BIOMASS RENEWABLE ENERGY

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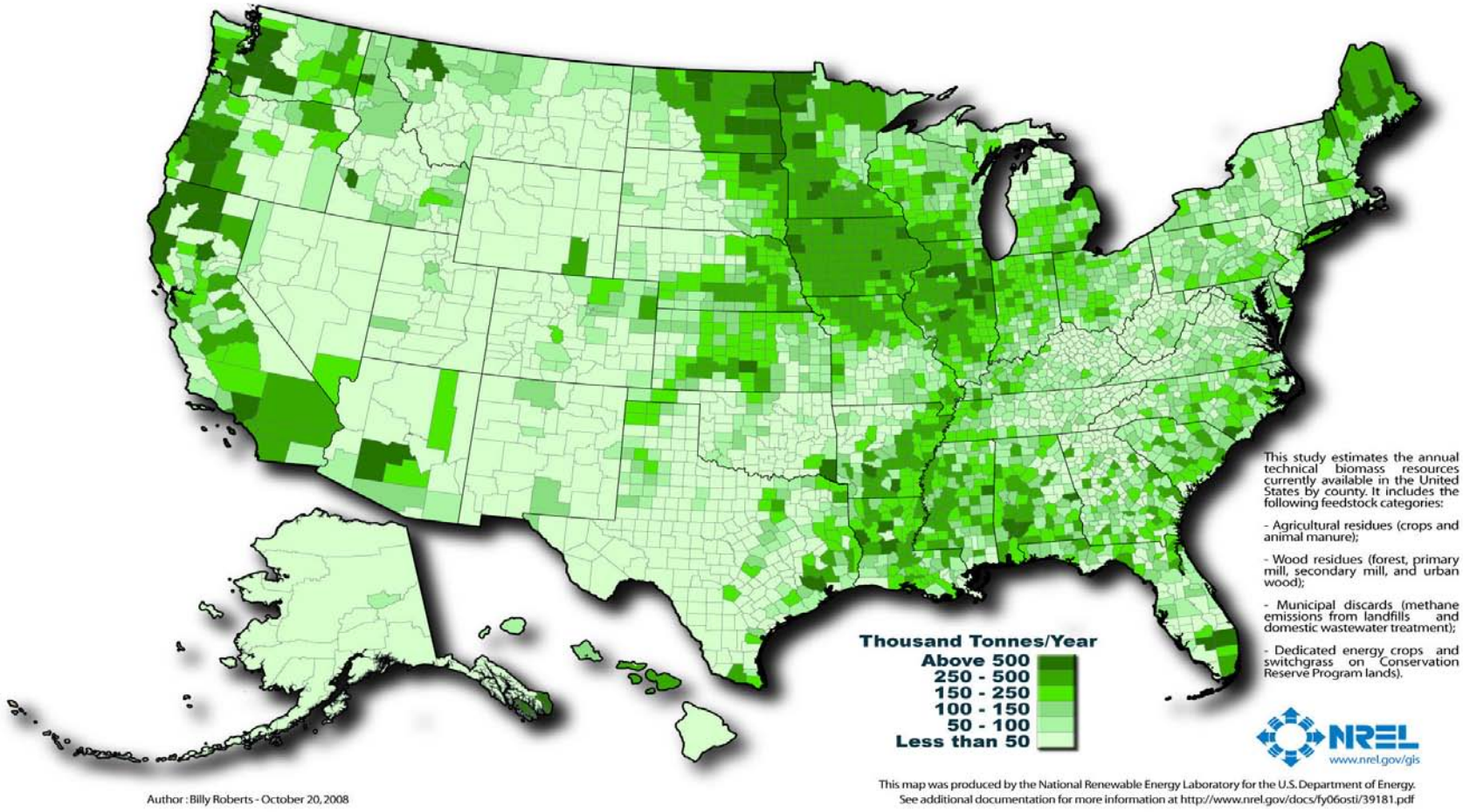
Biomass Resources

- Organic material from:
  - Agricultural and livestock waste, crop and forest byproducts & residues
    - Dedicated crops (e.g., corn, sugarcane, etc.)
    - Municipal solid waste
  - Methane recovery – methane gas is recovered from a landfill, or through anaerobic digestion (e.g., from sewage treatment plants) and then used to produce electricity either directly on-site or the methane is put into a gas pipeline for use at another site.

U.S. Biomass Resource



Biofuels

- "Biofuels" are transportation fuels like **ethanol** and **biodiesel** that are made from biomass materials. These fuels are usually blended with the petroleum fuels — gasoline and diesel fuel, but they can also be used on their own.

What Is Ethanol?

Ethanol is an alcohol fuel made from the sugars found in grains, such as:

- Corn
- Sorghum
- Barley

Other sources of sugars to produce ethanol include:

- Potato skins
- Rice
- Sugar cane
- Sugar beets
- Yard clippings
- Bark
- Switchgrass

Use of Ethanol

- Nearly all gasoline sold now in the U.S. contains some ethanol. About 99% of the fuel ethanol consumed in the U.S. is added to gasoline in mixtures of up to 10% ethanol and 90% gasoline.
- Ethanol cannot be transported in existing pipeline system. It is trucked.
- Ethanol cannot be processed in oil refineries.

US Ethanol Production

- As of October 2011, the United States had the capacity to produce 14.7 million gallons of ethanol, operating refineries producing **14.2 million gallons of ethanol per year,** and had construction or expansion plans for an additional 271 million (0.3 billion) gallons. There were 209 refineries.

Location of Ethanol Producers in US – 95% of Ethanol Production from Corn (Red – Existing, Yellow – Wet Mills, Blue – Under Construction)

Ethanol Production Site Issues

- Minimally 30 to 40 acres in a rural area with:
  - Low cost feedstock (typically corn)
  - Good rail access
  - Good road access
  - Adequate utilities at reasonable cost
  - Close proximity to co-product markets
  - Access to ethanol markets
  - Access to labor

Ethanol Exports

- **Exports of Ethanol for 2011 Could Total More Than 700 Million Gallons (Compared to 400 Million in 2010)**
- Through the first two months of 2011, ethanol exports were 116.9 million gallons. If that pace is maintained all year, exports for 2011 could total more than 700 million gallons (compared to 400 million in 2010).

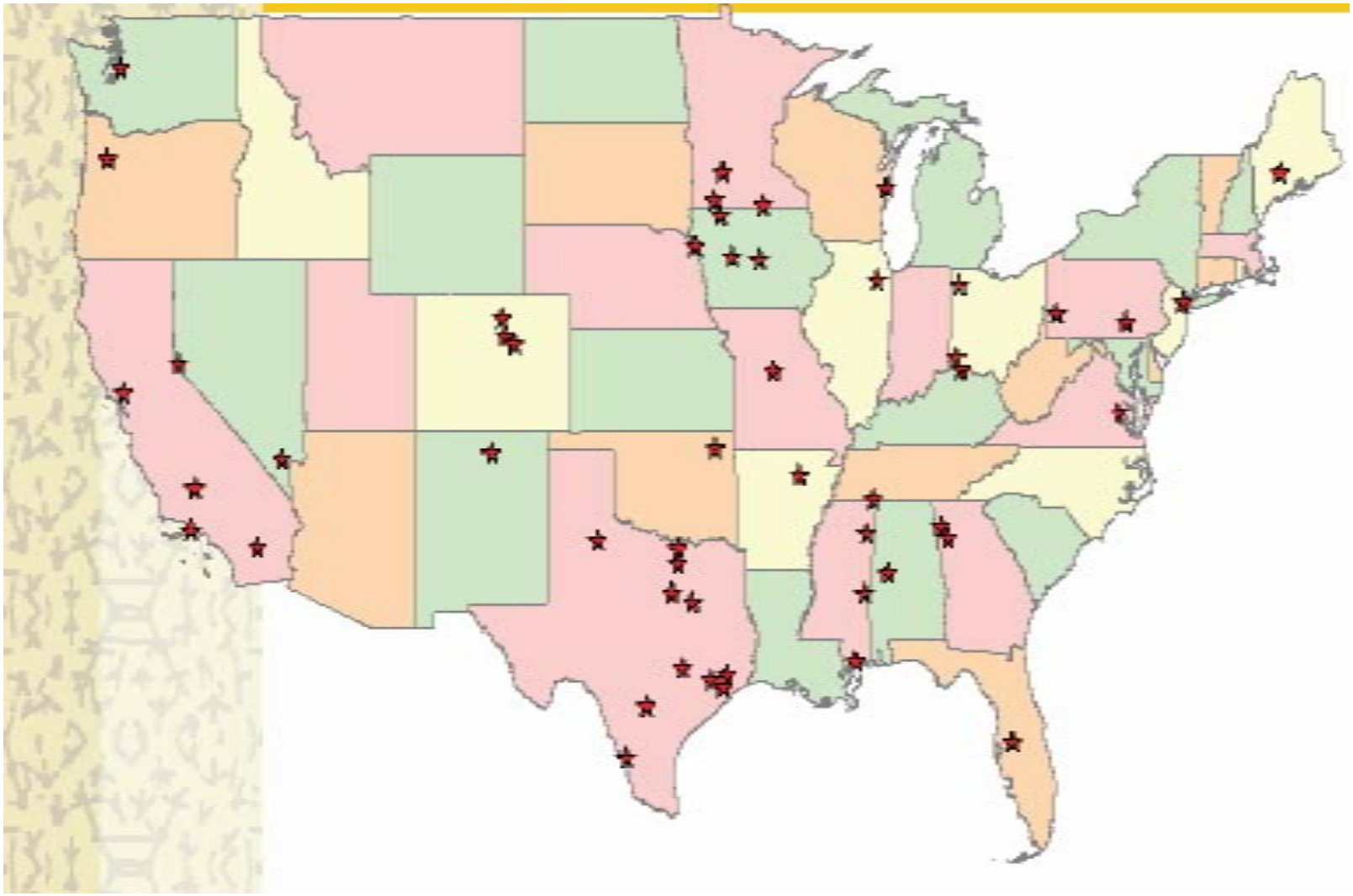
Colorado Ethanol Plants

- Sterling, CO (Sterling Ethanol LLC – 42 million gallons)
- Windsor, CO (Front Range Energy LLC – 40 million gallons)
- Yuma, CO (Yuma Ethanol – 40 million gallons)
- Denver, CO (Merrick & Company – 3 million gallons)

What Is Biodiesel?

- Biodiesel is a fuel made from vegetable oils, fats or greases — such as recycled restaurant grease. Biodiesel fuel can be used in diesel engines without changing them. It is the fastest growing alternative fuel in the United States. Biodiesel, a renewable fuel, is safe, biodegradable, and produces lower levels of most air pollutants than petroleum-based products.

Biodiesel Producers, 2006



Key Us Biofuels Policies and Requirements

- **Military Leadership in Biofuels Policy Demand**
- Department of Defense military leadership; 25% of its electricity will come from renewable energy by 2025; **by 2016 all military fuel will be 50% biofuels**.

Key Us Biofuels Policies and Requirements

- EPA - under the Energy Independence and Security Act of 2007, volume requirements of renewable fuel to be blended into transportation fuels prescribed in RFS2 are **36 billion gallons per year by 2022**, compared to 1 billion gallons per year currently. According to *U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030*, a report released by Bio-Era Research Chemicals Ltd. in 2009, **achieving the 2022 target will require nearly $80 billion in capital investment over the next 10 years**.

Biofuels IPOs in 2010

- Initial public offerings in advanced biofuels over the past year included Amyris, Solazyme and Codexis.

Key Colorado Biofuel Companies

- **ClearFuels-Rentech**

  Operates a pilot-scale facility in Commerce City, CO, to convert wood waste, agricultural residue, and bagasse—the unused portion of sugarcane-- into renewable diesel and jet fuel.

  John H. Diesch **- Senior Vice President of Operations**
  As Senior Vice President of Operations for Rentech, John Diesch is responsible for plant operations at Rentech Nitrogen Partners, L.P., Rentech's Product Demonstration Unit in Colorado, and any other future synthetic fuels plants developed by the Company..

  Contact: Rentech Energy Technology Center (RETC), Commerce City, CO

  1331 17th St # 720, Denver, CO 80202-1557
  (303) 298-8008

Key Colorado Biofuel Companies

- Biofuel Energy Corp. is a publicly traded company (NASDAQ: BIOF) whose goal is to become one of the leading ethanol producers in North America. Headquartered in Denver, Colorado, the company owns and operates two of the largest dry mill ethanol facilities in the United States. Produce 230 million gallons per year of fuel grade ethanol and 720,000 tons of distillers grains at these facilities and deliver these products to fuel blenders and agricultural users both locally and nationwide. Mark Wong, Chairman

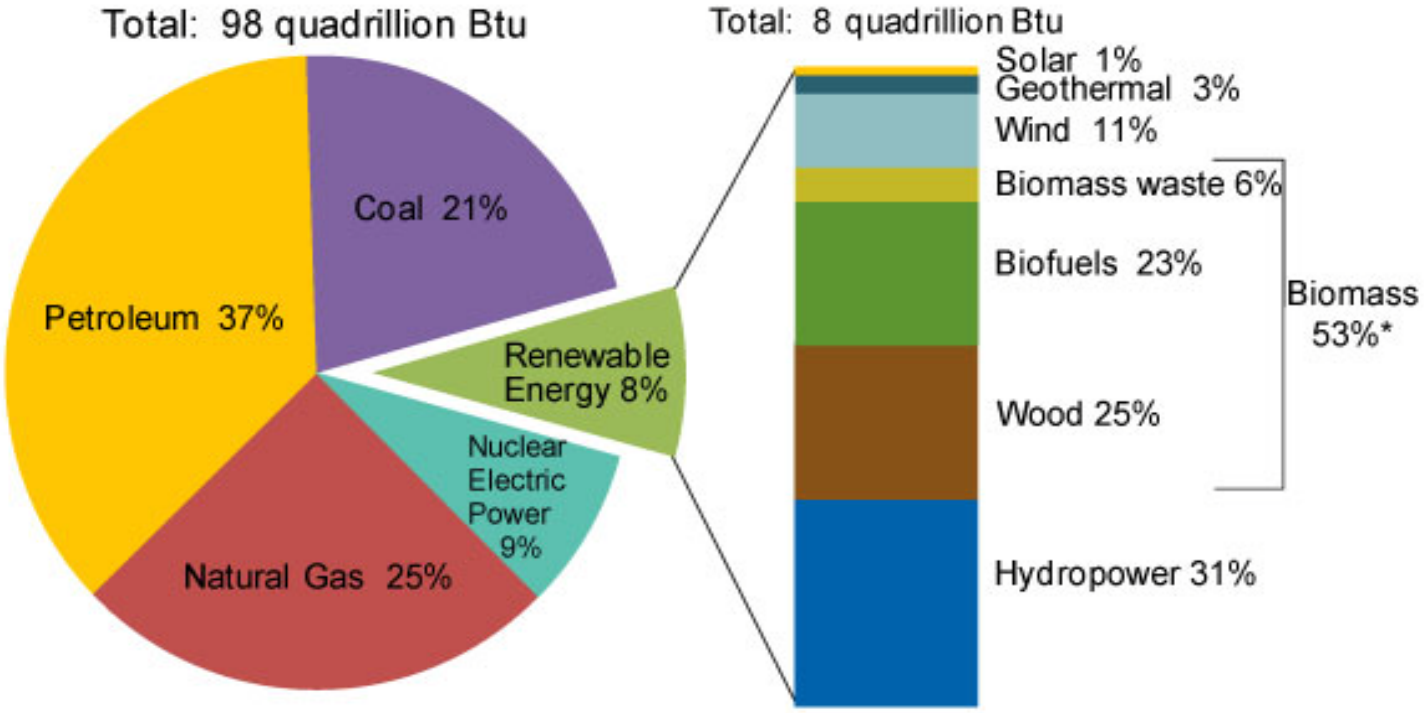
Key Colorado Biofuel Companies

- Solix Biofuels
- A company working with Colorado State University to mass-produce biodiesel from algae
- Large scale cultivation of algae in southwest CO

CO Biodiesel Grant Awards, 2011

- Boulder County was awarded $24,500 to develop a local biodiesel supply chain in the county, and Yuma Conservation District was awarded $20,870 to assess the feasibility of a northeastern Colorado biodiesel facility. RMSE Biodiesel of Morgan County was awarded $100,000 to assist in the development of a vertically-integrated biodiesel production facility. SE Colorado RC&D of Otero County was awarded $49,186 for engine performance testing, fuels evaluation and enterprise budgeting for diesel biofuel.

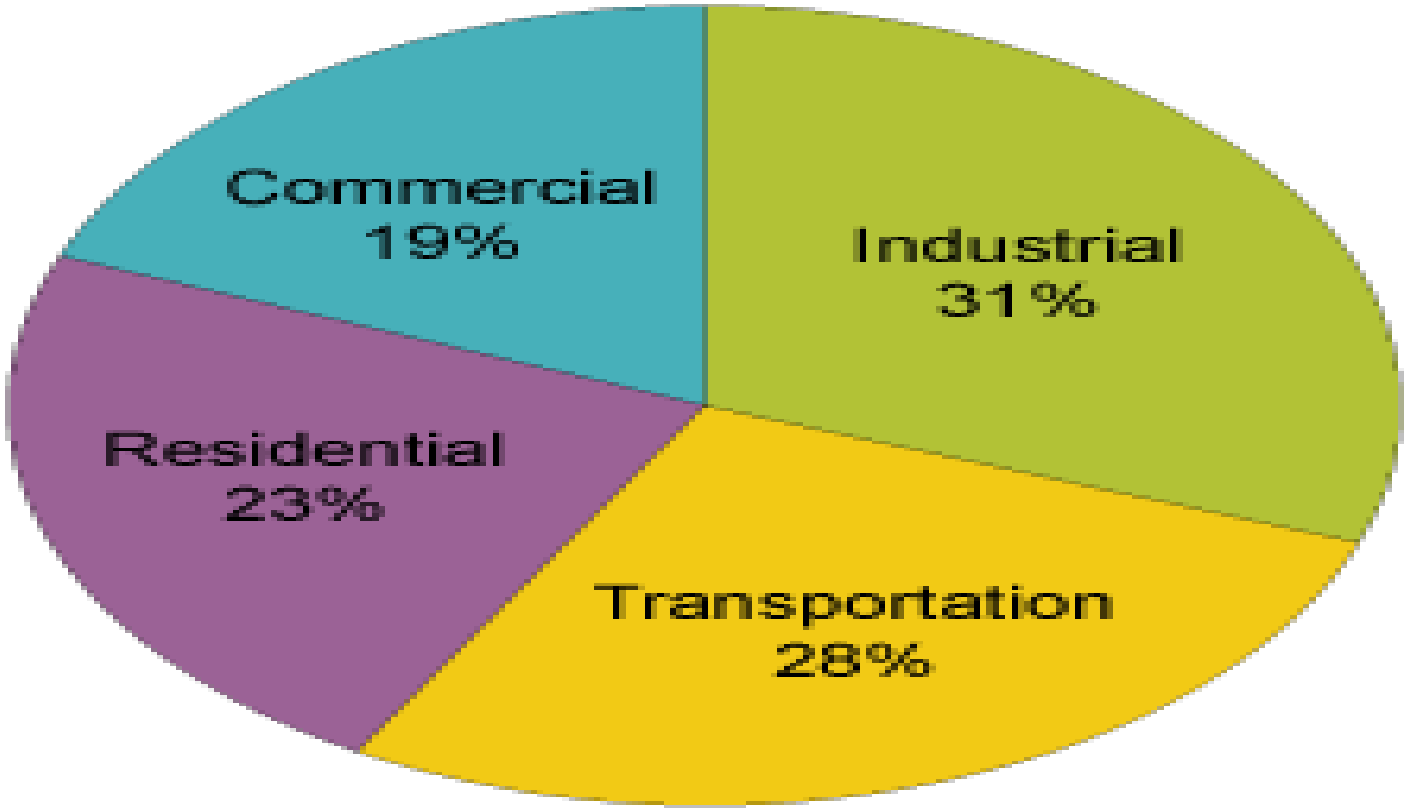
U.S. Primary Energy Consumption by Energy Source, 2010



Note: Sum of biomass components does not equal 53% due to independent rounding.

Source: U.S. Energy Information Administration, *Annual Energy Review 2010.*

Share of Energy Consumed by Major Sectors of the Economy, 2010



Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, and *Monthly Energy Review (June 2011)*, preliminary 2010 data.

Renewable Share of Total Energy Use Forecast, 14% in 2035

- Renewable share of total energy use forecast to increase from 8% in 2008 to 14% in 2035.

Levelized Costs of Biomass – 2016, $112.5 mwh

Table 1. Estimated Levelized Cost of New Generation Resources, 2016.

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 $/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	65.3	3.9	24.3	1.2	94.8
Advanced Coal	85	74.6	7.9	25.7	1.2	109.4
Advanced Coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural Gas-fired						
Conventional Combined Cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced Combined Cycle	87	17.9	1.9	42.1	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional Combustion Turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced Combustion Turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced Nuclear	90	90.1	11.1	11.7	1.0	113.9
Wind	34	83.9	9.6	0.0	3.5	97.0
Wind – Offshore	34	209.3	28.1	0.0	5.9	243.2
Solar PV[1]	25	194.6	12.1	0.0	4.0	210.7
Solar Thermal	18	259.4	46.6	0.0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1.0	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

[1] Costs are expressed in terms of net AC power available to the grid for the installed capacity.

Source: Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)

Biomass Fuels Use in 2010

- Biomass fuels provided about 4% of the energy used in the United States in 2010. Of this, about 46% was from wood and wood-derived biomass, 43% from biofuels (mainly ethanol), and about 11% from municipal waste.

Worldwide Biomass Capacity

Worldwide estimate 14 to 45 GW installed capacity largest source of non-hydro renewable electricity

- possibly 30 –50 GW by 2020
- Leading countries: USA, Sweden, Germany, Indian and Brazil.
- Leading companies: small businesses

53% of US non-hydro renewable power

Annual growth rate 3 -4 %

Emission requirements in US led to stagnation of growth in US starting in 1990’s

Biomass Technologies

Dry

- Thermochemical Processes
  - Direct Combustion
  - Gasification/Pyrolysis

Wet

- Biochemical Processes
  - Fermentation (Ethanol)
  - Transesterification (Biodiesel)
  - Anaerobic (Methane)

Dry Thermochemical Processes (Heat and Chemicals)

- **Direct combustion** –
- First type used, still most plentiful.
- **Directly burn organic material in a boiler, creating steam for power**.
- In general, feedstock is moved to boiler on a conveyor belt (grate feeder).
- Only change to this technology in last 50 years has been in emissions controls. A typical plant may use several different types of organic material, such as crop residues and construction waste.

Direct Combustion Plants

Similar to conventional coal or natural gas plants

Can burn variety of materials in single plant

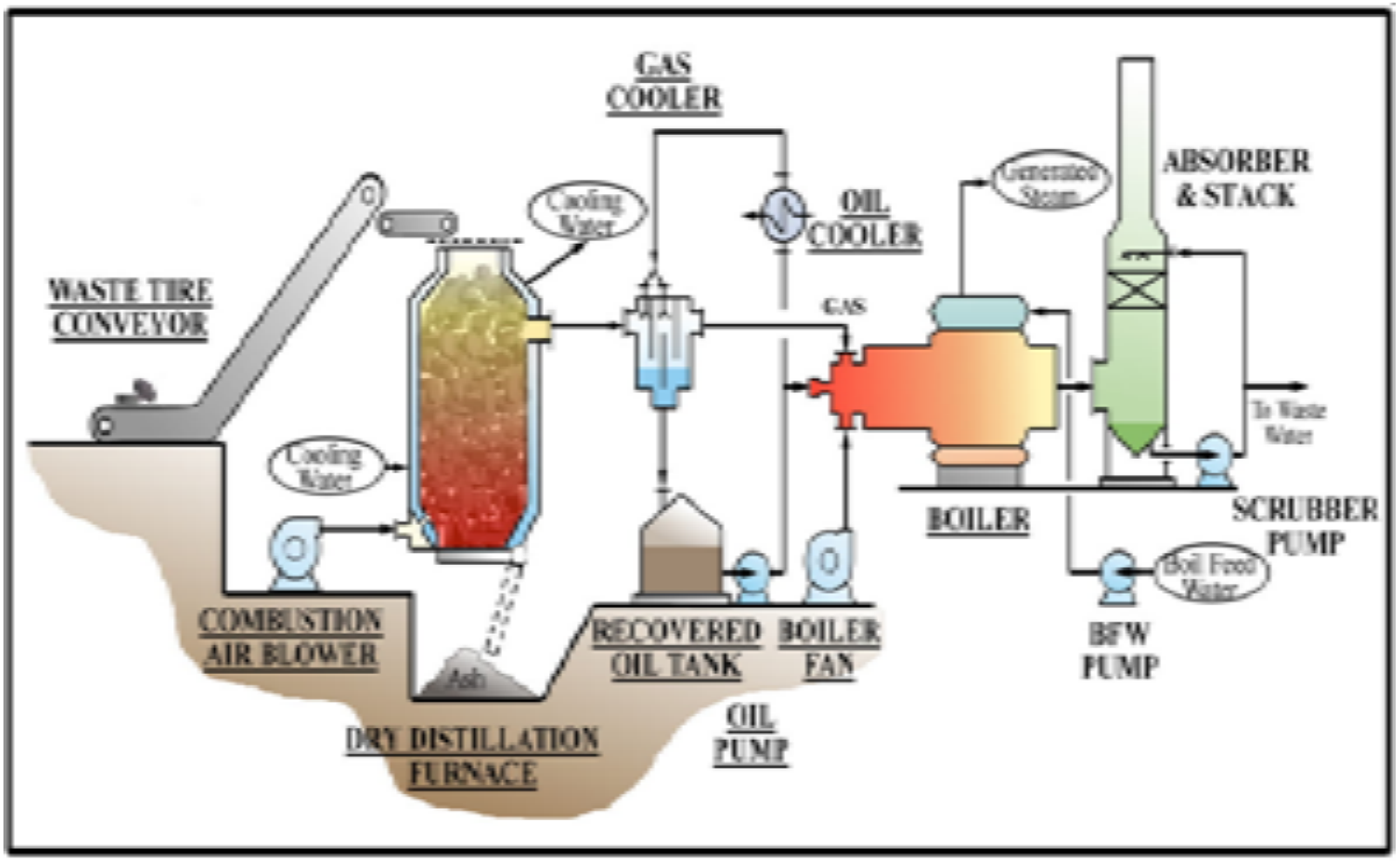
Easily integrated to the grid

Emissions controls and offsets add a major expense

Dry Thermochemical Processes

- **Pyrolysis/Gasification** – Pyrolysis and gasification are the newest types of biomass conversion technologies. Pyrolysis uses **heat and pressure with absence of oxygen** to create various forms of biogas from wood and other forms of cellulosic waste. Pyrolysis has also been used for decades to create charcoal.

Pyrolysis/Gasification



Biochemical Processes

- Ethanol fermentation, also referred to as alcoholic fermentation, is a biological process in which sugars such as glucose, fructose and sucrose are converted into cellular energy and thereby produce ethanol and carbon dioxide as metabolic waste products. Because yeasts perform this conversion in the absence of oxygen, ethanol fermentation is classified as anaerobic.

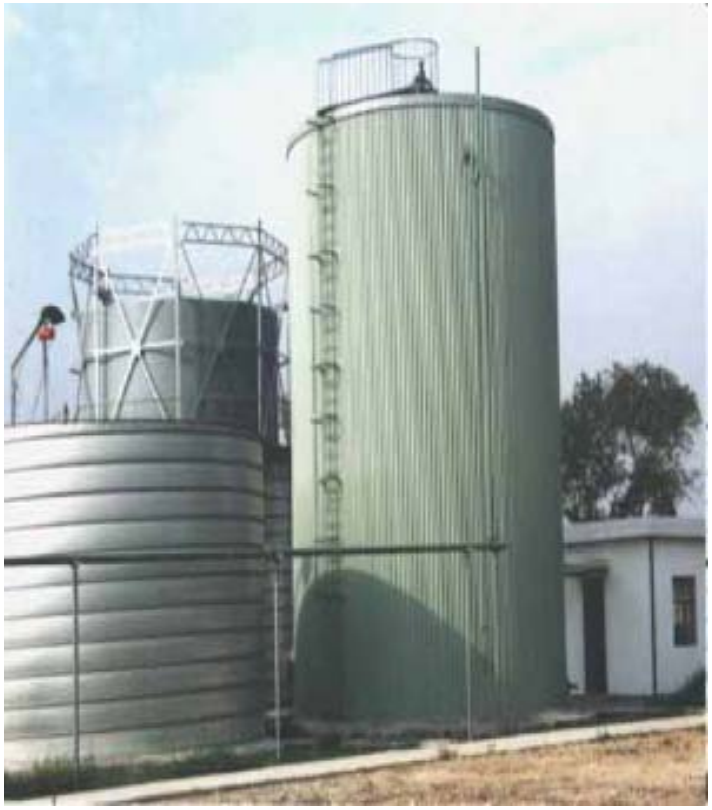
Ethanol Plant

Biochemical Processes

- Transesterification – biodiesel - involves reacting vegetable oils or animal fats catalytically with a short-chain aliphatic alcohols (typically methanol or ethanol).

Biochemical Processes

Anaerobic Digestion – remove oxygen and add bacteria to organic material, such as sewage or animal waste (dairies and feedlots), to produce methane.



Biomass Advantages

- Advantages:
  - May solve waste disposal problems (reduces landfill burden)
  - Provides reliable baseload power
  - Can reduce overall carbon emissions
  - Enhances rural economic development
  - Creates jobs

Mesquite Lake Plant, California, US
Used 900 tons/day of manure from adjacent feedlots; now being refurbished

Biomass Challenges

- High upfront capital costs
- Technological barriers - current technology maturity-level for several advanced biofuels concepts is too low and therefore poses a significant investment risk
- Uncertainties in capital and operating costs, and development costs and revenues
- Lead times to develop projects
- Permitting constraints
- Difficulty and certainty in securing feedstock stream results in price risk (due to large deviations in operational costs)
- Grid access
- Biomass collection and storage facility barriers
- Uncertain government policy framework

Biomass Issues

- Food security concerns (use of corn for ethanol production)
- Competition for use of land & water
- Feedstock competition for transport fuels
- Competition for residues for soil enhancement
  - Solves one waste problem but creates another: ash/mineral or sludge disposal (Potential to use ash to make sellable products)

Biomass Decline in California – Example of Expiration of Government Price Support

- From 1990 to 1993, California's biomass power generation was at highest (more than 800 MW of installed capacity). In 1996, energy production from biomass dwindled to 590 MW. Expiration of price support to biomass industry from government is main reason for reduction. Currently, there are about 30 direct-combustion biomass facilities in operation with a capacity of 640 MW. This is less than half of the facilities in operation (66) during the industries' peak.

Biomass Decline in California – Feedstock Competition

- **<u>United States Agency for International Development</u>**

  Other reasons given for the decline given by the United States Agency for International Development include:

- **Inaccurate assessments of fuel availability and difficulty in obtaining contracted waste streams.**

  Eleven plants shut down because too many biomass plants built for available fuel supply.

Best Practices

- ISO/IEEE standards required virtually everywhere
- Hazardous materials handling and retention
- Storm water retention

- Focus on sustainability
  - Forest and field management
  - Replace nutrients in fields
  - Select fuel with high heat rate & low emissions
  - Promote carbon neutrality
  - Poplar grown for biomass fuel

2012 Biofuels Agenda

- Tax policy, commercialization, expansion of infrastructure, new farm bill, greenhouse gas regulation, market expansion.

Key Colorado Biomass/Renewable Energy Associations

- **Colorado Center for Biorefining and Biofuels** (C2B2) exists to improve fundamental understanding and develop new technologies in areas relevant to the future commercialization of integrated, sustainable biorefining and biofuels processes.
- ***Alan Weimer*, Executive Director**
  H.T. Sears Professor, Chemical and Biological Engineering Department
  University of Colorado at Boulder
  alan.weimer@colorado.edu

- **Colorado Renewable Energy Society**
  Tony Frank, Executive Director

Key Colorado Biomass R&D Centers

- **Sustainable Bionergy Development Center**, Colorado State University
- Mission of the SBDC:
- Enhance the capability of America's bioenergy industry to produce transportation fuels and chemical feedstocks on a large scale, through processes that are sustainable and efficient
- ***Kenneth Reardon***
  Department of Chemical and Biological Engineering
  Director, Sustainable Bioenergy Development Center
  Site Director, Colorado Center for Biorefining and Biofuels
  Kenneth.Reardon@Colostate.edu

Key Colorado Biomass Government Offices

- National Renewable Energy Office, Golden, CO
- Department of Energy, Biomass Program, Golden, Co
- EPA, Office Biomass Program, Golden, CO