2.2 Current and Projected Use of Biomass Resources

The U.S. biomass consumption for energy has increased by almost 2 trillion Btu (roughly 2 EJ) over the last decade (Figure 18). This increase however was solely observed in the liquid biofuels sector. Woody and waste biomass for energy use remained stagnant. The overall trend may not be reflected across all regions of the U.S.

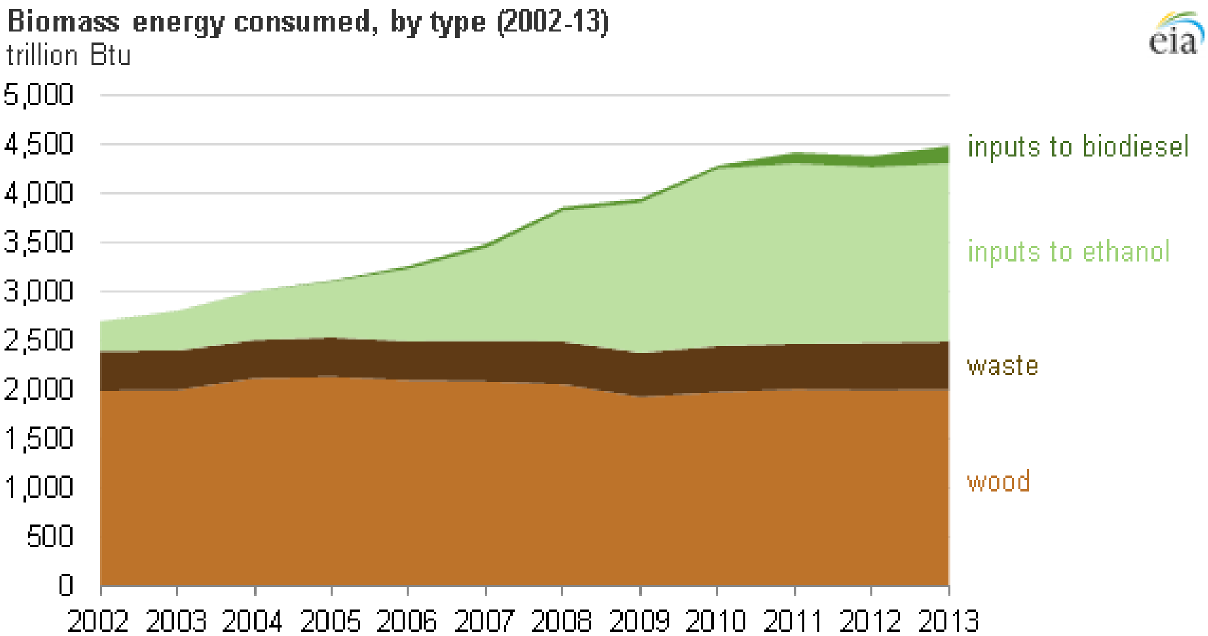

Figure 18. Biomass energy consumed by type between 2002-2013.[41]

2.2.1 U.S. Fuel Ethanol Plant Production Capacity

In its third release, the U.S. Energy Information Administration (EIA) provides data on fuel ethanol production capacity. Table 6 contains production capacity data for all operating U.S. fuel ethanol production plants as of January 1, 2013. 'Nameplate Capacity' is the volume of denatured fuel ethanol that can be produced during a period of 12 months under normal operating conditions.

Table 6. U.S. Fuel Ethanol Plant Production Capacity in 2012 and 2013.[42]

PAD District	*Number of Plants*	*Nameplate Capacity 2013*		*Nameplate Capacity 2012*	
		(MMgal/year)	(mb/d)	(MMgal/year)	(mb/d)
PADD 1	4	360	23	316	21
PADD 2	172	12,598	822	12,488	815
PADD 3	5	419	27	449	29
PADD 4	5	190	12	190	12
PADD 5	7	285	19	285	19
U.S. Total	**193**	**13,852**	**903**	**13,728**	**896**

Legend: Petroleum Administration for Defense (PAD) Districts are the geographic aggregations of U.S. into five districts by the Petroleum Administration for Defense in 1950. These districts were originally defined during World War II for purposes of administering oil allocation.

2.2.2 U.S. Biorefinery Capacity and Locations

The U.S. biorefinery industry is concentrated within the Midwestern states including Iowa, Minnesota, South Dakota, Nebraska, Illinois, Indiana, Ohio, Missouri, and Kansas. The primary reason is the direct link to the corn production industry. The majority of biorefineries are corn based fuel ethanol plants (see green dots in Figure 19). Additional facilities for biodiesel and other fuel ethanol feedstock, including advanced biorefineries exist.

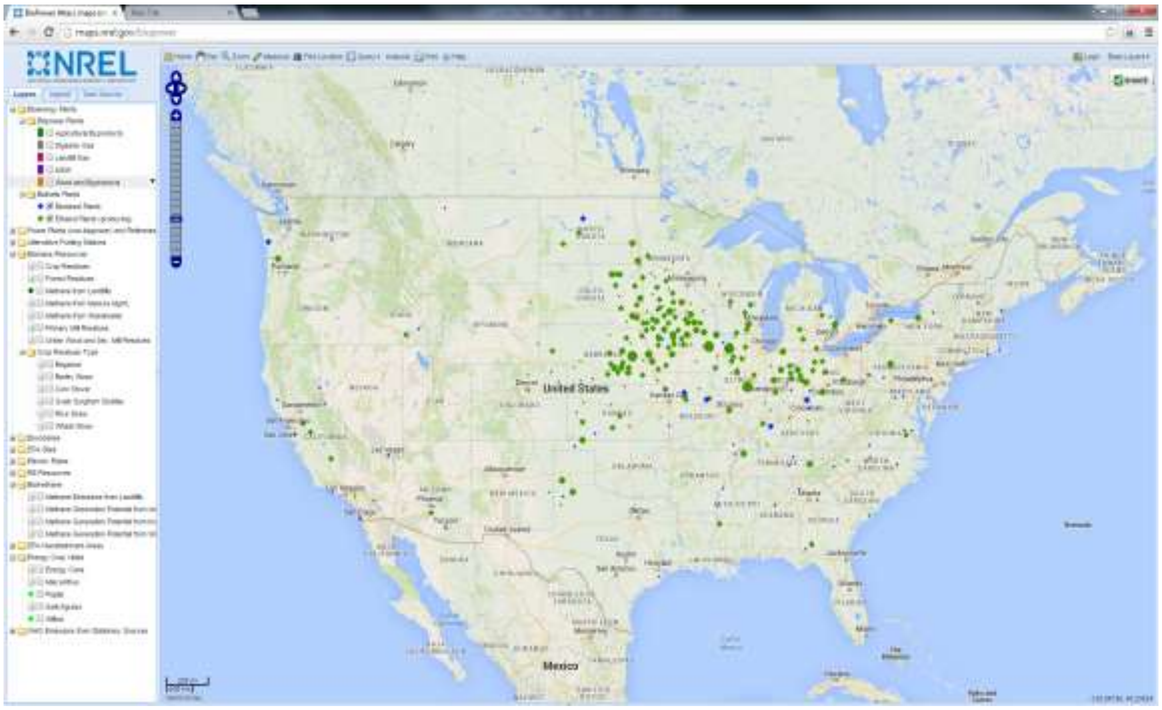

Figure 19. U.S. biorefineries by location (Biodiesel in blue, Bio-ethanol in green).[43]

By the end of 2014, the total production capacity stood at just over 14 billion gallons per year for operating biorefineries. An additional project pipeline worth 120 million gallons annual capacity was under construction/expanding.[44]

Three cellulosic biorefineries, converting corn stover to ethanol, were operating by the end of 2014: Abengoa in Hugoton, KS, DuPont in Nevada, IA, and Poet in Emmetsburg, IA (Table 7 and Table 8).

Table 7. Three biorefineries that are converting cornstover to ethanol.

Company	*Location*	*Fuel*	*Annual production volume (million gallons)*
Projected for 2014			
Abengoa	Hugoton, KS	Cellulosic ethanol	0-18
DuPont	Nevada, IA	Cellulosic ethanol	0-2
Poet	Emmetsburg, IA	Cellulosic ethanol	0-6

Additional EPA second-generation biofuel plant volumes are listed in Table 8.

Table 8. EPA listed second-generation biofuel plant volumes.[45]

Company	*Location*	*Fuel*	*Annual production volume (million gallons)*
Fiberight	Blairstown, IA	Ethanol	0
INEOS Bio	Vero Beach, FL	Ethanol	1.00
KiOR	Columbus, MS	Gasoline, Diesel	6.00
KL Energy Corp.	Upton, WY	Ethanol	0.10
ZeaChem	Boardman, OR	Ethanol	0.05
American Process Inc.	Alpena, MI	Ethanol	0.50
Fiberight	Blairstown, IA	Ethanol	2.00
INEOS Bio	Vero Beach, FL	Ethanol	3.00
KiOR	Columbus, MS	Gasoline, Diesel	4.80
KL Energy Corp.	Upton, WY	Ethanol	0.10
ZeaChem	Boardman, OR	Ethanol	0.05
AE Advanced Biofuels Keyes	Keyes, CA	Ethanol	0.50
Agresti Biofuels	Pike County, KY	Ethanol	1.00
Bell Bioenergy	Atlanta, GA	Diesel	11.90
Cello Energy	Bay Minette, AL	Diesel	8.50
Iogen Corporation	Ottawa, Canada	Ethanol	0.25
DuPont Danisco	Vonore, TN	Ethanol	0.15
Fiberight	Blairstown, IA	Ethanol	2.80
KL Energy	Upton, WY	Ethanol	0.40
Abengoa Bioenergy Corporation	York, NE	Ethanol	0.02
Bioengineering Resources, Inc. (BRI)	Fayetteville, AR	Ethanol	0.04
BPI & Universal Entech	Phoenix, AZ	Ethanol	0.01
Gulf Coast Energy	Livingston, AL	Ethanol	0.20
Mascoma Corporation	Rome, NY	Ethanol	0.20
POET Project Bell	Scotland, SD	Ethanol	0.02
Verenium	Jennings, LA	Ethanol	0.05
Verenium	Jennings, LA	Ethanol	1.50
Western Biomass Energy LLC. (WBE)	Upton, WY	Ethanol	1.50
Cello Energy	Bay Minette, AL	Diesel	20.00
Bell BioEnergy	Fort Stewart, GA	Diesel	0.01

2.2.3 U.S. Biopower Production and Facilities

The biomass based production of large-scale electricity (and heat) can be differentiated by input material. As shown in Figure 20, the majority of operations are based on landfill gas, followed by woody feedstock and byproducts, municipal solid waste, digester gas (biogas), and agricultural residues.

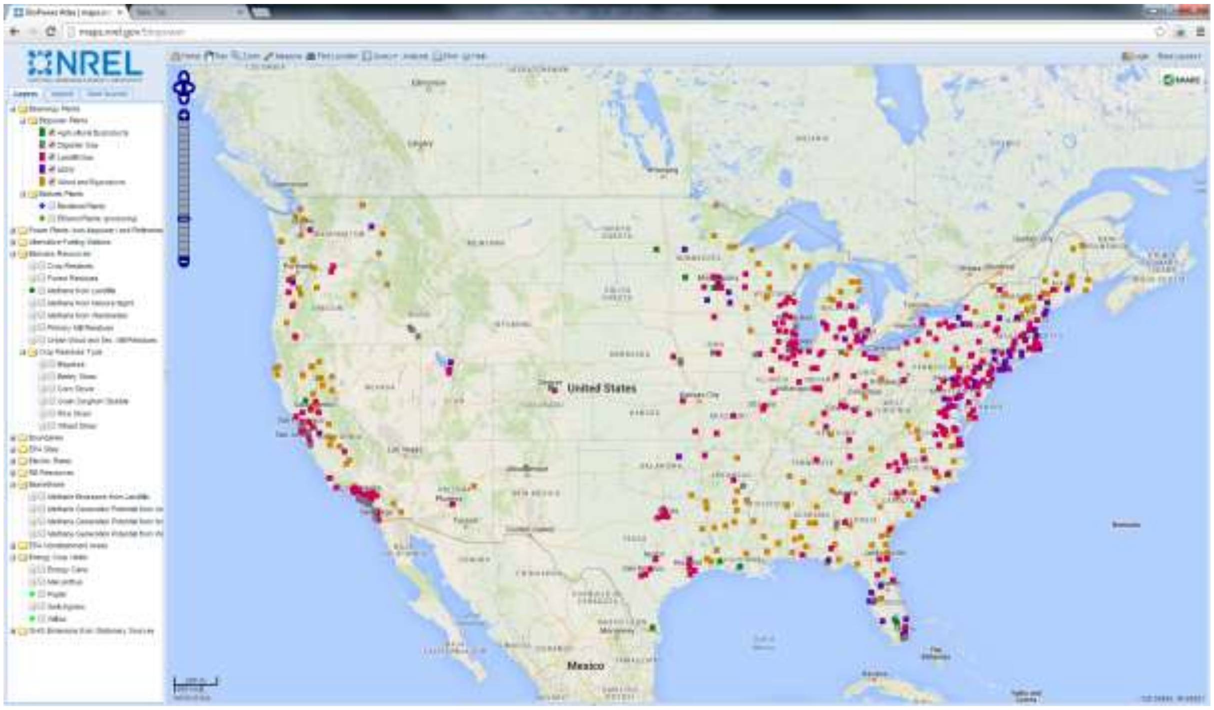

Figure 20. U.S. biopower facilities by location (colors represent different input material).[46]

2.2.4 Pellet plants

The vast majority of pelleting operations focus on woody feedstock (see below). However, there are also at least two known producer of pellets from agricultural residues namely:

- Pellet Technology, Nebraska [47]
- Show Me Energy, Missouri [48]

By the end of 2014, there were 128 wood pellet plants across the U.S. with a total annual capacity of 10.56 million short tons. Furthermore, there were an additional 20 projects proposed (totaling an additional 5.93 million tons of annual capacity) and 9 projects under construction with a total annual capacity of 3.56 million tons.[49] The average plant size was 128,000 short tons annual production. Table 9 lists all wood pellet plants above 250,000 short tons annual production. Figure 21 shows the regional distribution of pellet production plants across the U.S.

Table 9. Wood pellet plants above 250,000 short tons annual capacity in operation, proposed (P), and under construction (UC).[50]

Plant	*Location*	*Feedstock*	*Capacity*	*Status*
German Pellets Louisiana	La Salle, LA	Softwood	1,100,000	UC
Biomass Power Louisiana LLC	Baton Rouge, LA	Softwood	1,000,000	P
Georgia Biomass	Waycross, GA	Softwood	825,000	
Green Circle Bio Energy Inc	Cottondale, FL	Hardwood and Softwood	660,000	
Fram Renewable Fuels - Hazlehurst	Hazlehurst, GA	Softwood	551,155	UC
Enviva Pellets Northampton, LLC	Garysburg, NC	Hardwood and Softwood	551,155	
Enviva Pellets Southampton, LLC	Franklin, VA	Hardwood and Softwood	551,155	
German Pellets Texas	Woodville, TX	Hardwood and Softwood	551,155	
Enova Energy Group - Gordon	Gordon, GA	Woody Biomass	545,643	P
Enova Energy Group - Warrenton	Warrenton, GA	Woody Biomass	545,643	P
Enova Energy Group - Johnston	Johnston, SC	Softwood	500,000	P
Green Circle Bio Energy-Miss. plant	George County, MS	Softwood	500,000	P
Amite BioEnergy	Gloster, MS	Hardwood and Softwood	500,000	UC
Morehouse BioEnergy	Morehouse Parish, LA	Woody Biomass	496,040	UC
International Biomass Energy LLC	AL	Hardwood and Softwood	485,016	P
BlueFire Renewables Fulton LLC	Fulton, MS	Wood waste	440,924	UC
General Biofuels - Georgia	Sandersville, GA	Softwood	440,000	P
Ogeechee River Pellet Mill	Millen, GA	Woody Biomass	396,832	P
First Georgia BioEnergy	Waynesville, GA	Softwood	374,785	P
Enviva Pellets Ahoskie	Ahoskie, NC	Hardwood and Softwood	365,000	
F.E. Wood & Sons - Natural Energy	West Baldwin, ME	Hardwood and Softwood	343,921	P
Westervelt Renewable Energy, LLC	Aliceville, AL	Softwood	309,000	
Zilkha Biomass - Selma	Selma, AL	Hardwood and Softwood	303,135	UC
New Biomass Energy	Quitman, MS	Hardwood and Softwood	250,000	

Figure 21. Regional distribution of all wood pellet plants in operation, under construction, or proposed across the lower 48 States. [51] Note: yellow markers indicate plant density above 10, blue markers are used for less than 10 plants per data point.

3. POLICY SUPPORT AND EXPECTED FUTURE BIOMASS USE

A complete list of all renewable energy policies and measure with respect to the U.S. can be found at the International Energy Agency policy database. [52] This section exclusively focuses on those policies that have had an impact on the production, consumption or trade of biomass from the U.S.

Furthermore, due to the expanse of the U.S. with 50 individual states, we only detail federal laws. State laws can be found on the respective State's governmental websites as well as the Alternative Fuels Data Center. [53] The latter provides a database with details on clean transportation laws, regulations, and funding opportunities in a particular jurisdiction as well as on federal level.

3.1 Targets for Biopower

At this point there is no federal mandate for the production of biopower. Most states however have renewable portfolio standards or goals in place (Figure 22). These standards require that utility companies generate a certain amount of energy from renewable resources by a certain date. For example, a certain percentage of the utility's electric power sales must be generated from renewable energy sources. Biomass is however only one from of renewable energy eligible to meet these targets (see Section 0 for details on biomass to power facilities across the U.S.), in addition to wind, solar, hydropower, etc.

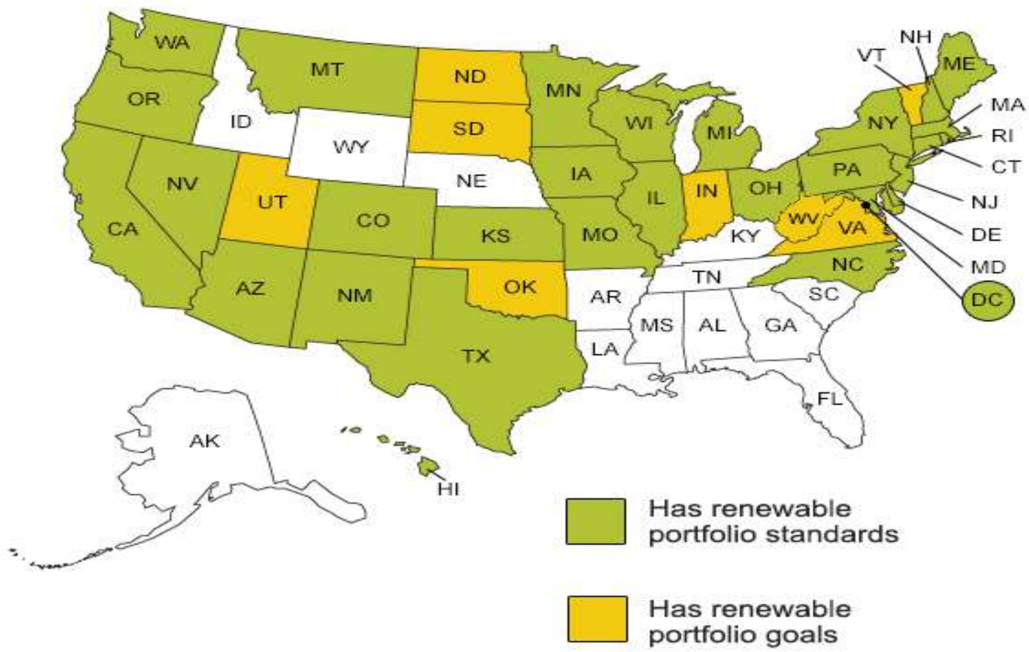

Figure 22. Distribution of renewable portfolio standards or goals.[54]

In 2014 the Environmental Protection Agency (EPA) proposed a plan to cut carbon pollution from power plants. [55] The current proposal sets up a national framework that gives individual states the power to chart their own customized path to meet the CO_{2e}-emissions targets proposed for each state. By 2030 the proposal would result in 30% less carbon pollution from the power sector across the U.S. when compared with 2005 levels.

3.2 Federal Targets for Biofuel Production

In 2007, Congress passed the Energy Independence and Security Act (EISA), amending the Renewable Fuel Standard (RFS) as established by EPACT in 2005. By 2022, the U.S. shall produce 36 billion gallons of biofuels. Of that, 21 billion gallons shall be advanced biofuels (derived from feedstock other than corn starch). Of the 21 billion gallons, 16 billion shall come from cellulosic ethanol. The remaining 5 billion gallons shall come from biomass-based diesel and other advanced biofuels.[56] The U.S. Environmental Protection Agency (EPA) is revising its current RFS to reflect the changes in the EISA.

In 2011, the EPA implemented the Renewable Fuel Standard 2 (RFS2) program, a credit trading system along with biofuel volumetric mandates. The RFS2 establishes specific volumetric requirements for the four overlapping categories of renewable, advanced, biomass-based, and cellulosic biofuels (Figure 23). Compliance with these requirements is tracked through renewable identification numbers (RIN), which are numbers that are used to identify specific fuel volume by category. The RIN market is complex relative to other credit trading systems with four categories of credits each corresponding to a RIN biofuel category (see Warner et al. 2014[57] for a detailed assessment of the RIN market).

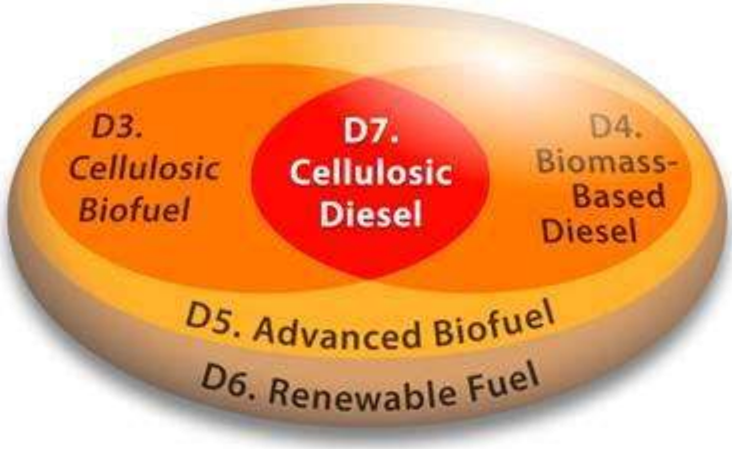

Figure 23. Nesting of biofuel categories under the RFS.[58]

Figure 24 below lists the new targets for biofuels production as prescribed by EISA.

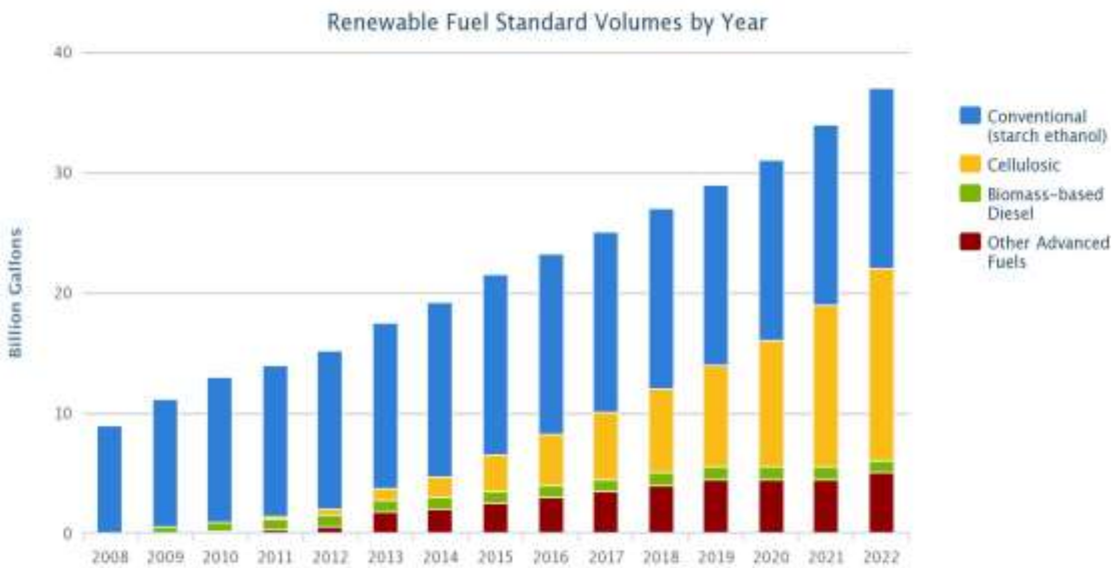

Figure 24. Renewable Fuel Standard Volumes by Year.[59]

Historically, the first federal endorsement of biofuel came with the passage of the 1978 Energy Tax Act. The act introduced a 100% exemption of the gasoline tax for alcohol fuel blends (which was $.04 at the time).[60] With the exemption still in place, biofuel, particularly ethanol, received more attention as a possible oxygenate to be used in reformulated gasoline as outlined in the Clean Air Act Amendments of 1990, which directed the U.S. EPA to establish a standard for reformulated gasoline.[61] Another possible oxygenate defined in the Clean Air Act was methyl tertiary butyl ether (MTBE). Until recently, MTBE was the preferred oxygenate because it was less expensive and easier to distribute than ethanol.[62]

However, concerns over MTBE's affect on ground water quality has resulted in many states adopting laws that ban or significantly limit its use in gasoline sold in those states. Twenty-five states have laws that phase out MTBE partially or completely.[63] In light of the MTBE bans in these states, one element of the EPACT of 2005 repealed the oxygenate requirement as described in the 1990 Clean Air Act Amendments.[64] A provision of the repeal required refiners to blend gasoline so that they still maintain the

Clean Air Act-mandated emissions reductions achieved in 2001 and 2002.[65] EPACT also established an RFS that required that 7.5 billion gallons of ethanol and biodiesel be produced by 2012.[66]

Prior to EPACT, Congress passed the American Jobs Creation Bill of 2004, which established a blender's tax credit for ethanol and a comparable credit for biodiesel production. [67] As of 2011, blenders received a $0.45 per gallon tax credit, regardless of feedstock; small producers received an additional $0.10 on the first 15 million US gallons; and producers of cellulosic ethanol received credits up to $1.01. Tax credits to promote the production and consumption of biofuels date back to the 1970s. For 2011, credits were based on the Energy Policy Act of 2005, the Food, Conservation, and Energy Act of 2008, and the Energy Improvement and Extension Act of 2008.

The import tariff and tax credit for ethanol both expired at the end of 2011. The biodiesel tax credit was set to expire by the end of 2013 but got extended to the end of 2014.[68] Since the end of the ethanol production tax credit, production volumes have fallen behind the legislated EISA and EPA required volumes (Figure 25).

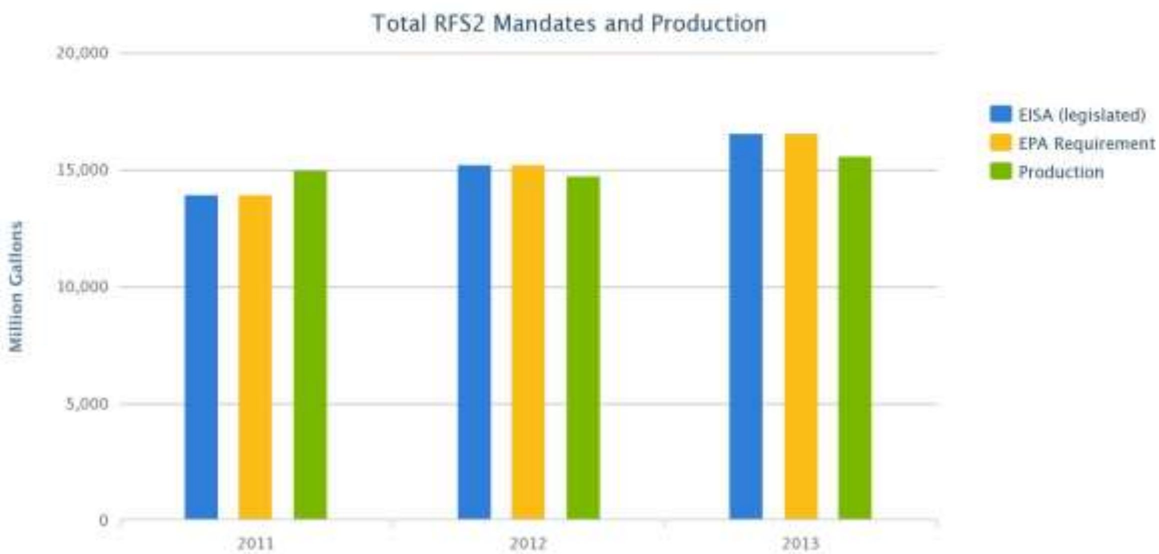

Figure 25. Recent RFS2 mandates *vs*. actual production volumes.[69]

3.3 Targets Set by Other Groups

In addition to biofuel targets set by Congress through the RFS, other organizations have set targets that while not mandatory, have helped drive federal policy. One such group is the Biomass Research and Development Initiative's (BRDI) Technical Advisory Committee, which was established by the Biomass Research and Development Act of 2000 and has diverse representation from industry, academia, non-governmental organizations, and state governments. In its 2006 Vision Statement, the committee set a goal that by 2030 biofuel consumption would be equivalent to 5 billion gallons of gasoline, roughly 20% of the total market share, and biopower consumption would be 3.8 quadrillion BTU, or 7% of the market share. By 2030, the committee envisions bioproducts consumption to be 55.3 billion pounds.[70] Another organization, 25×'25, whose steering committee is comprised of leaders from industry and state government, has released policy recommendations and strategies aimed toward producing 25% of America's energy needs by 2025 by utilizing the country's agricultural and forest resources, while still meeting demands for food and feed.[71]

3.4 Federal Agency Role as Mandated by Congress

Many U.S. federal agencies administer programs that seek to expand the production and consumption of biofuel. In most cases, federal responsibility was legislated by Congress. The BDRI board of directors, created by the Biomass Research and Development Act of 2000, is comprised of high-level officials from various agencies and offices within the federal government. The board is co-chaired by the U.S. Department of Agriculture (USDA) and the U.S. DOE. The other board member agencies include[72]:

- The National Science Foundation
- The Environmental Protection Agency
- The Department of the Interior
- The Office of Science and Technology Policy
- The Office of the Federal Environmental Executive
- The Department of Transportation
- The Department of Commerce
- The Department of the Treasury
- The Department of Defense.

In addition to serving as BRDI board members, these agencies also perform specific duties that further the advancement of biofuel research, production, and use within the United States. For example, the U.S. EPA is responsible for administering the RFS as prescribed by EPACT 2005 and as amended by EISA. The Internal Revenue Service (IRS) is responsible for overseeing the various tax credits given to blenders and producers of biofuel. For example, the IRS oversees the $.51 volumetric ethanol excise tax credit established by the American Jobs Creation Act of 2004 as amended by the Food, Conservation, and Energy Act of 2008.[73] The IRS also administers a biodiesel producer’s tax credit that was established by the American Jobs Creation Act of 2004. The USDA and the U.S. DOE are responsible for distributing loans and grants to stimulate biomass-related projects and research. For instance, the U.S. DOE announced in 2007 that it will provide up to $385 million to fund six biorefinery projects over 4 years that could produce 130 million gallons of cellulosic ethanol per year.[74] In addition, the U.S. DOE Office of Science operates three bioenergy research centers as part of the Genomics to Life Program. These centers are intended to further the basic research needed in order to cost-effectively produce cellulosic ethanol and other advanced biofuels.[75] USDA’s role was expanded with the passage of the Food Conservation and Energy Act of 2008. U.S. Customs and Border Protection (CBP) oversee the import duty for fuel ethanol.

3.5 Financial Support Measures for Biomass

A detailed analysis of subsidies provided in the energy sector including biomass was undertaken by the Energy Information Administration for the year 2010.[76] In this section, we limit our presentation to the two main sources, the Biomass Crop Assistance Program (BCAP) and the Demonstration and Deployment (D&D) subprogram.

3.5.1 Biomass Crop Assistance Program (BCAP)

While tax credits for ethanol and biodiesel have been terminated (ethanol at the end of 2011, biodiesel at the end of 2014), the biofuel industry is still able to benefit from indirect financing via agricultural and forest feedstock support programs, predominantly the Biomass Crop Assistance Program (BCAP).

The BCAP for USDA’s Farm Service Agency (FSA) was created as part of the 2008 Farm Bill (The Food, Conservation, and Energy Act of 2008) to reduce U.S. reliance on foreign oil, improve domestic energy security, reduce carbon pollution, and spur rural economic development and job creation.[77]

BCAP was set in place to help address bioenergy's "chicken-and-egg" challenge of establishing commercial-scale biomass conversion facilities and sufficient feedstock supply systems simultaneously:

- Conversion facilities must have reliable, large-scale feedstock supplies to operate, but there are no existing markets for accessing these materials
- Biomass feedstock producers do not have sufficient incentive to produce these materials because of the lack of existing markets to purchase their biomass.

The BCAP provides financial assistance to owners and operators of agricultural and non-industrial private forest land who wish to establish, produce, and deliver biomass feedstocks. It provides two categories of assistance:

(1) Matching payments may be available for the delivery of eligible material to qualified biomass conversion facilities by eligible material owners. Qualified biomass conversion facilities produce research, heat, power, biobased products, or advanced biofuels from biomass feedstocks.

(2) Establishment and annual payments may be available to certain producers who enter into contracts with the Commodity Credit Corporation (CCC) to produce eligible biomass crops on contract acres within BCAP project areas.

For instance, in 2006, 20% of the U.S. corn harvest was used for ethanol production. The total agricultural subsidies through the CCC (i.e., BCAP) for corn that year totaled $8.8 billion.[78] Thus, an estimated $1.8 billion went to subsidize corn destined for ethanol production.

3.5.2 Demonstration and Deployment (D&D)[79]

The Demonstration and Deployment (D&D) subprogram (formerly the Integrated Biorefinery Platform) is focused on demonstrating and validating biomass conversion technologies through successful construction and operation of cost-shared pilot, demonstration, and commercial scale integrated biorefinery (IBR) projects.

The purpose of the D&D subprogram is to "de-risk" emerging biomass conversion technologies sufficiently so that broad replication and industry expansion can occur. The U.S. DOE Bioenergy Technologies Office (BETO) does this by providing financial assistance for scale-up and demonstration of emerging technologies. BETO works in partnership with private-sector technology developers to leverage federal financial assistance funding. The D&D subprogram plays a vital role in "de-risking" technologies in two primary ways:

- Technologically, to scale-up and validate conversion process performance so that "Wrap-around" performance guarantees can be provided by EPC firms.
- Financially, to verify the CAPEX and OPEX so private-sector financing can invest without fear of default.

To date, 33 projects of R&D, pilot, demonstration, and commercial-scale IBR projects had been selected. Of these, five were mutually terminated, 5 completed, 19 are still active, while an additional four new awards are currently under negotiation. Figure 26 and Figure 27 show the geographic and pathway diversity of the projects.

Figure 26. BETO IBR Project Portfolio – Geographic Diversity. [80]

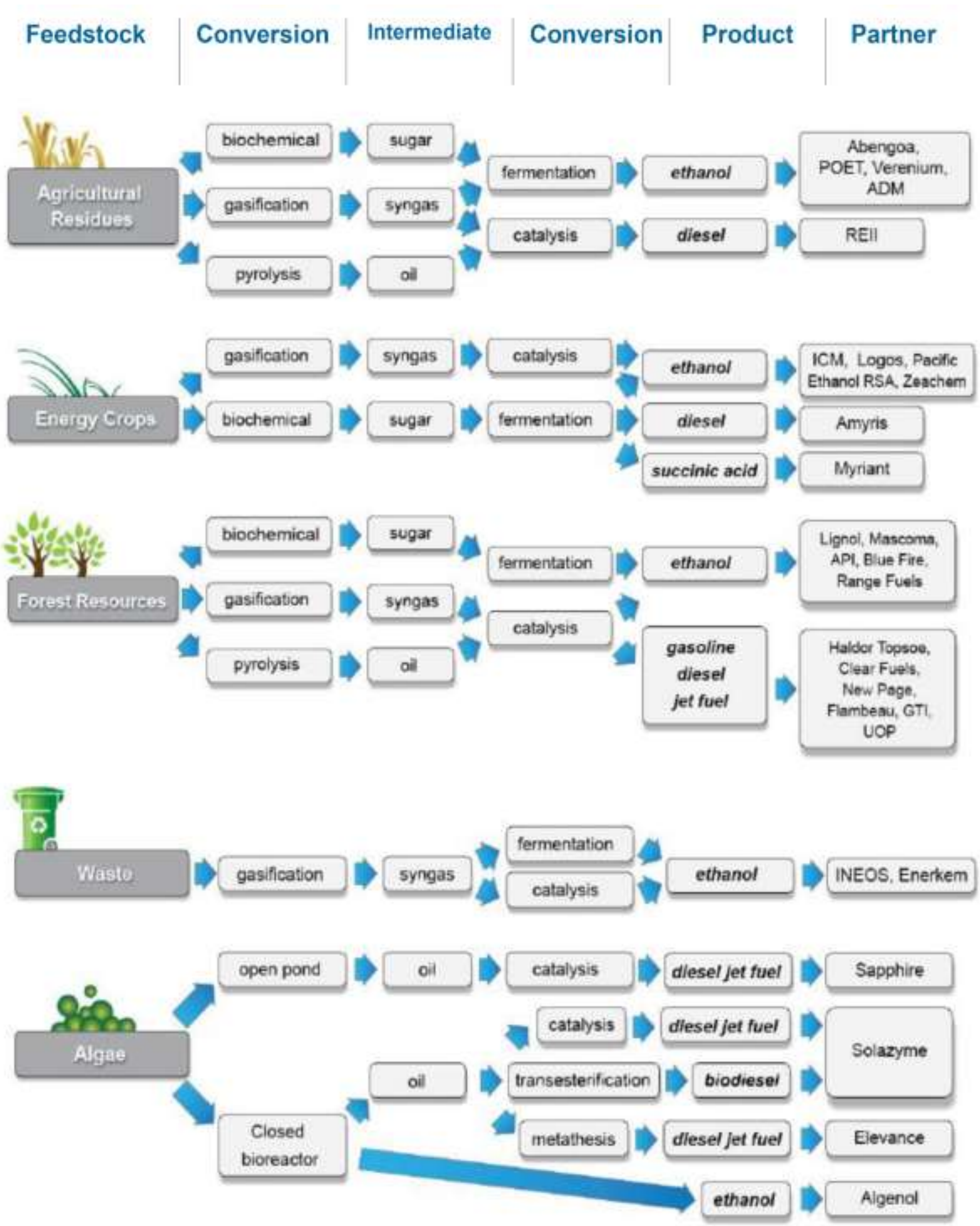

Figure 27. BETO IBR project portfolio – pathway diversity. [81]

4. BIOMASS PRICES

4.1 Average Prices of Main Biofuels for Large-scale Users

Corn is the primary feedstock for ethanol in the United States. Historically, the United States has been a large producer of corn for a number of reasons—chiefly because of its high carbohydrate yield relative to other crops and multiple uses as food, feed, ethanol, and exports. The price per bushel of corn has decreased greatly over the last 30 years as technologies have improved and supply has increased, but has increased over the last few years. The price increase between may be due to the increase of demand caused by biofuel production (Figure 28).

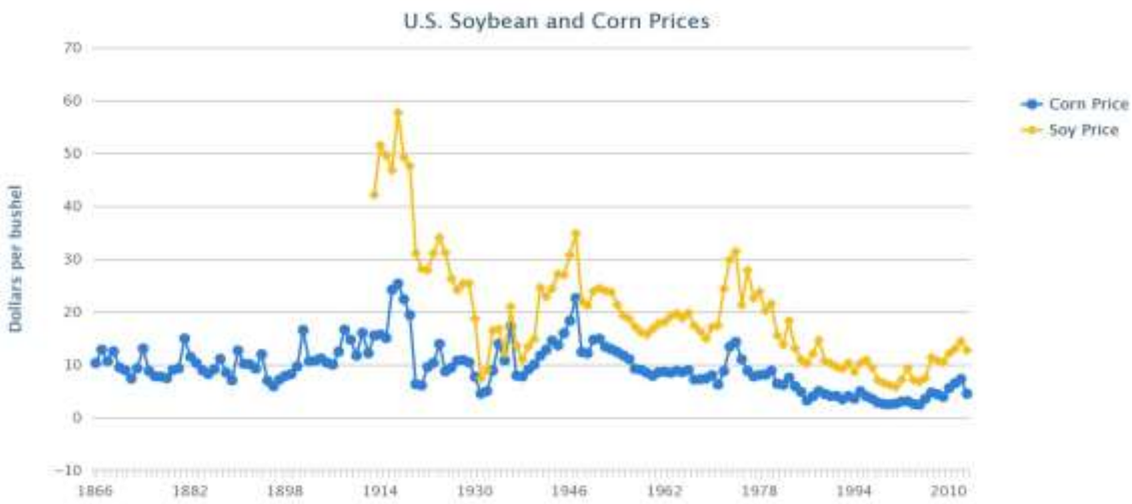

Figure 28. U.S. soybean and corn price history [82]

4.2 Fuel Price Comparisons over Time for Large-scale Users[83,84]

Figure 29 compares the retail price between gasoline and diesel. Figure 30compares the gasoline prices with alternative fuel such as natural gas, ethanol and propane. Figure 31 compares historical price of diesel and alternative fuels such as biodiesel.

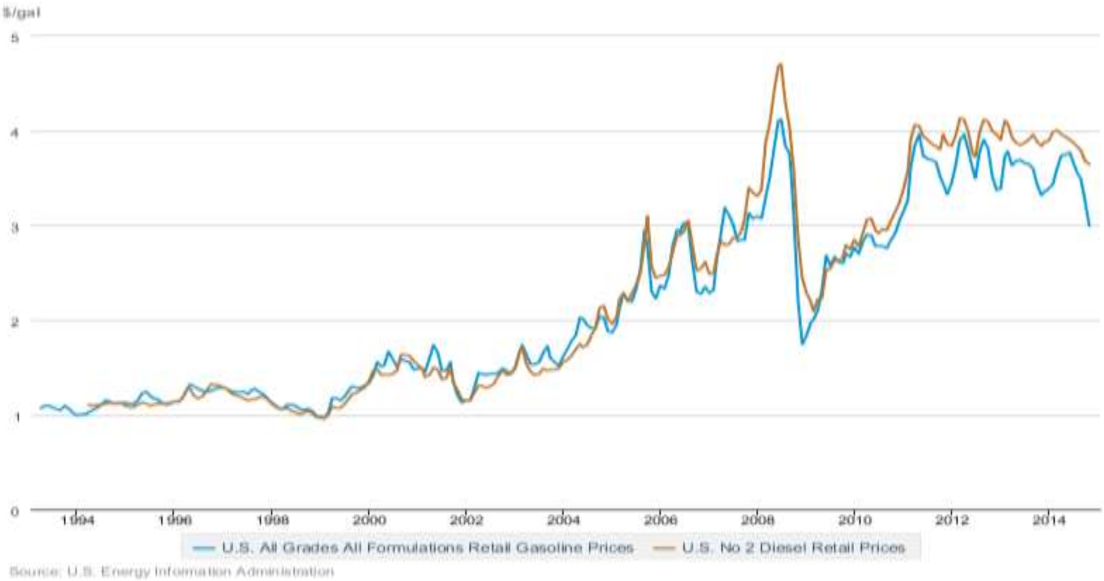

Figure 29. Price Ranges for retail gasoline prices and diesel prices.[85]

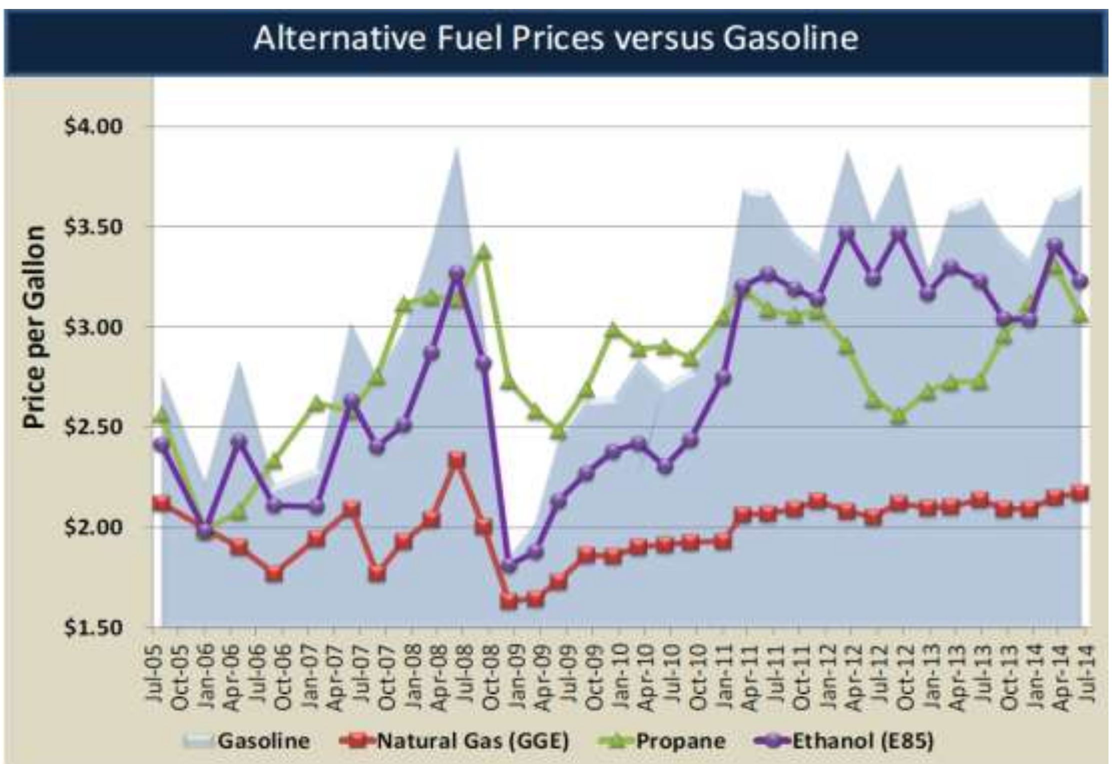

Figure 30. Historical price of alternative fuel and gasoline.[86]

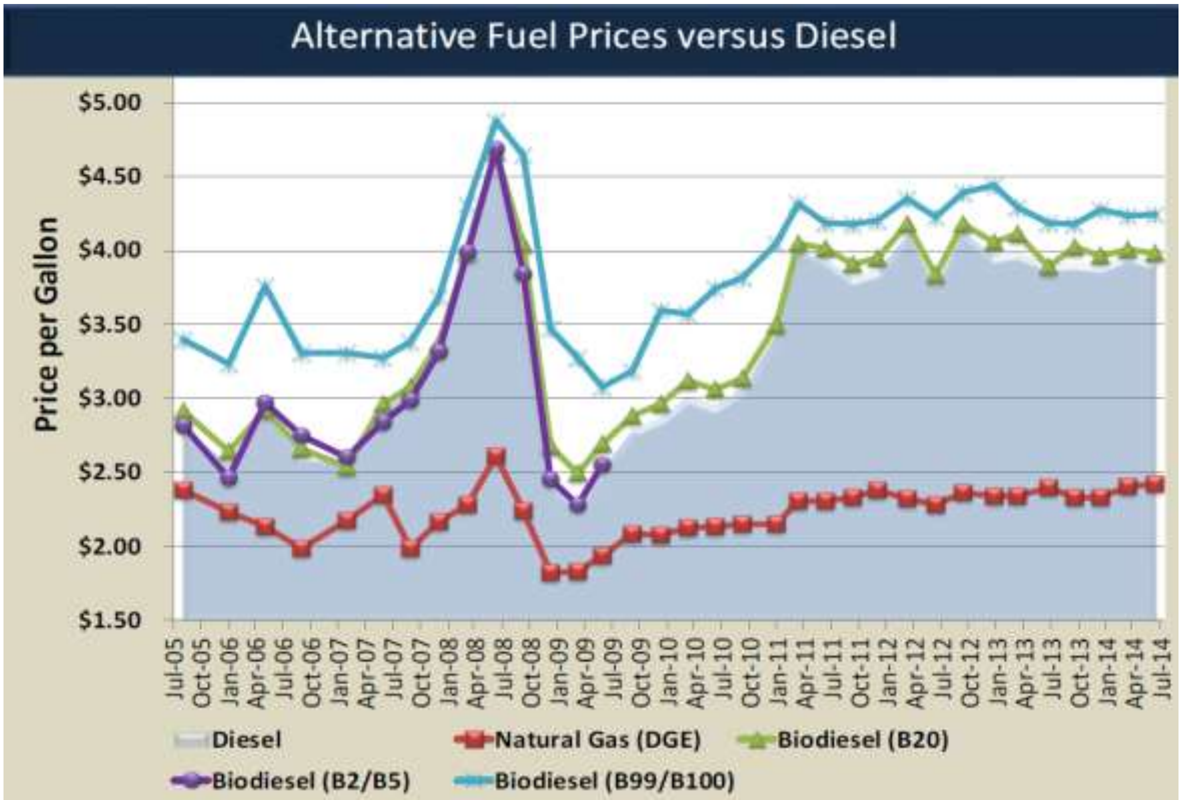

Figure 31. Historical price of diesel and alternative fuel. [87]

5. BIOMASS IMPORT AND EXPORT

5.1 Fuel ethanol

Ramping up local production reduced ethanol imports significantly since the high in 2006. Since 2010, U.S. production and consumption of fuel ethanol has been relatively steady (Figure 32, Table 14 Appendix). The main trade partners of the U.S. with respect to fuel ethanol are Brazil and other South American states. Until 2011, the trade flows were directed by import tariffs to offset the U.S. ethanol tax credit. Current import and export trends are predominantly bilateral trade between Brazil and the U.S.

As of 2004 blenders of transportation fuel received a tax credit for each gallon of ethanol they mix with gasoline. To offset the federal tax credit that applied to ethanol regardless of country of origin, a $0.54 per gallon import tariff was established. Essentially, this tariff reduced direct imports of Brazilian sugarcane based ethanol to the U.S. Brazilian exporters however circumvented the measure by exporting and reprocessing ethanol in Caribbean states, usually converting hydrated ethanol into anhydrous ethanol, for re-export to the U.S. The preferential trade agreement, i.e., the Caribbean Basin Initiative (CBI), enabled exports to avoid the 2.5% import duty and the tariff. The tax credit and the import tariff were abandoned at the end of 2011.

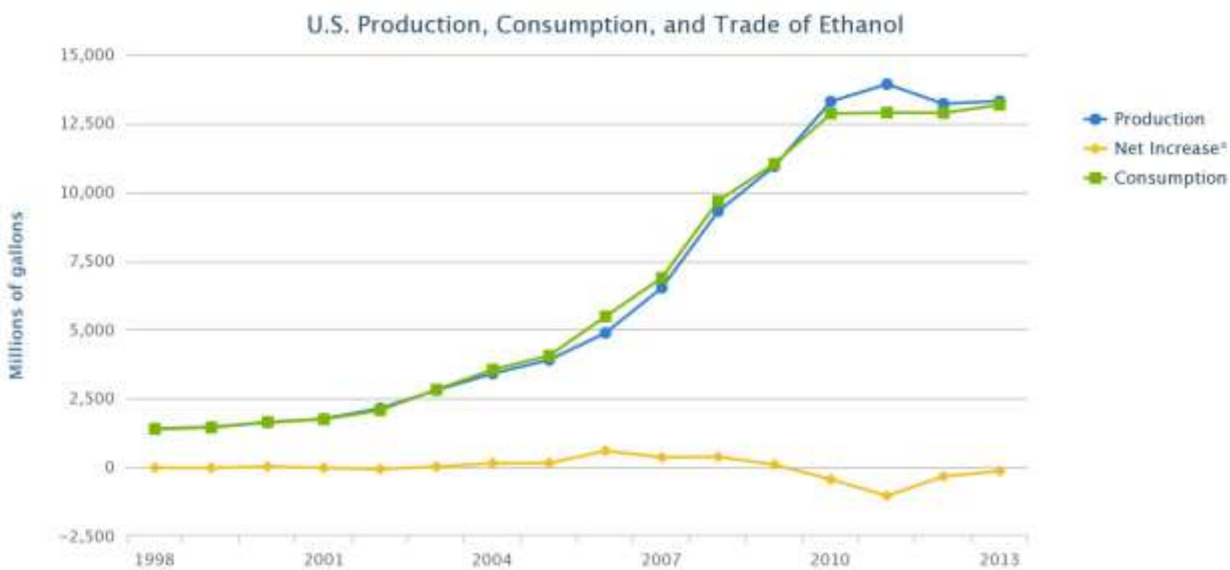

Figure 32. U.S. production, consumption and net trade increase of ethanol. [88]

Different biofuel policies have led to an increasing bilateral trade of physically identical ethanol between the U.S. and Brazil since 2011 (Figure 33). The two-way trade is predominantly driven by the ability to count sugarcane derived fuel ethanol from Brazil as an advanced biofuel under the RFS2 in the U.S. Additional drivers include seasonality, production cost differentials, and U.S. surplus production given the blend wall (see Section 3).

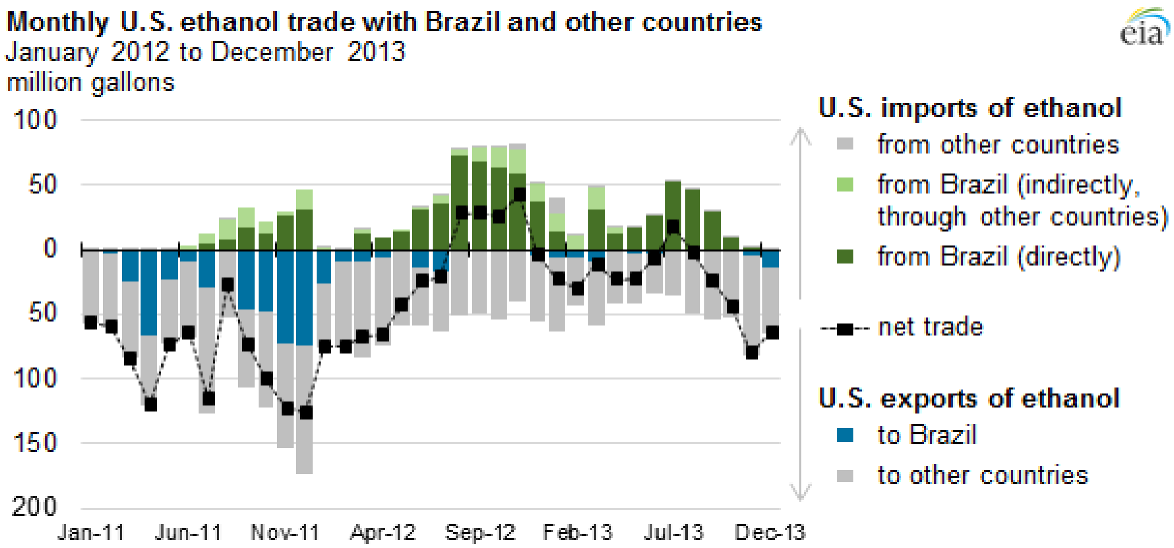

Figure 33. Quarterly bilateral ethanol trade between Brazil and the United States 2011-2013, with and without exports through the Caribbean countries.[89]

5.2 Biodiesel

U.S. biomass-based diesel production has grown again in recent years after the initial drop post 2008 (Figure 34 and Table 15 Appendix). With the implementation of EU import duties, put in place early 2009, U.S. net exports have declined and local consumption has increased.

The U.S. imports two varieties of biomass-based diesel fuel: biodiesel and renewable diesel. Biodiesel refers to fatty acid methyl esters (FAME) produced via transesterification of vegetable oils or animal fats with alcohol. It is commonly blended with fossil diesel in up to 5% or 20% by volume (B5 and B20). Renewable diesel refers to a diesel-like fuel that is compatible with existing infrastructure and in existing engines in any blending proportion. It is produced by refining vegetable oils or animal fats using a hydrotreating process.[90]

Up until 2012, the U.S. was a net exporter of biomass-based diesel. In 2013, total U.S. imports of biomass-based diesel however reached 525 million gallons (compared to 61 million gallons in 2012) (Figure 35). This was stimulated by a domestic growth in biodiesel demand to satisfy renewable fuels targets and by increased access to biodiesel from other countries. [91] The 2013 surge in imports of regular biodiesel (FAME) was primarily out of Argentina. It is estimated that this is a direct result of the EU imposed antidumping duty on Argentinean biodiesel in late 2013. The EU was previously the main destination for most of Argentina's biodiesel exports.

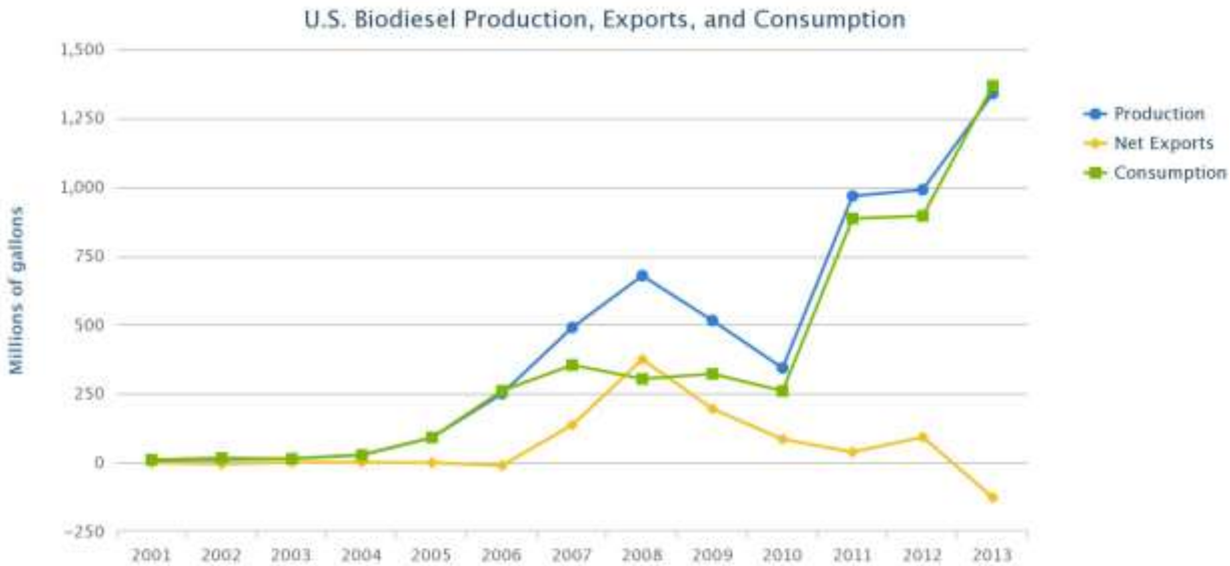

Figure 34. U.S. Biodiesel production, exports, and consumption.[92]

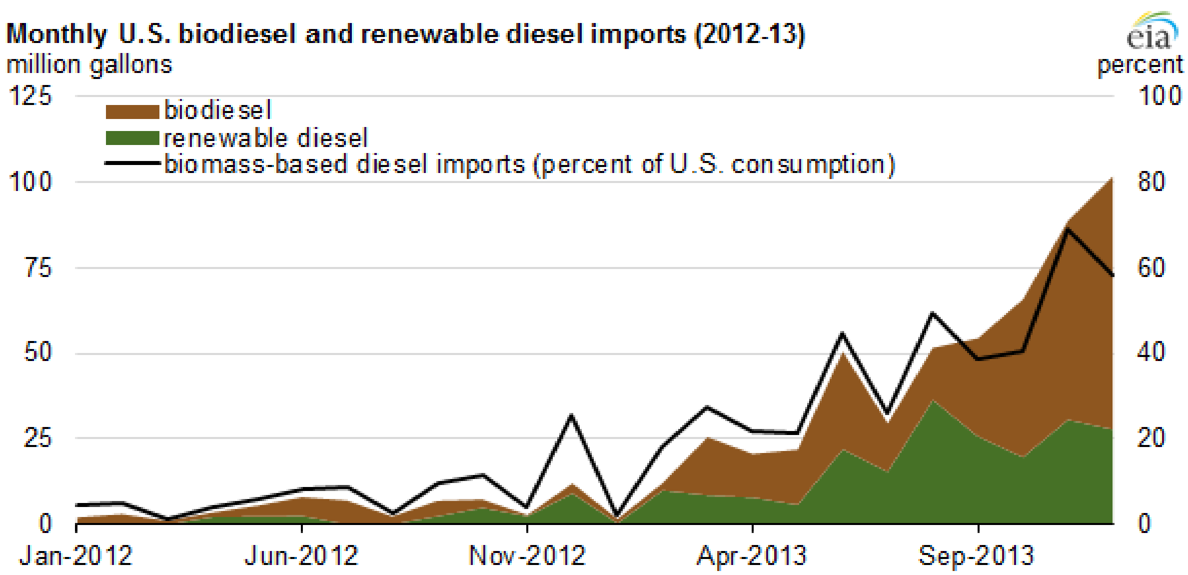

Figure 35. Monthly U.S. biodiesel (FAME) and renewable diesel (hydrotreating) imports.[93]

5.3 Wood pellets

A small wood pellet industry came into existence in the 1930s. Its main growth began in the wake of the energy crisis in the 1970s, with an even greater acceleration of growth in the past decade, driven largely by renewable energy standards and opportunities in export markets. Until 2009/2010, most plants were small, relying on sawmill residue outputs for fiber and thus were typically limited to 100,000 tons or less per year. Post 2010 saw a strong increase in the construction of large-scale plants and production capacity intended for shipment to Europe. Wood pellet export volumes increased from 811,000 short tons in 2010 to 1.6 million short tons in 2012 and doubled over the course of 2013 to reach close to 3.2 million short tons [94] [95] (Figure 36). Almost all exports were destined for Europe, originating to 99% from ports in the southeastern (SE) and lower Mid-Atlantic regions of the country. [96]

Section 2.2.4 details the number, size, and location of pelleting plants across the U.S.

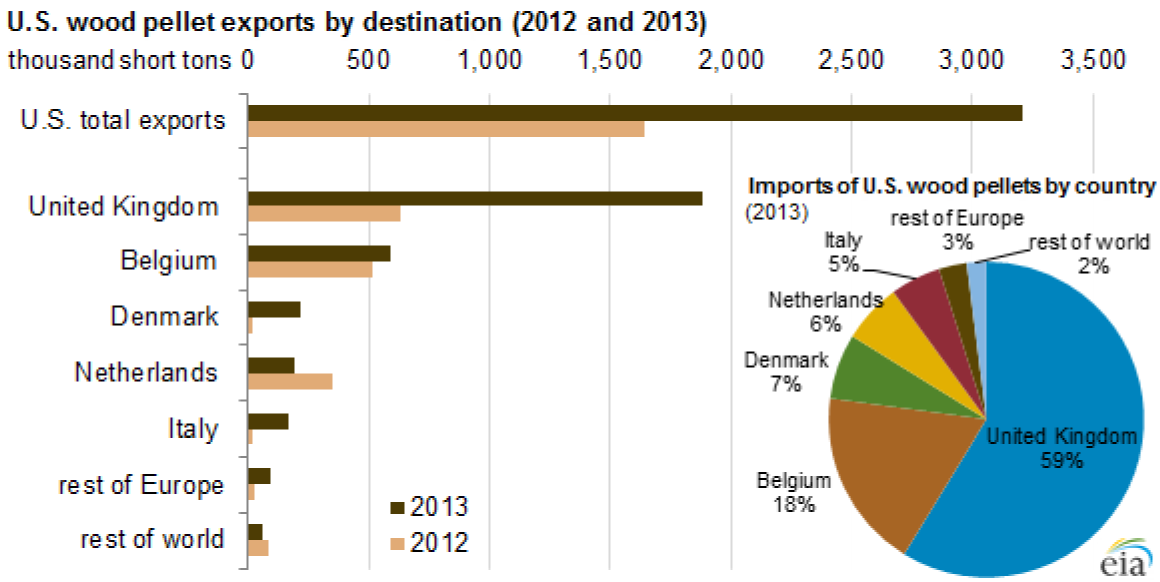

Figure 36. U.S. Biodiesel production, exports, and consumption [97]

6. BARRIERS & OPPORTUNITIES

6.1 General Barriers and Opportunities for Biomass

In addition to the blend wall, which limits the possible biomass-based fuel ethanol volume entering the transport sector, the key barriers for biomass to energy and/or material conversion pathways are the sustainable and cost efficient mobilization of biomass (see below for details) and the competitiveness to fossil fuel-based alternatives. The latter aspect is heavily influences by the recent push for hydro-fracking and shale gas developments across the U.S.

Newly proposed legislation by the EPA to reduce emissions of the power sector probably represents the main opportunity for an increased biomass production and use (see Section 3.1). A co-firing of biomass with coal in the ranges of 5-10% (by energy content) could increase annual biomass consumption by 870-1,740 PJ representing 55-110 million tons of wood pellets annually.

U.S. biomass assessments[98] identify sufficient resources to meet the production targets set forth by the RFS2. Much of that resource however is inaccessible because of unfavorable economics that result from agronomic systems that are not designed for commercial-scale biomass production, material handling and environmental constraints, and limited market access.[99]

The following tables show costs and targets for a modeled scenario (Scenario 1)[100] that are driving current R&D in feedstock supply system design.

Table 10. Biomass Volume and Price Projections through 2030.[101]

Feedstock Category	*Feedstock Resource*	*2013 SOT*	*2017 SOT*	*2022 Projection*	*2030 Projection*
		MM Dry Tons			
Agricultural Residues	Corn stover	73.0	126.5	181.4	209.0
	Wheat straw	15.4	23.7	30.0	39.4
Energy Crops	Herbaceouse	-	12.7	45.1	70.6
	Woody	-	-	11.7	25.8
Forest Residues	Pulpwood	8.9	6.0	13.1	40.1
	Logging residues and fuel treatment	54.4	54.7	58.9	64.0
	Other forestland removals	2.2	1.8	2.4	2.7
	Urban and mill wood wastes	26.1	26.2	28.5	31.5
Totals (MM Dry Tons/Year)		179.9	251.7	371.1	483.0
Average Price to Reactor (2011$/Dry Ton		$102	$80	S80	$80

Legend: MM Dry Tons = Million dry (U.S. short) tons

Table 11. Unit Operation Cost Contribution Estimates (2011$) and Technical Projections for Thermochemical Conversion to Gasoline and Diesel Baseline Process Concept.[102]

(Process concept: wood energy crop, fast pyrolysis, bio-oil upgrading, fuel finishing)

Processing Area Cost Contributions & Key Technical Parameters	*Metric*	*2009 SOT*	*2010 SOT*	*2011 SOT*	*2012 SOT*	*2013 SOT*	*2014 Projected*	*2015 Projected*	*2016 Projected*	*2017 Projected*
Conversion Contribution	$/gal gasoline blendstock	S12.400	$9.22	$7.32	$6.20	$4.51	$4.02	$3.63	$2.96	$2.44
	$/gal diesel blendstock	$13.03	$9.69	$7.69	$6.52	$5.01	$4.46	$4.03	$3.29	$2.07
Conversion Contribution, Combined Blendstock	$/GGE	$12.02	$8.94	$7.10	$6.02	$4.59	$4.09	$3.69	$3.01	$2.47
Programmatic Target	$/GGE	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
Combined fuel selling price	$/GGE	$13.40	$10.27	$8.26	$7.04	$5.60				$3.39
Production gasoline blendstock	mm gallons/yr	30	30	30	30	29	29	29	29	29
Production diesel blendstock	Mm gallons/yr	23	23	23	23	32	32	32	32	32
Yield combined blendstock	GGE/dry U.S. ton	78	78	78	78	87	87	87	87	87
	mmBTU/ddry U.S. ton	9	9	9	9	10	10	10	10	10
Natural Gas Usage	scf/dry U.S. ton	1,115	1,115	1,115	1,115	1,685	1,685	1,685	1,685	1,685
Feedstock										
Total Cost Contribution	$/GGE fuel	$1.38	$1.33	$1.17	$1.03	$1.01				$0.92
Capital Cost Contribution	$/GGE fuel	$0.00	$0.00	$0.00	$0.00	$0.00				$0.00
Operating Cost Contribution	$/GGE fuel	$1.38	$1.33	$1.17	$1.03	$1.01				$0.92
Feedstock Cost Contribution	$/GGE fuel	$106.92	$102.96	$90.57	$79.71	$88.10				$80.00
Feedstock Pyrolysis										
Total Cost Contribution	$/GGE fuel	$0.97	$0.93	$0.91	$0.90	$0.78	$0.78	$0.77	$0.76	$0.76
Capital Cost Contribution	$/GGE fuel	$0.82	$0.79	$0.76	$0.75	$0.66	$0.65	$0.65	$0.65	$0.64
Operating Cost Contribution	$/GGE fuel	$0.15	$0.15	$0.15	$0.15	$0.12	$0.12	$0.12	$0.12	$0.11
Pyrolysis Oil Yield (dry)	Ib organic/lb dry wood	0.60	0.60	0.60	0.60	0.62	0.62	0.62	0.62	$0.62

Legend: GGE = Gallon of Gasoline Equivalent; lb = pound; mm = million

Table 12. Technical Projections for Thermochemical Conversion to Gasoline and Diesel Baseline Process Concept.[103]

Processing Area Cost Contributions & Key Technical Parameters	*Metric*	*2009 SOT*	*2010 SOT*	*2011 SOT*	*2012 SOT*	*2013 SOT*	*2014 Projected*	*2015 Projected*	*2016 Projected*	*2017 Projected*
Upgrading to Stable Oil via Multi-Step Hydroeoxygenation/Hydrocracking										
Total Cost Contribution	$/GGE fuel	10.071.38	7.05	5.23	4.17	2.88	2.39	2.01	1.35	0.95
Capital Cost Contribution	$/GGE fuel	0.71	0.68	0.66	0.65	0.59	0.57	0.51	0.45	0.42
Operating Cost Contribution	$/GGE fuel	9.36	6.37	4.57	3.52	2.29	1.82	1.50	0.90	0.52
Annual Upgrading Catalyst	WHSV.[2] number of reactors, catalyst replacement rate, and $/lb	512	344	243	184	130	100	80	43	19.4
Upgrading Oil Carbon Efficiency on Pyrolysis Oil	wt%	65%	65%	65%	65%	68%	68%	68%	68%	68%
Fuel Finishing to Gasoline and Diesel via Hydrocracking and Distillation										
Total Cost Contribution	$/GGE fuel	0.25	0.24	0.24	0.24	0.25	0.25	0.24	0.24	0.14
Capital Cost Contribution	$/GGE fuel	0.16	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.07
Operating Cost Contribution	$/GGE fuel	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.07
Balance of Plant										
Total Cost Contribution	$/GGE fuel	0.74	0.72	0.71	0.71	0.68	0.68	0.67	0.66	0.63
Capital Cost Contribution	$/GGE fuel	0.36	0.34	0.33	0.33	0.29	0.29	0.29	0.29	0.29
Operating Cost Contribution	$/GGE fuel	0.38	0.38	0.38	0.38	0.39	0.38	0.38	0.37	0.34
Models: Case References		2009 SOT 090913	2010 SOT 090913	2011 SOT 090913	2012 SOT 090913	2013 SOT 122013	2014 P 122013	2015 P 123013	2016 P 123013	2017 P 093013

Table 13. Production Cost Breakdown by Supply Chain Element.[104]

Supply Chain Areas	*Units*	*2009 Wood Pyrolysis to Hydrocarbon Fuel Design Report*	*2012 MYPP 2017 Goals/Targets*	*2014 MYPP 2017 Goals/Targets*
Year $	Year	2007	2011	2011
Feedstock Production				
Grower Payment	$/DT	$22.60	$26.25	$21.90
Feedstock Logistics				
Harvest and Collection	$/DT	$18.75	$19.53	$10.47
Landing Preprocessing	$/DT	$11.42	$11.73	$10.24
Transportation and Handling	$/DT	$8.95	$6.37	$7.52
Plant Receiving and In-Feed	$/DT	$17.65	$16.88	$29.87
Logistics Subtotal	$/DT	$56.77	$54.50	$58.10
Feedstock Total	$/DT	$79.37	$80.75	$80.00
Fuel Yield	(Gal Gasoline + Diesel) DT	106	106	84 (87 DT/GGE)
Feedstock Production				
Grower Payment	$/gal total fuel	$0.21	$0.25	$0.26
Feedstock Logistics				
Harvest and Collection	$/gal total fuel	$0.18	$0.18	$0.12
Landing Preprocessing	$/gal total fuel	$0.11	$0.11	$0.12
Transportation and Handling	$/gal total fuel	$0.08	$0.06	$0.09
Plant Receiving and In-Feed	$/gal total fuel	$0.17	$0.16	$0.36
Logistics Subtotal	$/gal total fuel	$0.54	$0.51	$0.69
Feedstock Total	$/gal total fuel	$0.75	$0.76	$0.94 ($0.92/GGE)
Biomass Conversion				
Feedstock Drying, Sizing, Fast Pyrolysis	$/gal total fuel	$0.34	$0.39	$0.76/GGE
Upgrading to Stable Oil	$/gal total fuel	$0.47	$0.55	$0.95/GGE
Fuel Finishing to Gas and Diesel	$/gal total fuel	$0.11	$0.13	$0.14/GGE
Balance of Plant	$/gal total fuel	$0.65	$0.75	$0.63/GGE
Conversion Total	$/gal total fuel	$1.57	$1.83	$2.47/GGE
Fuel Production Total	$/gal total fuel	$2.32	$2.83	$3.39/GGE

6.2 Barriers and Opportunities for International Biomass Trade

Other countries that produce ethanol and import it into the United States may be subject to import tariffs or duties, depending on trade agreements. A general *ad valorem* tax of 2.5% is assessed on imports.

Two other trade policies affect imports. Some countries can import ethanol without a tariff as long as they import less than the quota set by the U.S. International Trade Commission each year. In addition, a tax of $.1427 per liter, or $.54 per gallon, is assessed on imports that are not exempt from the tariff or that exceed the limits allowed by other countries. Brazil, a large producer and exporter of ethanol, is subject to the tariff, thus the tariff is frequently called the Brazilian ethanol tariff.[105,106] The U.S. International Trade Commission has estimated that these assessments amounted to approximately $252.7 million in 2006.

However, some imported ethanol from Caribbean Basin Initiative (CBI) countries can enter the United States without paying duties, even if the ethanol was actually produced in a non-CBI country. Ethanol can be dehydrated in a CBI country and then shipped to the United States to avoid the duty.[107] In addition, current law allows duties that are paid when ethanol is imported to be refunded if a related product (e.g., jet fuel) is exported.[108] This is called "duty drawback." There are no data regarding the amounts subject to this drawback, but there are tax proposals at the federal level to repeal the exemption for ethanol-related export refunds.[109]

Almost every major oil-consuming country around the globe has projections for future ethanol consumption. This projected consumption (Figure 37), coupled with an increasing demand for a gasoline-type fuel, the international market for biofuels is expected to expand greatly over the next few decades. The major players in international trade of ethanol to meet these demands are the United States (U.S.), the European Union (EU), Japan, China, Brazil, and the "Rest of the World-Brazil" (ROW-BR).[110] While Brazil is not a one of the leading consumers of gasoline, it will be a major ethanol producer. Other countries that have similar production capacities (ROW-BR) will also have a significant role in biomass trade (Figure 37, Figure 38, and Figure 39).

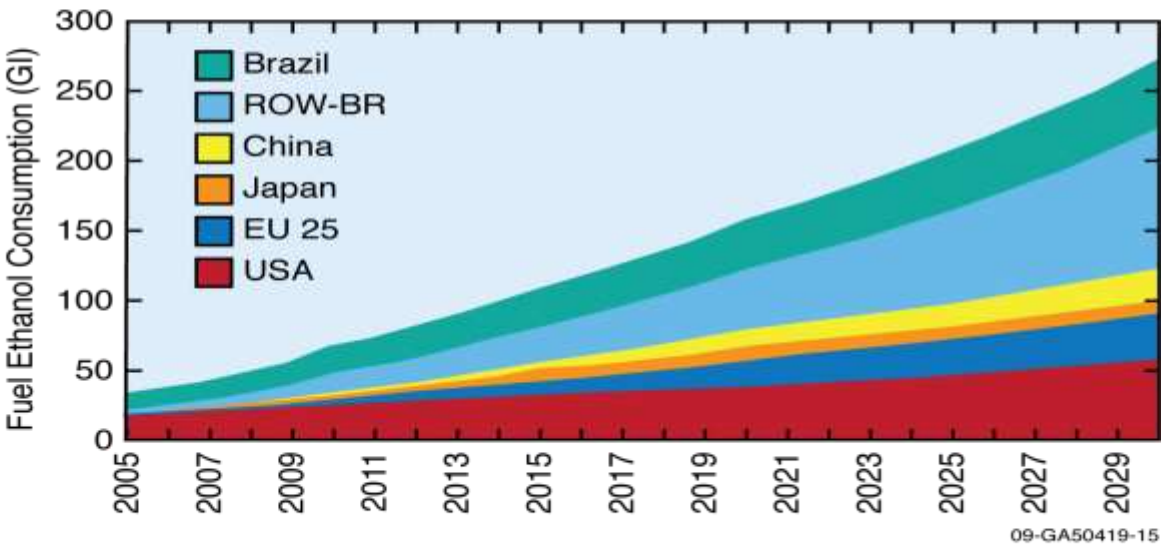

Figure 37. Estimated consumption of fuel ethanol from 2006 to 2030 (Scenario 1).[111] (Assumes ethanol displaces 10% of global gasoline production by 2030.)

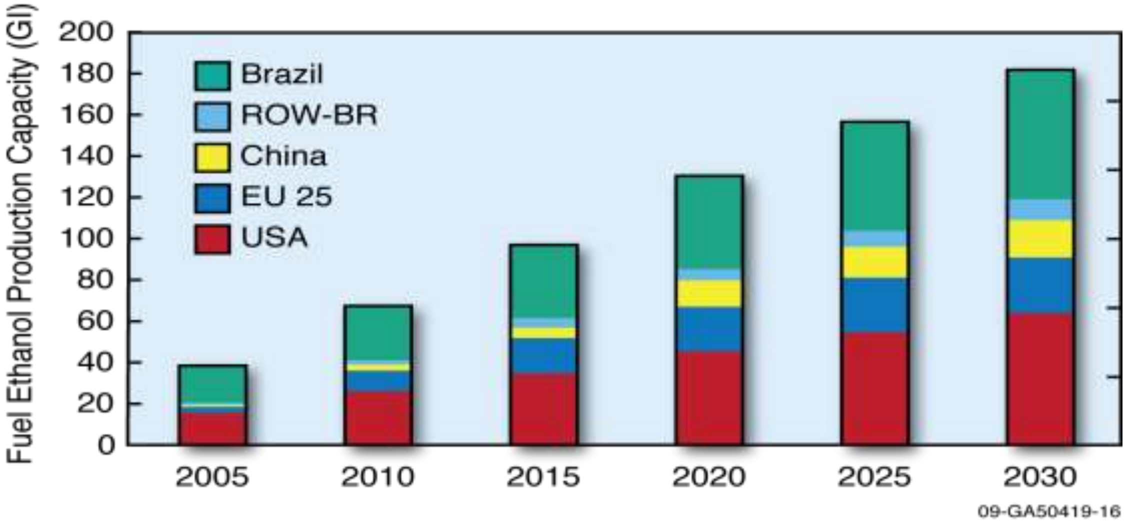

Figure 38. Estimated fuel ethanol capacity of production (conventional technologies).[112]

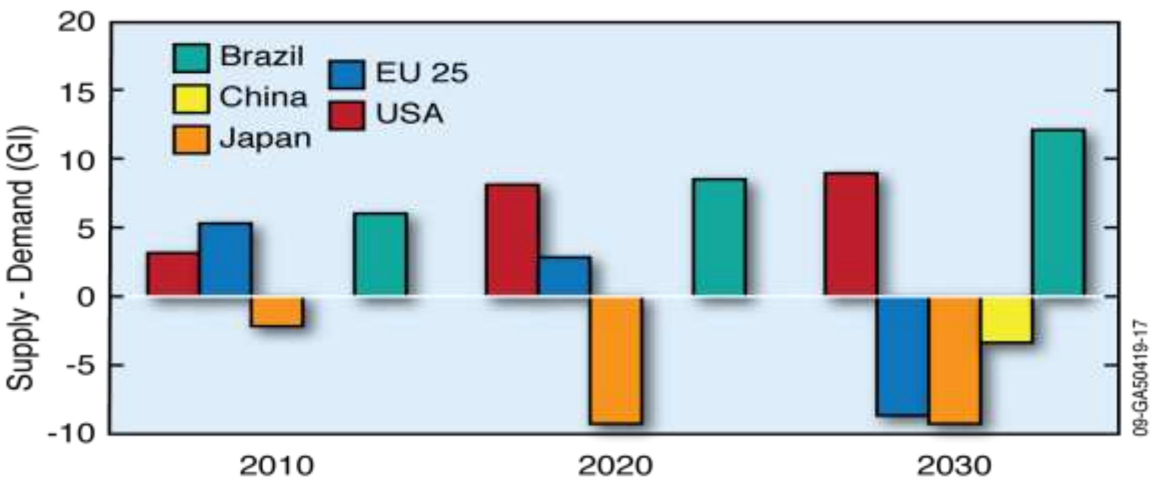

Figure 39. Estimated balance between potential supply and demand of fuel ethanol (Scenario 1 for U.S. [GI]).[113]

In considering barriers and opportunities that will impact U.S. participation in international biomass trade, it is worthwhile to emphasize relevant issues identified by earlier IEA Bioenergy Task 40 efforts and include recommendations for addressing them.[114]

6.2.1 Economic

One of the principal barriers for the use of biomass energy in general is the competition with fossil fuel on a direct production cost basis (excluding externalities). The limiting factor in biomass supply often is not the amount available, but rather the investment required to gather and pre-treat or densify the biomass to make transportation economical. Capital for investment in these regions may be limited, or investment may be deemed too risky until markets show some long-term stability and growth. Another limiting factor is the lack of long-term, consistent federal policies. Lenders will not consider federal incentives and subsidies as income in the consideration of loan applications if it is perceived that federal (and state) policies and financial support mechanisms are uncertain. In summary, while the strong increase in overall biomass demand is a positive development in itself, the market is hampered at this moment by many factors such as its dependence on (short-term) policy support measures and typical problems of emerging markets such as small bilateral volumes, lacking market transparency, etc.

6.2.2 Technical

A general problem of some biomass types is variety in physical properties (e.g., low density and bulky nature) and chemical properties, such as high ash, moisture, nitrogen, sulfur, or chlorine content. These properties make it difficult and expensive to transport and often unsuitable for direct use, say, for co-firing with coal or natural gas power plants. Power producers are generally reluctant to experiment with new biomass fuel streams (e.g., bagasse or rice husks). As shipments within these streams often fail to meet the required physical and chemical properties, power producers are afraid to damage their installations (designed for fossil fuels), especially the boilers.

The success of the biorefinery business model depends on advances in integrated conversion process technologies. Integration of total process – from feedstock production to end-product distribution is could be challenging, as it impacts both performance and profitability.

Pioneer biorefineries will require adopting a variety of new technologies. This variety of new technologies implemented in pilot- and demonstration-scale could be a strong predictor of future commercial performance shortfalls. Heat and mass balances, along with the implications, are not likely to be well-understood in new technologies. In addition, start-up and commissioning the equipment may take longer than expected due to issues that were not observed at smaller scales, including buildup of impurities in process recycle streams, degradation of chemical or catalyst performance and abrasion, fouling, and corrosion of plant equipment. The current level of understanding regarding fuels chemistry is insufficient for optimization, scale-up, and commercialization. To better understand how fuel chemistry affects commercial viability, rigorous computational fluid dynamic models are needed. Engineering modeling tools are also needed to address heat integration issues.

6.2.3 Logistical

Logistical barrier are tied to feedstock harvesting, collection, storage and distribution. Current crop harvesting machinery is unable to selectively harvest preferred components of cellulosic biomass while maintaining acceptable levels of soil carbon and minimizing erosion. Actively managing biomass variability imposes additional functional requirements on biomass harvesting equipment. A physiological variation in biomass arises from differences in genetics, degree of crop maturity, geographical location, climatic events, and harvest methods. This variability presents significant cost and performance risks for bioenergy systems. Currently, processing standards and specifications for cellulosic feedstocks are not as well-developed as for mature commodities. Biomass that is stored with high moisture content or exposed to moisture during storage is susceptible to spoilage, rotting, spontaneous combustion, and odor problems. Appropriate storage methods and strategies are needed to better define storage requirements to preserve the volume and quality of harvested biomass over time and maintain its conversion yield. Raw herbaceous biomass is costly to collect, handle, and transport because of its low density and fibrous nature. Existing conventional, bale-based handling equipment and facilities cannot cost-effectively deliver and store high volumes of biomass, even with improved handling techniques. Current handling and transportation systems designed for moving woodchips can be inefficient for bioenergy processes due to the costs and challenges of transporting, storing, and drying high-moisture biomass. The infrastructure for feedstock logistics has not been defined for the potential variety of locations, climates, feedstocks, storage methods, processing alternatives, etc., which will occur at a national scale.

When setting up biomass fuel supply chains, for large-scale biomass systems, logistics are a pivotal part in the system. Various studies have shown that long-distance international transport by ship is feasible in terms of energy use and transportation costs, but availability of suitable vessels and meteorological conditions (e.g., winter time in Scandinavia and Russia) need to be considered. However, local transportation by truck (both in biomass exporting and importing countries) may be a high-cost factor, which can influence the overall energy balance and total biomass costs.

6.2.4 International

As with other traded goods, several forms of biomass can face technical trade barriers. As some biomass streams have only recently been traded, so far no technical specifications for biomass and no specific biomass import regulations exist. This can be a major hindrance to trading. For example, in the EU, most residues containing traces of starches are considered potential animal fodder, and thus it is subject to EU import levies.

A major constraint is that countries with large markets (the United States, Japan, and the EU) are completely or partially closed due to trade barriers. The United States applies *ad valorem* duties of 2.5% for imports from most-favored-nations (MFN) and 20% for imports from other countries. Japan applies *ad valorem* duties of 27% (MFN treatment). At present, these duties represent a significant barrier to trade, influencing the competitiveness of foreign imports.

Other international barriers include import transportation tariffs and risk of pathogens or pests in bioproducts.

6.2.5 Ecological

Large-scale biomass-dedicated energy plantations may in principle pose various ecological and environmental issues that cannot be ignored (e.g., monocultures and associated (potential) loss of biodiversity, soil erosion, fresh water use, nutrient leaching, pollution from chemicals).

6.2.6 Market barrier

Various types of biomass can be used for end uses other than energy (i.e., as raw material for the pulp and paper industry, as raw material for the chemical industry [e.g., tall oil or ethanol], as animal fodder [e.g., straw], or for human consumption [e.g., ethanol or palm oil]). This competition can be directly for biomass, but is also often focused on land availability.

An overarching market barrier for biomass technologies is the inability to compete, with established fossil energy supplies and supporting facilities and infrastructure. Reductions in production costs along the entire biomass supply chain—including feedstock supply, conversion processes, and product distribution—are necessary to make advanced biofuels, bioproducts, and biopower competitive with petroleum-derived analogs.

The lack of local, state, and federal regulations, as well as inconsistency among existing regulations, create barrier in developing biomass market. The long lead times associated with developing and understanding new and revised regulations for technology can delay or stifle commercialization and full market deployment. Consistent standards and sampling methods are lacking for feedstock supply and infrastructure, as well as for biofuel and other bioproducts.

6.2.7 Legal

Before large-scale international trade of bioenergy can be implemented, clear rules and standards need to be established, such as who is entitled to the CO_2 credits. Another related issue concerns the methodology that should be used to evaluate the avoided emissions throughout the fuel life cycle.

6.2.8 Information

The benefits of sustainable biomass energy in general, and specifically the need for international biomass trade, are still largely unknown to many stakeholders such as industrial parties, policy makers, non-governmental organizations, and the general public. More active dissemination of information by the IEA Bioenergy Program, various United Nation institutions, national governments, and other organizations is required.

7. APPENDIX – TRADE BALANCES

Table 14. U.S. fuel ethanol supply and trade balance (thousand gallons).[115]

	Supply				*Disappearance*			
	Beginning stocks	Production	Imports	Total	Domestic	Export	Total	**Ending stocks**
2001	142,800	1,765,176	13,230	1,921,206	NA	NA	1,740,690	180,516
2002	180,516	2,140,152	12,852	2,333,520	NA	NA	2,073,120	260,400
2003	260,400	2,804,424	12,264	3,077,088	NA	NA	2,826,012	251,076
2004	251,076	3,404,436	148,764	3,804,276	NA	NA	3,552,192	252,084
2005	252,084	3,904,362	135,828	4,292,274	NA	NA	4,058,628	233,646
2006	233,646	4,884,348	731,136	5,849,130	NA	NA	5,481,210	367,920
2007	367,920	6,521,046	439,194	7,328,160	NA	NA	6,885,690	442,470
2008	442,470	9,308,754	529,620	10,280,844	9,580,715	102,637	9,683,352	597,492
2009	597,492	10,937,808	198,240	11,733,540	10,978,206	58,386	11,036,592	696,948
2010	696,948	13,297,914	15,666	14,010,528	12,845,406	398,580	13,243,986	766,542
2011	766,542	13,929,132	171,864	14,867,538	12,906,348	1,195,194	14,101,542	765,996
2012	765,996	13,217,988	442,302	14,426,286	12,830,034	741,552	13,571,586	854,700
2013	854,700	13,312,488	304,836	14,472,024	13,053,516	728,910	13,782,426	689,598

Table 15. U.S. biodiesel supply and trade balance (thousand gallons).[116]

	Supply				*Disappearance*	
	Beginning stocks	Production	Imports	Total	Total	**Ending stocks**
2001	NA	8,577	3,288	11,865	10,213	NA
2002	NA	10,484	8,018	18,502	16,168	NA
2003	NA	14,211	3,933	18,144	13,533	NA
2004	NA	27,982	4,085	32,067	26,878	NA
2005	NA	90,787	8,682	99,469	90,827	NA
2006	NA	250,439	44,906	295,345	260,584	NA
2007	NA	489,825	140,366	630,191	358,156	NA
2008	NA	678,106	315,067	993,173	315,796	NA
2009	NA	515,805	77,431	593,236	563,374	29,862
2010	29,862	343,445	22,912	396,219	367,995	28,224
2011	28,224	967,481	36,174	1,031,879	947,391	84,488
2012	84,488	990,712	35,826	1,111,026	1,023,525	87,501
2013	87,501	1,339,243	314,874	1,741,618	1,552,222	189,396

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