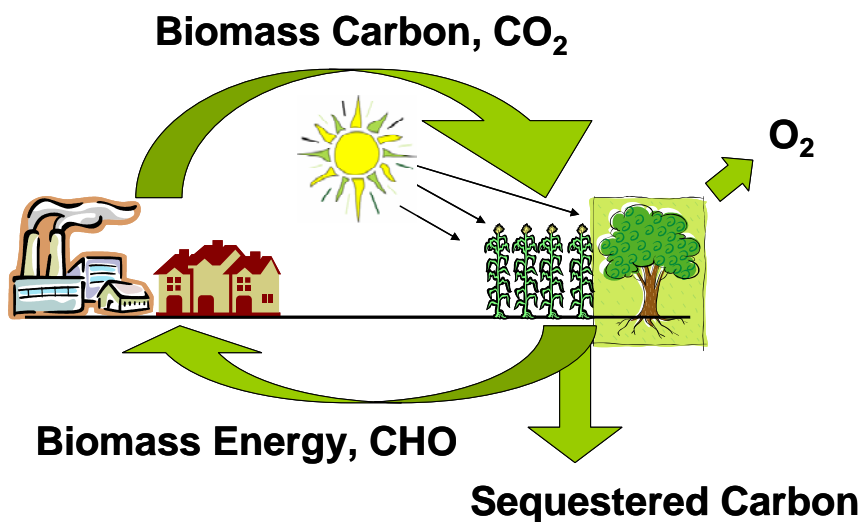


San Benito County Sourcebook of Biomass Energy



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For

The Central Coast Recycling
Market Development Zone

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Biomass Energy Sourcebook Basics

The State of California is racing to implement AB 32, Global Warming Solutions Act, which reduces greenhouse gas emissions back to 1990 levels by the year 2020. It also expands the State's renewable portfolio standard from 20 percent to 33 percent. At the same time, the economy is challenged with high energy and food prices, as well as other economic and environmental challenges. Moving from a fossil fuel-based economy to one that relies heavily on plants, or biomass, will cause a reduction in net emissions and expand the renewable portfolio standard.

This shift from ancient fossil-fuel carbon, to recent biomass carbon, is becoming known as the development of a 'bioeconomy.' Cultivation of a bioeconomy is important to San Benito County because it will:

- Move the County toward attainment of AB 32 reduction in net emissions.
- Move the County toward attainment of AB 32 renewable portfolio expansion
- Develop new local economic development opportunities
- Develop locally-grown energy production opportunities\
- Assist in increasing efficiencies with both environmental and energy benefits.

Adoption of a San Benito County Bioeconomy generally relies heavily on locally available resources. The challenges are largely in understanding that producing more plants and recycling more organic wastes will be good for the economy and the environment. It requires a new vision and will require new laws and regulations. The great news is that most of the materials available to cultivate a San Benito County Bioeconomy are already in San Benito County.

This San Benito County Sourcebook of Biomass Energy is an inventory of biomass resources that are available to the County. These projections are based more completely using existing waste carbon and, in the margin, adding new crops on underutilized land. ***This analysis does not attempt to divert land from high valued agricultural or forestry crops.*** It does serve as an introduction to less traditional economic concepts that allow locally-grown biomass energy to enhance the environment and the economy. The fundamental principles are listed in this document, but explained in greater detail in appendices by subject.

Biomass Is Broadly Defined as New and Recycled Plant Parts

- Fossil fuel is also derived from plants but the characteristic that separates biomass fuel from fossil fuel is that biomass is new or recently created, as opposed to the ancient carbon of fossil fuels.
- Plants convert sunshine (energy from the sun) to sugars, starch and fiber through photosynthesis. These are all called carbohydrates and represent stored solar energy.
- Biomass energy is exciting in relationship to greenhouse gas emissions because biomass pulls carbon out of the atmosphere and stores it (or sequesters) in the plant fibers or in the roots. This is referred to as being carbon-negative. Conceptually if coal or oil were not being used as fuel the concentration of carbon in the atmosphere would be less. Fossil fuels are prehistoric and were not part of the functional biosphere until they began to be pulled from underground with the industrial revolution several hundred years ago. Fossil fuels are referred to as carbon-positive, because they add carbon to the atmosphere. Other non-carbon energy sources like solar, wind and hydro-electric energy are considered carbon-neutral (Figure 1).

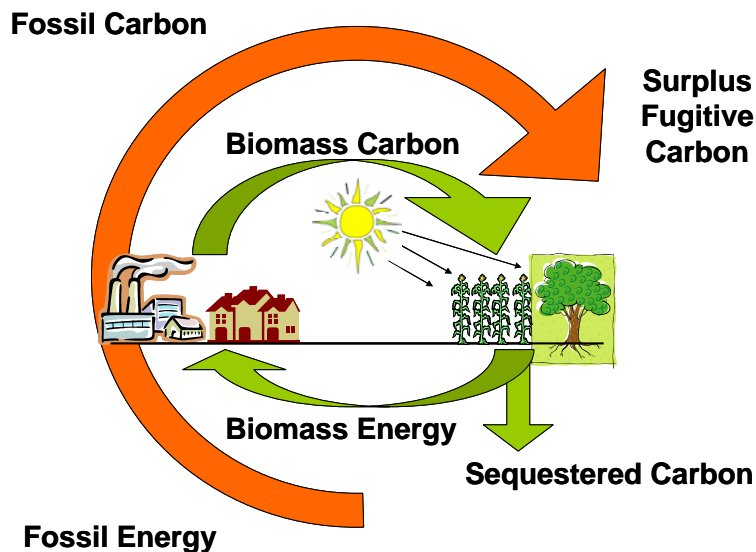


Figure 1 Fossil and Biomass Carbon Cycles

- There are two main kinds of recent biomass: new biomass and used or recycled biomass. This latter group is more commonly called wastes and includes any kind of liquid or solid organic residual such as municipal wastewater or municipal solid waste (MSW). It also includes wood wastes, manure, food wastes, and used fats and vegetable oil. By pulling these 'wastes' back into the economy as energy, waste treatment shifts to a profitable enterprise. The new biomass refers to crops grown primarily for energy.
- Finally, it is important to realize that biomass materials are more than just energy, or carbohydrates. Biomass also includes macro-nutrients like nitrogen (N), phosphorus (P), and potassium (K). Complete utilization of all these products must be included when planning a biomass energy system. For instance manure or wastewater can be processed in an anaerobic digester which captures methane gas (CH₄). The nutrients are still available for use as a relatively odorless and pathogen-free fertilizer for crop production.

Current California Biomass Energy Production

California is a geographic leader on the frontier of renewable energy and environmental quality. California's renewable energy goals have been legislated and charted in Figure 2. This timeline from the California Energy Commission 2007 Integrated Energy Policy Report shows current progress as well as future targets to meet the existing California Energy Policies in place.¹

California is off to a good start, producing 11 percent renewable energy, up through 2007 (the vertical line). As renewable power standards move beyond 2007, the renewable energy challenges climb very quickly.

The role of renewable biomass energy provides economic benefits including alternatives to high energy costs, local economic development, and a reduced dependence on imported energy. The environmental benefits occur directly as production of replacement fuels (lower particulate matter and eliminating methane emissions) and indirectly as alternatives to conventional waste treatment (offsets in fossil-fuel generation required for conventional operation).

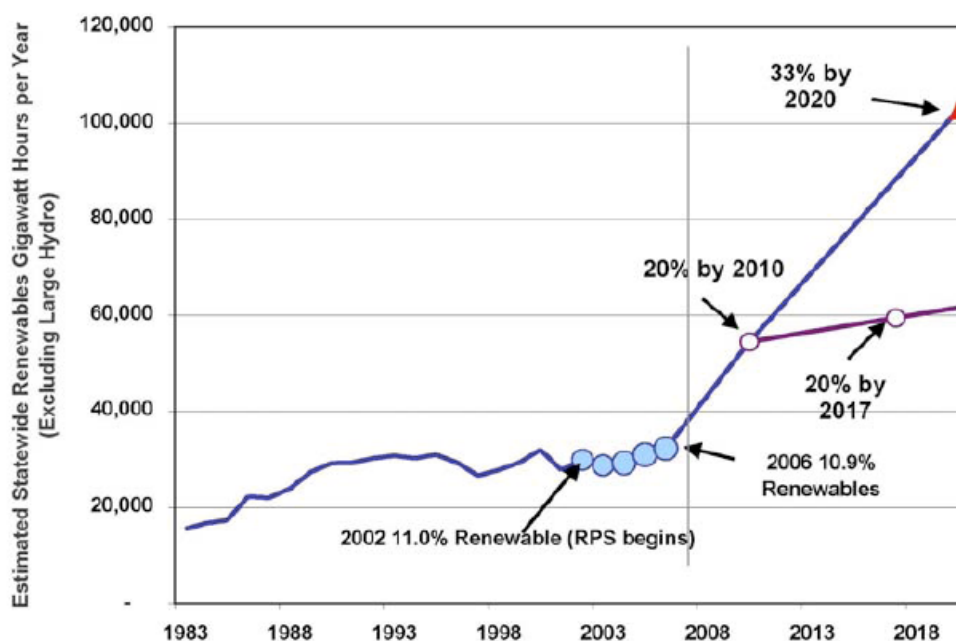


Figure 2 California's Renewable Energy Goals, CA Energy Commission IEPR

¹ California Energy Commission 2007, 2007 Integrated Energy Policy Report, CEC-100-2007-008-CMF. http://www.energy.ca.gov/2007_energypolicy/index.html

California already has established commercial biomass energy systems in place. The total biomass-derived electricity in California is currently at 1,100 MW.² The quantities of generation capacity available in California by fuel are summarized in Table 1.

Table 1 Bio Power (Electricity) Generation Capacity by Fuel Source

Power Source	Generation MW
Electricity from combustion of wood/manure	678.4
Electricity produced from landfill gas	366.3
Electricity produced from wastewater treatment	64.1
Electricity produced from manure-methane	4.2
Total BioPower	1,112.9

The distribution of these power plants is illustrated in the map in Figure 3. The larger wood-powered power plants are distributed largely away from the large cities, as are the small red dots representing manure anaerobic digesters. The power generated from urban wastes: municipal solid waste (MSW) and municipal wastewater treatment plants (WWTP); are clustered around the urban areas.

In addition to biomass electrical power, California is producing additional replacement natural gas equivalent energy from landfill gas and anaerobic digesters. Four recently announced dairy manure Environmental Power digesters will generate 2 million MMBTU (million BTU). These direct-use projects for methane gas do not always show up with the projects producing electricity from methane gas.

Furthermore, California has 77 million gallons of ethanol production capacity and 31 million gallons of biodiesel capacity already built. Both fuels have projects underway that will more than double the existing production capacity.

² The California Biomass Collaborative maintains an excellent database which served as a starting place. California Biomass and Biofuels Production Potential, December 2007.
http://biomass.ucdavis.edu/materials/reports%20and%20publications/2007/CA_biofuelsPotential_FinalDraft_Dec07.pdf. This was supplemented with EPA dataset on landfill gas power plants, municipal anaerobic digesters, manure digesters, and Biomass Rules, LLC internal datasets

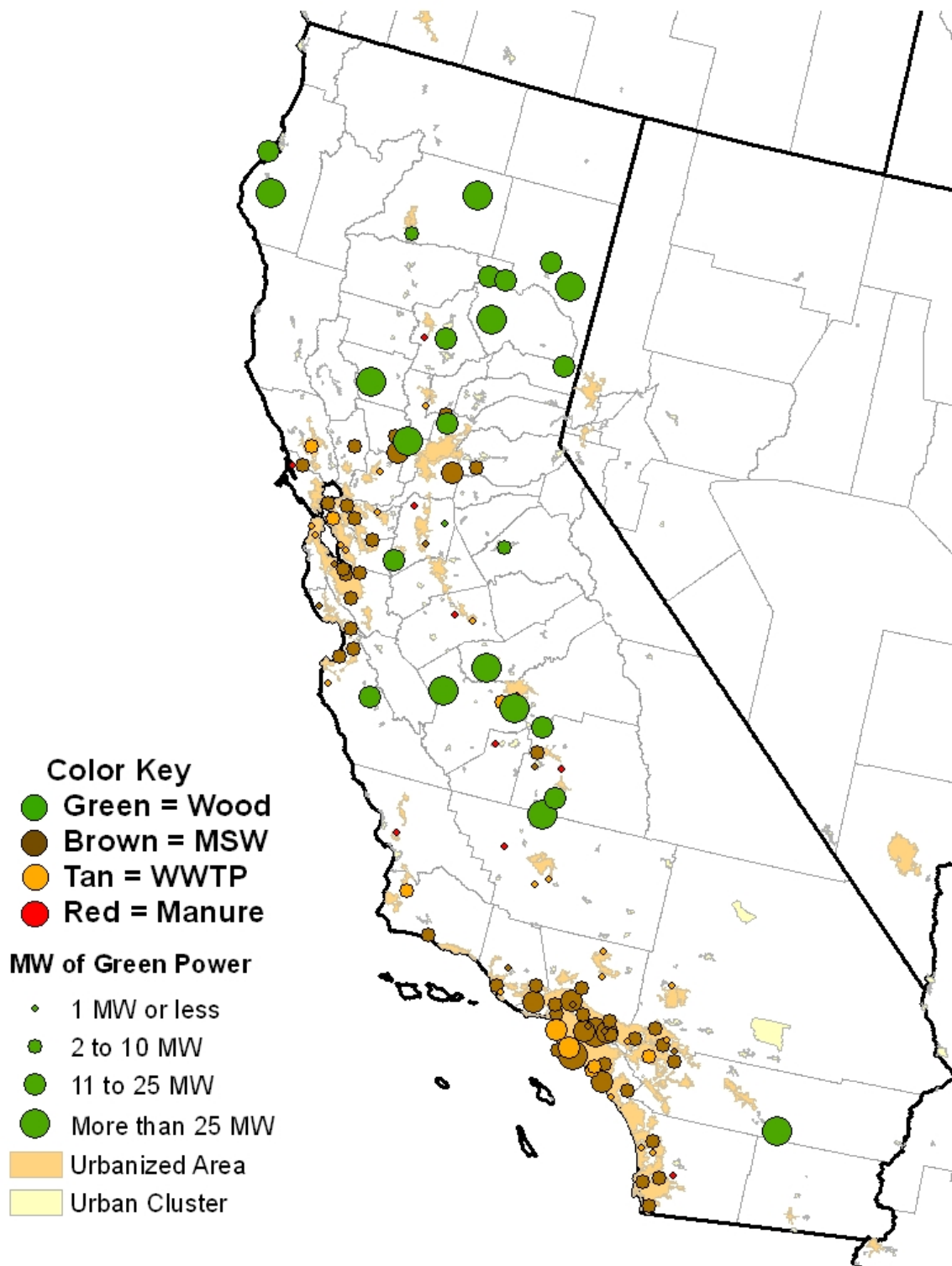


Figure 3 Map of California biomass-derived power plants

Biomass Energy Motivators

Biomass is influence by many different laws and policies. The first legal qualifier is that biomass is recent as opposed to prehistoric fossil carbon. Fossil coal and crude oil can be described as ancient biomass. Ancient biomass is not included as biomass in this discussion.

The basic elements of various biomass materials are: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), chlorine (Cl), and ash. These are the fundamental building blocks of life: carbohydrates, fats, oils, water, proteins, oxygen and carbon dioxide. They are also the components of environmental pollutants like greenhouse gases (carbon dioxide, methane gas, and nitrous oxide), VOCs (Volatile Organic Compounds), ammonia gas, as well as treated organic wastes in wastewater and municipal solid waste (MSW).

Energy

As the cost of energy has sky rocketed the few years, it has brought new compelling interest in using locally grown, recent biomass as an energy source. Five years of energy price data are presented in Figure 4. In 2008 the price of crude oil approached \$150/barrel, but by September 2008 it had fallen back to near \$100/barrel. See Appendix A for a more detailed explanation on energy drivers.

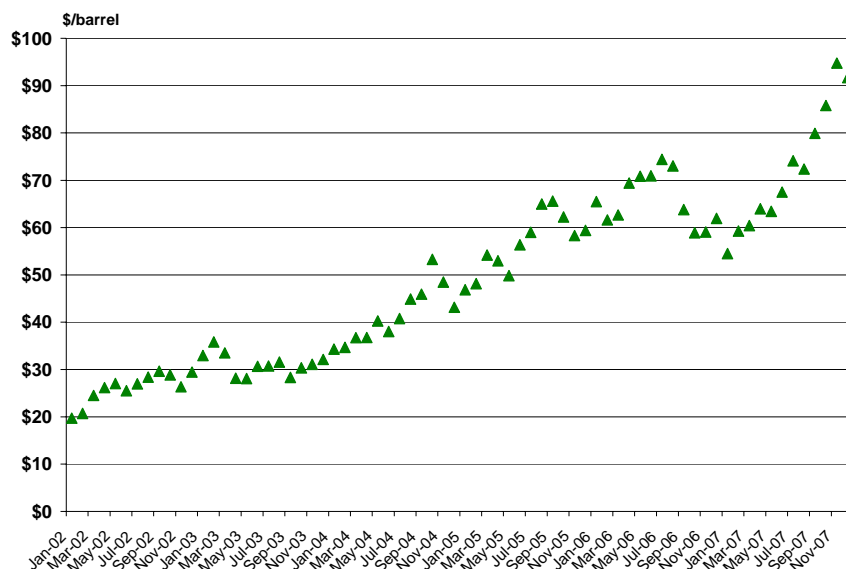


Figure 4 Crude Oil Prices, Cushing, OK, 2002-2007, US EIA data

The rising energy prices have influenced many levels of the economy. But not all the economic energy news is bad. California implemented some very stringent energy efficiency standards for appliance in the 1970's. This has been influential in keeping the per-capita electricity consumption for California constant for more than 30 years. In addition, on a per-capita electricity use basis, San Benito County uses the lowest level of electricity per person in California. In fact, all four of the Central Coast Recycling Market Development Zone Counties are in the lowest 7 California counties in per-capita electricity use (Appendix A:Table A.2).

Environment

In California, long before energy prices began setting records, the environment has been a significant driver. Air emissions, MSW, and wastewater treatment all have very sophisticated regulations that protect the environment and human health. The most recent environmental law of note is AB 32, The Global Warming Solutions Act of 2006, which requires a 25 percent reduction in greenhouse gas emissions from 1990 levels by 2020.

One of the ways this will happen is by pulling the residual energy from carbon air emissions, solid waste and wastewater back into the economy with added value through energy production. The energy conversion technologies also cover many of the waste remediation responsibilities while adding economic growth. Biomass has additional environmental benefits because using biomass as an energy source has the potential to provide a carbon negative source of energy.

Annual Energy Use of San Benito County

Just as California has set environmental benchmarks on air (greenhouse gas), solid waste (landfill diversion) and wastewater (BOD) benchmarks, it is important to have an energy consumption benchmark to target. A convenient measure for energy value is a BTU.³

The annual energy use for San Benito County has been estimated based on the US Department of Energy (DOE) energy facts for California (Table 2).⁴ Electricity values are based on the

³ BTU = British Thermal Unit = 252 calories = 1.055 kilojoules. One million BTU = 1 MMBTU.

⁴ US Department of Energy, Energy Information Administration, State & US Historical Data, California. http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA

documented electricity use in San Benito County (2005). Based on assumptions that are detailed in Appendix A, San Benito County used 7,200,000 million BTU (MMBTU) in 2005.

Table 2 Estimated Annual Energy Use of San Benito County, million BTU (MMBTU, 2005)

Fuel	Annual Consumption	Energy Conversion	California MMBTUs	San Benito MMBTUs
Gasoline	381,301 thousand bbls	5,250,000 BTU/barrel	2,001,800,000	2,200,000
Distillate Fuel	96,902 thousand bbls	5,825,400 BTU/barrel	564,500,000	600,000
Liquified Gas	12,375 thousand bbls	3,834,600 BTU/barrel	47,500,000	100,000
Jet Fuel	104,612 thousand bbls	6,287,400 BTU/barrel	657,700,000	700,000
Natural Gas	2,292,056 million cu ft.	1,027 BTU/cu ft.	2,353,900,000	2,600,000
Residential Electricity	115,000,000 kW-hr	3,412 BTU/kWh		400,000
Commercial Electricity	187,000,000 kW-hr	3,412 BTU/kWh		600,000
Total Annual Energy Consumption				7,200,000

Consumption of 7,200,000 MMBTUs will be challenging to replace. But whatever energy San Benito County can replace with biomass energy sources will also bring reductions in air emissions, wastewater discharges and landfilled material, as well as off-set the fossil energy currently used to manage those activities.

San Benito County Land, Human and Biomass Resources

San Benito County Land Resources

An appropriate starting place is the land base of San Benito County. San Benito County has a surface area of 888,997 acres with 578,351 acres in farmland.⁵ The USDA Census of Agriculture, land use category of 'Land Not in Farms' includes all non-private land that is not a farm. It includes the public, non-farm land, waste land, as well as the urban and industrial areas. Figure 5 shows that cropland uses 9 percent of the county land. Rangeland uses 49 percent of the county. Other farmland makes up 7 percent, and Land Not in Farms is 35 percent of the county.

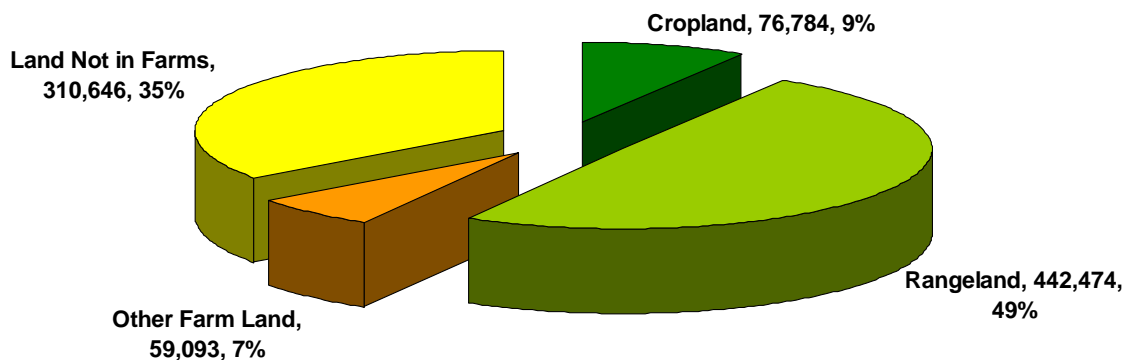


Figure 5 Land use in San Benito County, 2002 USDA Census of Agriculture (acres, %)

The vegetative cover for San Benito can be viewed graphically in Figure 6.⁶ The dark green acres are where the agricultural crops are grown. The light green is labeled vegetative, but it is reflective of the rangeland grasses. The orange land is shrub land and the brown land represents predominately hardwood acres. Most of the level cropland lies along the San Benito River at the north end of the county near Hollister and San Juan Bautista. As mentioned above, about half to the county is in rangeland. The hardwood stands are scattered throughout the county.

⁵ USDA, 2002 Census of Agriculture. <http://www.agcensus.usda.gov/Publications/2002/index.asp>

⁶ California Department of Forestry and Fire Protection website, Multi-source Land Cover Data (v02_2), San Benito County. http://frap.fire.ca.gov/data/frapgisdata/download.asp?rec=fveg02_2.

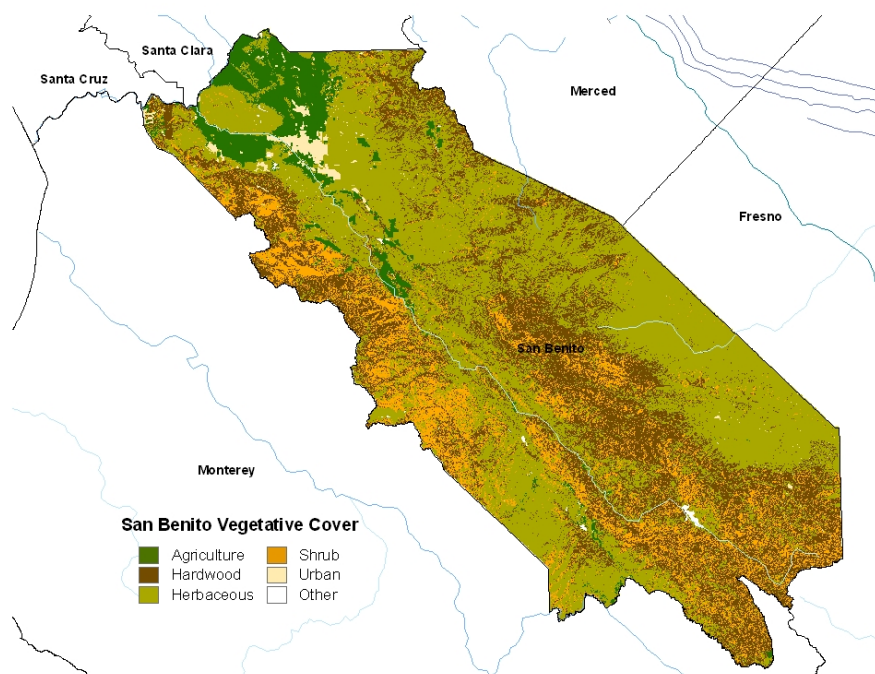


Figure 6 Vegetative Cover of San Benito County

San Benito County Human Resources

San Benito County is home to a population of 57,000 people. San Benito County is growing. Based on the US Census numbers in Table 3, San Benito County has grown by 150 percent since 1980. The City of Hollister has grown by 180 percent and contained 62 percent of the County population in 2005.

Table 3 San Benito County population changes 1980 to 2005.

Population	1980	1990	2000	2005
Hollister	12,473	19,212	30,387	35,452
San Juan Bautista	1,365	1,570	1,553	1,600
San Benito County	23,005	36,700	50,497	57,064

San Benito County Biomass Resources

- **Agricultural Production** In 2006, the value of agricultural production in San Benito County was \$271 million dollars (Table 4).⁷ Nine of the top 10 commodities sold in 2006 were composed of high valued nursery and food crops which had a value of \$184 million dollars

⁷ San Benito Count, Annual Crop Report 2006. Paul J. Matulich, Agricultural Commissioner/ Sealer of Weights and Measures, San Benito County, Hollister, California. May 2007.

and required 27,000 acres. The other commodity in the top ten was cattle. The 2006 sales of San Benito cattle had a value of \$11 million dollars and utilized 510,000 acres.

Table 4 Value of San Benito County agricultural production, 2006

Crop	Value, 2006	Acres	\$/acre
Nursery Stock	\$33,428,000	689	\$48,517
Peppers, Bell	\$28,418,000	1,696	\$16,756
Misc. Vegetables	\$25,781,000	4,787	\$5,386
Grapes, Wine	\$19,569,000	3,788	\$5,166
Lettuce, Romaine	\$18,329,000	3,057	\$5,996
Lettuce, Salad	\$18,233,000	5,159	\$3,534
Spinach	\$16,829,000	3,898	\$4,317
Onions, Dry Bulb	\$14,275,000	1,742	\$8,195
Pasture and Stockers	\$10,819,000	510,000	\$21
Lettuce, Iceberg	\$8,881,000	2,339	\$3,797
Total of Top 10 commodities	\$194,562,000	537,155	
Total of all commodities	\$270,940,000	568,889	
Top 10 as a Percent of Total	71.8%	94.4%	

- With the exception of grazing cattle, the other high-valued, Top 10, agricultural commodities had an average return of \$6,800 per acre. This land is best used in its current use. The fruit and nut crops (including wine grapes) are valuable for their respective fruits and nuts. San Benito County Apples, Apricots, Cherries, Grapes, Walnuts, and other fruits and nuts had a value in 2006 of \$32.7 million and used 7,880 acres.

The climate in San Benito County is an arid mountain climate, with sloping shallow soils and thirteen inches of annual rainfall over the winter months.

- **Forest Biomass** The California Biomass Collaborative has amassed county-level estimates of timber stands and biomass generated each year. Based on the estimates for San Benito County timber residuals amount to a total 82,000 tons of timber waste wood produced each year.⁸ Hardwood and scrub timber stand locations can be identified in the San Benito County map in Figure 6. About half of this estimated to be technically usable (42,500 tons).
- **Municipal Solid Waste** The most detailed waste data for San Benito County was characterized for the 1999 solid waste stream. That data reported 44,755 tons of residential and commercial solid waste entering the landfill.⁹ The top three categories: paper, other organic, and plastic; account for over 80 percent of the 1999 waste stream (36,179 tons). While this material is not easy to separate out, it might be reasonable to utilize 10 percent, or 3,618 tons. If it was possible to segregate 50 percent of the energy-laden solid waste stream for energy production, 18,090 tons could be used for energy.

⁸ California Biomass Collaborative, 2005 County level biomass production level estimates.

<http://cbc2.ucdavis.edu/cbc/biomassResource/resourceByCounty.asp>

⁹ California Integrated Waste Management Board (CIWMB) Waste Stream for San Benito County by material type in 1999. Residential

<http://www.ciwmb.ca.gov/WasteChar/ResComp.asp?J=625&SortBy=MatTypes> Commercial Waste Stream,

<http://www.ciwmb.ca.gov/WasteChar/wcabscrm.asp?Sector=MatlOverall&J=625&SortBy=Disposal>

An additional benefit of this direct diversion for energy production would be extension of the landfill life. If the waste stream was reduced by 10 percent, it would increase the life of the landfill by the same amount (10 percent).

- ***Municipal Wastewater Treatment*** The newly, upgraded Hollister Wastewater treatment plant is nearing completion of the installation of new technologies. These technologies are very efficient, so some of the bioenergy opportunities from wastewater materials will be somewhat limited. There are two resources leaving the new treatment plant that may play a role in future biomass production. These are the treated water and the treated solids.
- ***Waste Oil and Grease*** Area restaurants and groceries serve as an indicator of used vegetable oil from fryers and waste food. While the size of the population in San Benito County limits the availability of waste grease and oils, it may be possible to export current grease and oil supplies to other communities or to import grease and oils to San Benito County.

Energy Alternative Solutions, Inc. is headquartered in neighboring Watsonville and has their biodiesel plant in Gonzales, CA. Their website, www.bioecasi.com, indicates that they are also in partnership with Salinas Tallow Company, San Jose Tallow Company, and thousands of restaurants on the California Central Coast and in the San Francisco Bay Area.

This is an excellent illustration of the ease at which biomass materials can be imported and exported. Our food and fuel currently move around the globe. San Benito County would be hard pressed to consume all the vegetables it grows each year. Bringing biomass solids and liquids into San Benito County to be converted into liquid fuels, electricity, natural gas replacement, or simply as a heat source, should be included in the bioenergy possibilities.

Feedstock Quality and Handling

Biomass production, harvest, and storage are important components of biomass resource development. Biomass materials can be wet and are always less dense than traditional fuels. Wheat straw, for instance, is less dense on both an energy and volumetric-basis than coal. To replace a cubic foot of coal with energy from wheat straw, it would take 14 cubic feet of wheat straw. Feedstock quality and handling issues are discussed more extensively in Appendix B.

Future Crops and Biomass

This category shows promise for San Benito County even though there are some significant resource crop production limitations when it comes to rainfall and available flat, tillable acres. San Benito agriculture does very well with the valuable irrigated farmland it does have. But with water use pressures mounting in California, expanding available irrigation will become difficult. Not all crops produce the same amount of energy per acre. The first generation energy crops in the US have been corn and soybeans. These are not really energy crops, although energy can be produced from them. Cellulosic ethanol is able to produce twice as much ethanol per acre as

corn-based ethanol. Soybeans are not an impressive liquid fuel feedstock on a per-acre basis. Again, corn and soybeans are not energy crops.

Several emerging crops yield significant amounts of oil and they can be grown in the San Benito climate. Two arid oil seed crops that have emerged recently in North America are camelina and the jatropha tree. Groups in Montana and Canada have been working in recent years to develop camelina commercially for oil production. The jatropha plant is a prolific shrub that produces inedible nuts that are loaded with oil. It is grown in Asia and Central America. It can do well in arid regions, but does not do well in areas that freeze. A third emerging energy crop, algae, isn't widely considered a cash crop.

- ***Camelina*** Camelina is conservatively 'rated' at about 63 gallons of biodiesel per acre. Camelina is an arid mountain crop that yields an amount of oil similar to soybeans. The Great Plains Oil and Exploration Company of Montana has a target of growing 100,000 acres of camelina and is paying growers a premium to produce it.

Camelina does well in areas with limited rainfall and it is a short season crop, (100 days or less). Its high oil content has 35 to 45 percent omega-3 fatty acids, which make it an excellent source of food-grade nutrients¹⁰. The University of Montana is taking the US lead in agronomic research on camelina production¹¹.
- ***Jatropha*** Jatropha is a new oilseed crop that is being grown extensively in Asian countries like India¹². The jatropha plant is a hardy bushy shrub that produces nuts that are very high in oil and requires very little water. Jatropha has not been grown in Central California, so it is conservatively estimated to produce 200 gallons per acre. This is at the low end because it may not grow well in San Benito County. Jatropha research and production has reached the U.S. with research beginning in Florida, Hawaii, Texas and Missouri. In fact, Alternative Energy Solutions, a biodiesel company with a biodiesel plant in Gonzales, CA, is even looking at growing jatropha in the Central California region¹³.
- ***Algae and Other Aquatic Crops*** Water for crop irrigation is too costly as an energy crop input in San Benito County. However there is an abundance of water that passes through the wastewater treatment facility that is currently not obligated for irrigation. This could provide a supply of water for energy crops that will not be used directly for food consumption. In

¹⁰ Is there room for Camelina? Khalila Sawyer. Biodiesel Magazine. BBI International. July 2008. http://biodieselmagazine.com/article.jsp?article_id=2475&q=&page=all

¹¹ Camelina Production in Montana. K. A. McVay and P. F. Lamb Montana State University Extension. Montana State University, Bozeman, MT. Revised 3/08. <http://msuextension.org/publications/AgandNaturalResources/MT200701AG.pdf>

¹² Centre For Jatropha Promotion. Rajasthan, India. www.jatrophaworld.org

¹³ Central Coast biodiesel maker plans expansion. Mary Duan. Silicon Valley/San Jose Business Journal. November 23, 2007 <http://sanjose.bizjournals.com/sanjose/stories/2007/11/26/story12.html>

addition the wastewater treatment plant has access to 90 acres of percolation ponds that could be used for aquatic energy crop production. Biodiesel oil yields for intensively managed open pond algae production have been estimated to yield 4,000 gallons per acre. This yield per acre can go much higher if algae is grown in tanks and pipes in controlled environments.

Algae is a kind of ‘Wonder Crop’ and has the capacity to remediate carbon dioxide (CO₂) emissions, produce energy, generate a source of protein for animal feed and even provide dietary and medicinal supplements for humans.¹⁴ After decades of trying to keep algae from spontaneous production in the wild from bursts of nutrient spills, now developers are rushing to find a way to grow it. In the blink of an eye algae technology is moving to an intensively managed, confined production system of algae.

San Benito County has significant land, human and biomass resources. These have been summarized in Table 5 by category and whether there is potential to develop these resources.

Table 5 Available Biomass Resources in San Benito County

San Benito County Resource	Yes	No	Maybe	Explanation
Current Agricultural Production		XXX	???	Nothing can (or should) compete with the high value of ag production. There are opportunities to develop some marginal land for arid energy crops and to use existing processing residuals for energy. Energy crop \$/acre would have to surpass food crop \$/acre value.
Forest Biomass	XXX			County hardwood stands should be managed for energy production from waste wood.
Municipal Solid Waste	XXX			There is potential to channel incoming carbon and plastic into energy conversion technologies. Any material diverted from the landfill will also lengthen the life of the landfill.
Municipal Wastewater			XXX	The new wastewater treatment plant has effectively met the needs of waste remediation. To the extent that the treated effluent, and percolation ponds can be utilized for aquatic energy crops like algae, it should be considered.
Waste Oil and Grease			XXX	There is not a great quantity of waste oil and grease in San Benito County. The quantities that are available could be developed for demonstration projects at the schools or organizations. Larger scale energy projects will require importing materials from surrounding counties
New Energy Crop Production	XXX			There is potential to grow non-irrigated, arid energy crops like camelina and jatropha in San Benito County. It will need to be addressed on a small scale initially, but even utilization of 10 percent of marginal land in the county will have a benefit to energy production.

¹⁴ Algae - The Wonder Crop Of Tomorrow? Mark Jenner. Biomass Energy Outlook. BioCycle June 2008, Vol. 49, No. 6, p. 44

Biomass Energy Conversion Fundamentals

To clearly understand the opportunities for maximizing biomass production and use, it is important to understand some fundamental concepts. These fall into the three basic categories of biomass chemistry, biomass physics and biomass economics. These are introduced here with a more extensive discussion included in Appendix C.

Biomass Chemistry

Photosynthesis The most important relationship in biomass production and use is the phenomenon of photosynthesis. Solar energy hitting the green plants on earth converts carbon dioxide and water into sugar. The energy from the sun makes the reaction happen. The process uses some of the energy, and some of the energy is stored in the carbohydrate (sugar). Carbohydrates, which include sugars, starches, and cellulose, are really stored solar energy.

Humans and other oxygen-breathing animals on the planet ‘respire.’ Respiration is the reverse reaction to photosynthesis. Oxygen and carbohydrates get converted back into carbon dioxide, water, and usable biochemical energy. The same stored solar energy in sugars and starches can be used for food or for powering vehicles and making electricity. The difficulty comes when plants store the energy as plant fibers (cellulose). We can not digest grass or wood for food. But work is progressing on turning these fibrous carbohydrates into cellulosic ethanol fuel, or ethanol made from cellulose.

Carbohydrates, Fats, Oils, and Lignin Carbohydrates include sugars, starches, hemicellulose, and cellulose molecules. Carbohydrates include multiple combinations of carbon (C), hydrogen (H), and oxygen (O). Sugars are the smallest, identified as 5 or 6 carbon sugars. Starches are larger being combinations of several sugars. Hemicellulose molecules are much larger, but are also composed of combinations of sugar molecules. Cellulose molecules are the largest carbohydrates and form the structure for the toughest woody fibers. All of these are combinations of sugars. Since carbohydrates are combinations of sugar molecules, the large cellulose molecules can be reduced back to sugars. It may not be easy, but it can be done.

So the cellulose molecules are principally composed of one type of sugar. The hemicellulose molecules are composed of another type of sugar. All these sugar molecules are held together by something known as lignin. It is often referred to as the 'glue.' It also has a lot of energy, but is often locked so tightly in the hemicellulose and cellulose molecules that it takes more energy to break it down than the carbohydrates contain. For using cellulose in a thermal technology like a gasifier, the lignin is great. For liquid fuels like cellulosic ethanol, the lignin is a problem.

Fats and oils are very similar to carbohydrates. These lipids have lots of energy also, but technically they are not simply carbohydrates, so we can talk about them as fats and oils. Proteins also have energy in them, but they are more than energy. They are best used for the highest valued use, which may not be bioenergy.

Biomass Physics

Energy in the universe is constant. We can store solar energy in plants or in batteries, but the energy that comes from the solar energy isn't created here. It comes from the sun. Unlike energy, nutrients can be recycled and reused. The trick using energy is to capture and use as much energy as it passes through before it dissipates. For nutrients, we want to keep them in the production system as long as possible, because they can be used over and over again.

Moisture Water in biomass provides no energy value. For thermal conversion technologies like gasification or combustion, water displaces material that does have energy value. If corn stalks are 20 percent moisture that means that only 80 percent of the feedstock provides energy (the 20 percent water provides no heat value).

Four Phases of Combustion There is much more to combustion than a flame. There are four phases that occur when materials burn. These are: 1) heating and drying, 2) pyrolysis, 3) flaming combustion 4) char combustion.¹⁵

- *Heating and Drying.* As heat enters the solid fuel, water is driven off. The next phase, *pyrolysis* can not begin as long as the water remains.

¹⁵ Brown, Robert, Biorenewable Resources: Engineering New Products from Agriculture. Iowa State Press. Ames, IA 2003.

- *Pyrolysis.* Elevated temperatures decompose organic compounds into volatile gases including: carbon monoxide, carbon dioxide, methane, and other compounds that condense into tar when cooled. The resulting char is more porous.
- *Flaming Combustion.* The introduction of oxygen (oxidation) ignites the volatile gases of *pyrolysis*. The ultimate products are carbon dioxide and water, but in the process many intermediate compounds combust. When conditions are right, the intermediates will be consumed in the process.¹⁶
- *Char Combustion.* The solid core is oxidized in the last phase. Under optimal operating conditions, char combustion produces carbon monoxide and carbon dioxide.

By understanding that combustion can be separated into these four phases, it allows a discussion between combustion in an incinerator and a gasifier. The incinerator has no restrictions on the process and has more emissions. A gasifier efficiently halts the combustion process after the volatile gases/vapors are pulled out in the pyrolysis phase. This significantly reduces the emissions. As explained in the next section on conversion technologies, there is a difference between the second phase of combustion, named pyrolysis, and the conversion technology of a similar name of fast pyrolysis. At this point, knowing there is a difference is sufficient.

Biomass Economics

The basic laws of economics do not change for the supply and demand of biomass. The challenge is that materials like manure, solid waste, and wastewater do not generally fit the traditional commodity economics. When processed into energy commodities, they do fit. Some of these biomass economic principals that are relevant to biomass energy projects are reviewed.

- *Uncertainty and Prices* In conventional energy or agricultural projects there are generally well developed, historical prices data available. With biomass energy projects price projections of both costs and revenues are at best educated guesses.
- *All Prices are Relative* When the price of crude oil goes up to \$140 per barrel, all the research that was done when oil was selling for \$40 per barrel is irrelevant. Current prices are always the most relevant. And with biomass energy prices change a lot.
- *Data Collection* On the frontier of developing new projects, the importance of collecting data can not be emphasized enough. Tabled values from other projects may be sufficient in concept design, but when money begins to be invested in equipment, it is time to conduct specific testing on the actual materials that will be used. It does not pay to invest several million dollars without doing aggressive testing.
- *Project Size or Scale* One way useful data is collected is by testing technologies on a very small scale and working up to a full scale commercial plant. There are four conventional project

¹⁶ Incomplete combustion, due to improper design or management, can produce toxic pollutants.

scales: laboratory, pilot/demonstration, commercial scale, and industrial. The laboratory scale is basically conducted on a table top model. Once the technology is fairly understood a larger pilot scale is operated. This allows a proof of concept away from the small, lab-sized project, and provides a framework to estimate the costs of building a commercial scale project. The industrial scale is when the commercial scale reaches a level that the functional, commercial technology can be replicated over and over using an established successful commercial scale technology.

- ***Specialization vs. Diversification*** There are economic reasons to become large and very specialized. This is common in conventional production systems. There is also a lesser recognized value in diversification. In the context here, it is a discussion about diversifying an asset – or how many products can be generated from a specific conversion technology asset. The best part about asset specialization and diversification is that they can be nested together. A dairy farm can be specialized to produce milk, but it can also produce bedding for the cows, heat, electricity, fertilizer, and provide environmental benefits.
- ***Profit*** Not all biomass materials come from a profit-making sector. Wastes are managed to minimize costs. Profit is revenue minus costs. The best that can be achieved with the lowest costs is zero. Zero profit does not provide a return on an investment. Revenue is key.
- ***Recycling Effects*** Recycling creates a greater supply of materials. When the paper industry began recycling cardboard, recycling influenced the prices of new cardboard. The total supply of new and recycled cardboard increased beyond what was needed. Cardboard prices have gone up and down ever since. It is a normal phenomenon. When a large supply of recycled materials competes with an existing market from new materials, the prices for both will change.

Non-energy Biomass Markets

Finally, there are multiple markets that exist for non-energy uses of biomass carbon as well as markets for the non carbon components of biomass, like fertilizer. Industrial chemicals, building materials, bioplastics and fertilizers must all be considered as opportunities in addition to the opportunities for producing energy.

Biomass Energy Conversion Technologies

Biomass conversion technologies, in California, take on some what of a different meaning than in the rest of the country, because conversion technologies are defined in the solid waste regulations. Because regulations change, the focus here is on the physical, biological and chemical attribute of the conversion technologies. A brief overview is provided here with a more extensive overview in Appendix D. California has several excellent publications of technology assessments that have been conducted in recent times. One of these is the first footnote referenced at the bottom of this page by the California Biomass Collaborative and UC Davis.

Thermal Conversion

Conversion technologies that involve a heat-driven process are called thermal technologies. The primary thermal technologies are combustion, gasification, and fast pyrolysis. The most significant difference between combustion and the other two processes is an unrestricted flow of oxygen. Incinerators involve unrestricted combustion. Once the oxygen is restricted, technically it is not an incinerator.

- **Combustion** Combustion is the burning of organic material in the presence of oxygen creating a flame. Wood stoves, fireplaces, and industrial burners are examples of biomass energy by combustion. *“Combustion is defined as the oxidation of the fuel for production of heat at elevated temperatures without generating commercially useful intermediate gases, liquid, or solids.”*¹⁷ Fundamentally combustion is unrestricted oxidation of fuel.
- **Gasification** Gasification is the liberation of volatile, gaseous compounds at high temperatures with the controlled restriction of oxygen.¹⁸ This creates a flammable producer gas ready to combust. One of the challenges with a gasifier is that this producer gas does not substitute directly for natural gas. In addition the composition of the gas varies with the feedstock entering the gasifier.
- **Pyrolysis (also known as Fast Pyrolysis)** The fast pyrolysis technology concept is a bit confusing because ‘pyrolysis’ is a step discussed in the combustion process. The process, ‘pyrolysis,’ used in that four-step combustion process actually occurs with both gasification and fast

¹⁷ Technology Assessment for Biomass Power Generation – UC Davis. Draft Final Report. Rob Williams and Bruce Vincent. California Biomass Collaborative website, October 2004.
http://biomass.ucdavis.edu/materials/reports%20and%20publications/2004/2004_Assessment_SMUD_ReGEN.pdf.

¹⁸ From BioTown USA Sourcebook. Mark Jenner. Indiana State Department of Agriculture 2006.
http://www.in.gov/oed/files/Biotown_Sourcebook_040306.pdf.

pyrolysis. The technology, 'fast pyrolysis,' condenses the volatile gases liberated by the process 'pyrolysis' and rapidly condenses them into a bio-oil.

Biological Conversion

Biological conversion is the process of converting carbohydrates into energy using living organisms. In biomass energy discussions, discussions here are limited to the very specific microbiological processes of anaerobic digestion and fermentation of carbohydrates.

- **Anaerobic digestion** Anaerobic digestion is the cultivation of methagenic bacteria in the absence of oxygen. Methagenic bacteria live in an aquatic environment. This is intuitive when thinking about manure and municipal sewage waste streams. This is also true for landfill gas methane. So the basics of anaerobic digestion described here also apply to landfill gas generation.

Intensively managed methane generating technologies, like anaerobic digesters, are very complex microbiological ecosystems. The efficiency of conversion of manure or sewage to methane gas depends on many factors like quality of the feedstock or waste material entering the digester and the intensity of digester management. This latter intensity includes things like: the retention time of manure in digester, temperature of the digester, and whether it is continuously loaded or not.

- **Biological Fermentation of Alcohol** Conversion of corn into ethanol by fermentation has been one of the bright stars of the biomass renewable fuels industry. As of July 2008, there are over 160 existing US ethanol plants currently listed on the Renewable Fuels Association (RFA) website with expansion or new construction planned at 49 more facilities.¹⁹ Ethanol production in 2007 was 6.5 billion gallons.

Indeed the expansion of the ethanol industry has been so rapid, it has created numerous conflicts. The industry has grown 200 percent since 2002. The greatest driver in this growth domestically has been the switch from using the oxygenate MTBE (methyl tertiary-butyl ether) to ethanol as an oxygenate. The rapid growth has created an increased demand for corn and the price of corn is nearly triple its traditional price. This has fueled the counter-productive 'Food vs. Fuel' debate.

Chemical Conversion

Like all the energy conversion technologies presented here, there are nearly always a combination of technologies in the conversion of biomass to energy. The principle chemical processes are the hydrolysis of cellulosic fiber into sugars, and the esterification of vegetable oil into biodiesel fuel.

- **Hydrolysis: Ethanol Fermentation Process (Cellulose/Fiber)** Hydrolysis is technically the breaking down of large molecules by splitting a water molecule into a hydrogen (H) molecule bonded to one product and a hydroxyl (OH) bonded to the other product.²⁰ Here we are

¹⁹ Renewable Fuels Association <http://www.ethanolrfa.org/industry/locations/>

²⁰ Brown, Robert, Biorenewable Resources: Engineering New Products from Agriculture.

referring to the break down of large cellulosic fibers into smaller sugars. Two chemical processes are use acid and enzymes.

One of the leading cellulosic technology developers is Iogen, a Canadian-based Company. They had initially been awarded a US DOE grant to design and build a cellulosic ethanol plant. Recently they decided to build their first commercial plant in Canada. Another commercial cellulosic technology developer is BlueFire Ethanol, who was also awarded a DOE commercialization grant. BlueFire Ethanol is building their first commercial plant in California. Their chemical hydrolysis process includes the acid hydrolysis process. BlueFire Ethanol is using MSW as their feedstock.

- ***Transesterification of Vegetable Oil (Biodiesel)*** The commercial biodiesel production process using vegetable oil begins with the oil as a feedstock, not the soybeans. This is different from the conversion of corn to ethanol, where corn is delivered to the ethanol plant. Soybeans contain about 18.5 percent oil which is separated from the high-valued protein soybean meal.²¹ A 60 pound bushel of beans yields about 11 pounds of oil and 48 pounds of meal.²² The oil and soybean meal (protein) are separated at a soybean processing facility and the meal and oil supply two completely different markets.

The National Biodiesel Board (NBB) estimates the current capacity for producing biodiesel at 2.24 billion gallons per year in the U.S.²³ The NBB points out that capacity is not the same as actual annual production. With the same 2.24 billion gallons of capacity, the production volume for 2007 reported by the NBB is only 450 million gallons of biodiesel fuel. Biodiesel plants will operate at full capacity only when it makes economic sense to do so. Production of 450 million gallons when the capacity is 2.24 billion gallons means that on average the biodiesel industry is only utilizing 20 percent of its capacity.

The cost of vegetable oil, the principle ingredient in biodiesel fuel, is also increasing very rapidly (Figure 7). This is a fairly accurate indicator that food is more important than fuel. About the first week of July 2008, the price also broke on vegetable oil. The price of vegetable oil has increased to the point that the fuel uses can not compete with the food uses.

²¹ Dirk E. Maier, Jason Reising, Jenni L. Briggs, Kelly M. Day & Ellsworth P. Christmas. "High Value Soybean Composition." Grain Quality Task Force. Fact Sheet #39. Purdue University. November 23, 1998. <http://www.ces.purdue.edu/extmedia/GQ/GQ-39.html>

²² The standard test weight of soybeans is 60 pounds at 13% moisture, while the standard test weight of corn is 56 pounds at 15.5% moisture.

²³ National Biodiesel Board. "U.S. Biodiesel Production Capacity." January 25, 2008. http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf

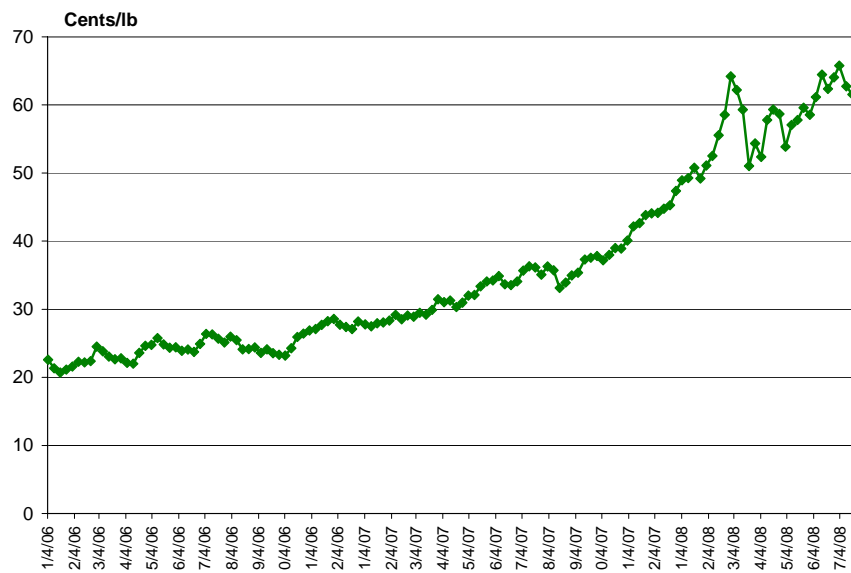


Figure 7 Price of vegetable oil January 2006 through July 2008

Table 6 lists California biodiesel products. According to the National Biodiesel Board, nine biodiesel plants representing 30.8 million gallons of biodiesel capacity exist in California (top nine facilities). Below the horizontal line are another 6 that are listed as under construction (40 million gallons of capacity). The last three entries in Table 6 are projects that have been in the news, but were not yet listed on the NBB website.

Energy Alternative Solutions, Inc. facility in Gonzales, CA is producing biodiesel fuel just outside San Benito County from used vegetable oil and animal fat. These same materials are being used in Watsonville, CA to generate methane by anaerobic digestion.

Table 6 California biodiesel facilities that are operating (top) and planned (bottom)

Facility	City	Capacity	Feedstock	Date	Website
Bay Biodiesel, LLC ^a	San Jose	3,000,000	Multi Feedstock	Mar-07	www.baybiodiesel.com
Blue Sky Bio-Fuels, Inc. ^a	Oakland	8,000,000	Multi Feedstock	Jan-07	www.blueskybio-fuels.com
Central Valley Biofuels, LLC ^a	Orange Cove	2,000,000	Multi Feedstock	May-07	www.cvbiofuels.com
LC Biofuels ^a	Richmond			Dec-07	
Energy Alternative Solutions, Inc. ^a	Gonzales	1,000,000	Multi Feedstock	Dec-06	www.bioeasi.com
Imperial Valley Biodiesel, LLC ^a	El Centro	3,000,000		Dec-07	www.imperialvalleybiodiesel.com
Imperial Western Products ^a	Coachella	8,000,000	Multi Feedstock	Oct-01	www.biotanefuels.com
Wright Biofuels, Inc. ^a	San Jacinto	5,500,000	Multi Feedstock	Sep-07	www.wrightbiofuels.com
Yokayo Biofuels, Inc. ^a	Ukiah	300,000	Used Cooking Oil	Apr-06	www.ybiofuels.org
Biodiesel Industries of Port Hueneme ^b	Port Hueneme	20,000,000	Full Spectrum	Dec-08	www.biodieselindustries.com
Central Valley Biofuels, LLC ^b	Orange Cove	5,000,000	Multi Feedstock	Aug-08	www.cvbiofuels.com
Community Fuels ^b	Stockton	7,500,000	Multi Feedstock	2Q 2008	www.communityfuels.com
GeoGreen Biofuels, LLC ^b	Vernon	3,000,000	Used Cooking Oil	1Q 2008	www.geogreenbiofuels.com
Greener Tomorrow ^b	Chino		Used Cooking Oil	2Q 2008	www.GreenerTomorrow.us
Noil Energy Group ^b	Commerce	5,000,000	Multi Feedstock	Apr-08	
Sacramento Biofuels, LLC ^c	Sacramento	60,000,000		Mar-08	
Crimson Renewable Energy ^c	Taft	30,000,000	Multi Feedstock		
	Pacifica	3,000,000	Used Cooking Oil		

a www.biodiesel.org/pdf_files/fuelfactsheets/Producers%20Map%20-%20existing.pdf

b www.biodiesel.org/pdf_files/fuelfactsheets/Producers%20Map%20-%20Construction.pdf

c www.biomassrules.com

Integrated Systems

Biomass energy production systems are composed of complementary conversion technologies.

Nearly every project contains more than one technology when the non-biomass technologies are also considered. There are two additional production systems that do not fit into the technologies discussed to this point.

- ***Thermal Depolymerization*** Thermal depolymerization is basically the use of high temperatures and pressures to replicate the ancient, natural decomposition of prehistoric plant material into crude oil. Changing World Technologies, Inc. (CWT) is commercializing a Thermal Depolymerization process (TDP).²⁴ In 2000, ConAgra Foods partnered with CWT to form a new company, Renewable Environmental Solutions, LLC (RES). RES established a commercial scale TDP plant in Carthage, MO using the turkey fat and offal from a ConAgra turkey processing plant. This plant became fully operational in February, 2005.

Another process using high temperatures and pressures is under development by agriculture engineers at the University of Illinois, Urbana-Champaign (U of I).²⁵ The U of I process produced an oil product similar to a pyrolysis oil. Professor Yuanhui Zhang continues to develop the process and has recently begun tests converting cellulosic fiber from miscanthus into oil.²⁶

- ***Integrated Ethanol Plant/Feedlot*** Another integrated biomass energy system is ethanol plant with an attached feedlot. This model has been in development for years. The E3 Biofuels' Mead, NE, facility opened in June of 2007 and included a 25 million gallon ethanol plant with a 28,000 head beef feedlot.²⁷ This facility included a number of energy and cost savings. First, wet distiller's grains would be fed as part of the beef ration without needing to be dried or transported. Beef manure would then be added to an anaerobic digester along with waste ethanol from the ethanol plant to supply the ethanol production facility with 90 percent of its energy needs.

Unfortunately in November 2007, E3 Biofuels filed for bankruptcy. The E3 Biofuels model is an excellent example of efficiency. It also is a painful reminder that not all well designed projects succeed economically.

²⁴ Renewable Environmental Solutions, LLC, press release www.res-energy.com/press/presskit.asp

²⁵ B.J. He, Y. Zhang, Yin, G.L. Riskowski, and T.L. Funk. "Thermochemical Conversion of Swine Manure: A process to Reduce Waste and Produce Liquid Fuel." ASAE/CSAE Annual International Meetings, Toronto, Ontario, Canada. July 18-21, 1999.

²⁶ Yuanhui Zhang. "Thermochemical Conversion of Biomass to Fuel and Other Value-Added Chemicals." *Biomass Energy Crops for Power and Heat Generation in Illinois.* University of Illinois, Champaign-Urbana. January 12, 2006.

²⁷ E3 Biofuels, Mead, Nebraska facility. <http://www.e3biofuels.com/press/official-launch.php>

Biomass Energy Opportunities in San Benito County

The annual energy use for San Benito County was estimated to be 7,200,000 MMBTU (million BTUs). That is a pretty big number but to put it in perspective, the annual national energy use is calculated to be right at 101.6 quadrillion BTUs.²⁸ San Benito's annual energy use could be written as 0.0072 quadrillion BTUs.

As a nation, biomass energy use has risen from 2.817 Quads (quadrillion BTU) in 2003 to 3.615 Quads in 2007. On the one hand that is a 28 percent increase in five years or an average of nearly 6 percent growth each year. In the big picture though, biomass energy provided 3.615 Quad of energy in 2007, or only 3.6 percent of the US, 101.6 Quad energy use.


A goal of this project was to identify as much available biomass materials as possible to replace the 7,200,000 MMBTU of estimated annual energy use from fossil fuels (ancient biomass). AB 32 calls for reduction of greenhouse gas emissions back to 1990 levels by 2020.

Achieving the reductions outlined in AB 32 will require increased use of both carbon neutral and carbon negative kinds of energy fuels. Biomass energy production will play a significant role. It will also require more conservation. Technology is helping with this by providing newer cars that have greater fuel efficiency, houses that require fewer emissions to build and that are better insulated requiring less energy (fewer emissions) to maintain.

General Biomass Energy Production

For most folks, 7,200,000 MMBTU of energy is just a number without much relevance to everyday life. To give it some perspective, this amount of energy can be replaced with the production of 55 million gallons of biodiesel fuel. Alternatively, this equivalent amount of energy could be generated by a 268 MW electrical power plant. These facilities are within the technological scope of commercial energy production. There is little preventing a facility of either

²⁸ Renewable Energy Consumption and Electricity Preliminary 2007 Statistics, Table 1: US Energy Consumption by Energy Source, 2003-2007. Energy Information Administration. Department of Energy (DOE). May 2008. http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table1.pdf.

size from being constructed in San Benito County. The difficult part comes from trying to feed local materials into projects of this .

The California Biomass Collaborative data became the foundation for available biomass in San Benito County. Using county-level reported units (acres, animals, etc.) the real data is transformed first into Gross Biomass. The Gross Biomass was transformed into Technical Biomass which is a measure of what is effectively available. This data takes into account agronomic and ecological requirements, terrain limitations, and political constraints.²⁹ It also factors in physical constraints on harvesting, transport, storage, and handling of the biomass materials.

This biomass inventory relies heavily on the coefficients and assumptions based on the California Biomass Collaborative.³⁰ The Collaborative goes into great depth collecting the best local data and using the current understanding of biomass energy production to create their state and county level estimates.

As presented in Table 7 San Benito County produces the second smallest quantity of biomass that is appropriate for thermal conversion in the State (just 0.25 percent of the State's biomass). Other Central Coast RMDZ Counties are highlighted in green. All produce less than 1 percent of the underutilized biomass of California. Three other counties that border San Benito County: Merced, Santa Clara, and Fresno Counties; produce between 1 and 3.6 percent of California's underutilized, available biomass.

²⁹ The California Biomass Collaborative, "An Assessment of Biomass Resources in California, Dec. 2006. http://biomass.ucdavis.edu/materials/reports%20and%20publications/2006/2006_Biomass_Resource_Assessment.pdf.

³⁰ The California Biomass Collaborative/Tools/Biomass Resources Data (2007). <http://biomass.ucdavis.edu/bfrs.html>.

Table 7 County estimates for California biomass production (2007, CA Biomass Collaborative)

County	Total Biomass	Biomass for Thermal Conversion	Biomass for Conversion (Percent)
Alpine	33,700	33,000	0.127%
San Benito	80,100	64,100	0.247%
Marin	106,800	67,500	0.260%
Mono	112,200	108,400	0.417%
San Francisco	144,600	109,900	0.423%
Solano	169,000	121,400	0.467%
Inyo	147,200	136,500	0.525%
Santa Cruz *	147,600	137,300	0.528%
San Mateo	186,800	153,300	0.590%
Amador	162,000	154,400	0.594%
Del Norte	168,800	160,900	0.619%
Mariposa	172,100	164,800	0.634%
Yolo	199,400	177,900	0.685%
Sierra	196,100	193,800	0.746%
Santa Barbara	232,800	193,900	0.746%
Contra Costa	290,100	195,400	0.752%
Yuba	227,700	213,400	0.821%
Napa	224,100	214,000	0.824%
San Luis Obispo *	252,500	215,900	0.831%
Sutter	235,400	228,000	0.878%
Monterey *	288,100	234,200	0.901%
Ventura	293,700	238,300	0.917%
Imperial	444,300	254,600	0.980%
Glenn	287,300	254,800	0.981%
Kings	495,500	257,600	0.992%
Calaveras	269,400	260,100	1.001%
Merced +	708,500	274,500	1.057%
Lake	291,900	287,700	1.107%
Alameda	367,400	293,600	1.130%
Placer	341,000	322,900	1.243%
Nevada	328,600	323,800	1.246%
Colusa	348,000	340,600	1.311%
Sacramento	474,900	345,900	1.331%
Stanislaus	672,700	347,700	1.338%
Tuolumne	387,400	371,500	1.430%
Santa Clara+	467,000	380,000	1.463%
Tehama	406,200	382,200	1.471%
Madera	527,300	405,100	1.559%
Modoc	456,800	435,200	1.675%
Sonoma	555,600	482,200	1.856%
San Joaquin	759,100	535,200	2.060%
Butte	584,500	570,300	2.195%
El Dorado	587,700	578,300	2.226%
Tulare	1,290,500	595,400	2.292%
Plumas	675,900	670,900	2.582%
Orange	1,023,400	673,200	2.591%
Lassen	706,200	691,600	2.662%
Riverside	1,019,700	709,500	2.731%
Trinity	742,300	740,800	2.851%
Kern	1,060,000	805,800	3.102%
Fresno+	1,317,800	934,900	3.599%
Shasta	955,900	937,000	3.607%
San Diego	1,210,900	955,100	3.676%
San Bernardino	1,359,600	1,034,100	3.980%
Siskiyou	1,137,100	1,116,600	4.298%
Mendocino	1,291,100	1,281,300	4.932%
Humboldt	1,363,600	1,331,700	5.126%
Los Angeles	2,822,900	2,192,400	8.439%
State Total	32,055,000	25,980,000	100%

* The Central Coast RMDZ includes Santa Cruz, San Luis Obispo, and Monterey Counties.

+ Other counties that boarder San Benito County include: Merced, Santa Clara, and Fresno County.

Summary of San Benito Annual Biomass Energy of Available Feedstocks

These available annual estimates are summarized in Table 8. The available energy in the local biomass is estimated at 1,717,503 MMBTU per year. This is 23.9 percent of the total annual estimated energy consumption for San Benito County. The evolution of all these estimates is explained in detail in Appendix E.

Table 8 Summary of San Benito County biomass energy content

Source	MMBTU
Current CA Biomass Collaborative	907,765
MSW	239,509
Future Crops	543,272
Waste Vegetable Oil	26,957
Total Biomass Energy	1,717,503
Total San Benito Energy Use	7,200,000
Percent Energy Offset with Biomass	23.9%

Other Critical Considerations

- **Conversion Efficiencies** Converting these raw materials into usable energy requires energy to do so. Conversion of firewood to heat has a 60 percent conversion efficiency.³¹ So 40 percent of the input energy is lost in the conversion process. Coal has a 75% conversion efficiency. Wood fuel pellets have an 80 percent heat conversion efficiency. Natural gas has a heat conversion efficiency of 85 percent.

Electrical generation is even less efficient. Biomass to electricity through a more efficient process of integrated gasification/combined cycle (IGCC) is about 35 percent efficient while more conventional systems closer to 25 percent efficient.³² Electricity is very efficient once it is created. Non-biomass sources of electricity generation may make a valuable contribution.

If all biomass was converted to heat production with a conversion efficiency of 80 percent, the maximum biomass energy produced would be 1,374,003 MMBTU of energy. This represents a maximum of 19 percent of the total energy use (7,200,000 MMBTU).

- **Conservation of Energy** Another component of balancing local energy production with local energy use is conservation. California has maintained a constant per capita consumption of electricity while nationally the per capita consumption of electricity has increased. Advances in technology play a role in conserving energy. The evolution of green buildings standards with better insulation, more efficient appliances, windows that capture more solar energy and leak less; are all examples of improved technology.

One of the challenges facing San Benito County is that the average citizen drives further to work than the state average (6 minutes each way). As liquid fuel prices have spiked in June of

³¹ Energy Cost Calculator. Dennis Buffington. Pennsylvania State University.
http://energy.cas.psu.edu/ENERGYCOSTS_08.XLS

³² California Biomass and Biofuels Production Potential. Robert B. Williams. California Biomass Collaborative. Draft Report. December 2007

2008, driving has scaled back. Driving less, car-pooling, bicycling and walking influence energy consumption. San Benito County already has in place a coordinating body in the Council of Governments, <http://sanbenitorideshare.org/about.htm>.

There have been frequent attempts to raise the national fuel efficiency standards for new vehicles. Again, the record crude oil prices have placed a premium on fuel efficient vehicles. SUVs and large luxury vehicle sales have plummeted. The markets are driving the average fuel efficiency up without setting high national standards. Adopting hydrogen and electric vehicles would lower the liquid fuel use. In cases where the hydrogen and electricity were generated from renewable sources, it would also lower emissions and the carbon footprint.

- ***Non-Biomass Sources of Energy*** While this document is focused on biomass energy, the non-biomass, solar resources are too significant to leave out. California has tremendous solar resources. Plant production, and therefore biomass production, is dependent on ample solar resources. The California Energy Commission estimated the San Benito County solar energy production potential at 822,419 MW-hours per day.³³ This compares with the total county electrical use reported in Table 2 of 302,000 MW-hours per year (302,000,000 kW-hr for both residential and commercial use). The available solar energy is many times greater than the annual energy use.

Solar energy is not necessarily the least cost technology, but is available in San Benito County. Replacing part or all of the annual electrical use in San Benito with solar energy would allow utilization of biomass energy in other media (liquid or gaseous fuels).

- ***Imported energy*** There are economic benefits to producing biomass energy locally. Transportation and storage of biomass can be cost prohibitive. As long as the environmental and economic benefits outweigh the costs, importing and exporting biomass is useful in balancing resources. Food and energy availability in the US would be quite restricted if it relied entirely on locally grown energy. Moving corn in from the Midwest to power an ethanol plant, may have high costs associated with it, but if the environmental benefits are significant they can justify the cost of importing the corn.

Likewise, exporting biomass from San Benito to neighboring counties may also make economic sense. Moving biomass from San Benito to biodiesel projects in Watsonville and Gonzales, CA; MSW and other to the proposed jet biofuels project in Gilroy, CA; or moving San Benito County biomass down the proposed biomass solar power plant in Coalinga, CA; may be excellent uses of San Benito County resources.

- ***People vs. Plants*** In general, biomass is more difficult to produce in the urban areas where the population density is high. Highly concentrated populations provide concentrated waste utilization opportunities. Organic residuals and wastes though are leftovers and will always produce only a fraction of the energy available with unused feedstocks.

Biomass grows best in the farmland and open areas out away from the urban centers. Just for discussion purposes, the estimates provided by the California Biomass Collaborative were divided by respective county populations. San Benito has a relatively small population and a

³³ California Solar Resources. California Energy Commission. CEC-500-2005.072-D. April 2005. <http://www.energy.ca.gov/2005publications/CEC-500-2005-072/CEC-500-2005-072-D.PDF>

relatively small output of biomass at the county level. Table 9 indicates that there is a relatively high ratio of biomass to humans of 1.15. It is the highest in per capita underutilized, biomass production of the other counties in the Central Coast Recycling Market Development Zone: Santa Cruz, San Luis Obispo, and Monterey. San Benito County has a biomass to human ratio similar to Merced and Fresno Counties that surround San Benito County.

Table 9 Per Capita Biomass Production of San Benito County and Surrounding Counties

	Total Biomass	Biomass for Thermal Conversion	US Census 2006 Pop.	Per Capita Biomass (tons/person)
San Benito	80,100	64,100	55,842	1.148
Santa Cruz	147,600	137,300	249,705	0.550
San Luis Obispo	252,500	215,900	257,005	0.840
Monterey	288,100	234,200	410,206	0.571
Central Coast RMDZ		651,500	972,758	0.670
Merced	708,500	274,500	245,658	1.117
Santa Clara	467,000	380,000	1,731,281	0.219
Fresno	1,317,800	934,900	891,756	1.048
Counties Surrounding San Benito		2,240,900	3,841,453	0.583

Conclusions

San Benito County uses an estimated 7,200,000 MMBTU of energy annually. The biomass and residual energy resources exist to provide 1,717,503 MMBTU of biomass fuel. This biomass contains nearly 24 percent of the annual energy use for the County. When assuming 20 percent energy losses through conversion of these biomass resources to heat, 1,374,003 MMBTUs of San Benito generated biomass is available to replace the annual energy use. This is 19 percent of the annual energy use.

Achieving this level production can be accomplished by targeting biomass energy projects in the following areas:

- Dry woody vineyard and orchard prunings, processing waste and pits, including nut processing waste (shells), could be gasified for heat or electricity.
- Agricultural residuals that are currently burned, including vegetable production and solid processing wastes could be composted, gasified, pelletized or potentially developed for cellulosic fuels.
- Hardwood timber stand waste, thinnings, slash, and mill residues, can be gasified, pelletized or converted to cellulosic liquid fuels.
- The biogenic, or combustible fraction of the solid waste stream, including plastics could be gasified for heat, electricity, or liquid fuels.
- The production of new, non-irrigated energy crops such as camelina or jatropha on 10 percent of County acreage. This could include road right-of-ways, airport land, and other open acreage that would not interfere with current uses.
- This would also include utilization of all or part of the treated wastewater for use in growing intensive algae production, perhaps in the existing wastewater treatment plant percolation ponds, or for use in growing irrigated energy crops on other non-public land.

The size of the targeted project is a key to its success. Discussions should begin with the current stewards of the biomass materials (vineyard and orchard owners, hardwood owners, landfill owners, wastewater treatment operators). It is also possible to begin by targeting benefactors, such as replacing annual energy use of a school, hospital, or city/county agency. This provides a tangible target for which to provide replacement biomass energy.

Additional factors to be considered in meeting the AB 32 emission reduction goals include:

- Developing energy conservation strategies
- The additional energy available from renewable, non-biomass sources like solar and wind.
- Tracking exports of County biomass to other counties.
- Consideration of importing biomass from other counties for energy production in San Benito County.

One of the greatest challenges facing the fulfillment of AB 32 is coordination of regulations and policies. As California moves forward toward the implementation of AB 32, conflicts between California Energy Commission objectives for energy production are conflicting with the Air Resources Board objectives in nitrous oxide emissions. The delays in the conflicts only add costs. The sooner the State government can chart a manageable course, the less costly it will become.

Other added costs and economic friction from ambiguous policies stem from confusion on the production and highway taxes related to production of biofuels for personal use, as well as the laws associated with contract law for waste haulers. Often, and with increasing frequency, restaurants are granting permission to individuals for collection and use of on-site waste vegetable oil supplies. This can conflict with contracted waste haulers who rely on utilization of the collected waste oil in their business plans. When it is given away, the value of hauler utilization is reduced.

Finally, regarding the policy and administrative regulations, is the interface between public and private responsibilities. Publicly regulated wastes have to follow the established laws, which often include private contractual relationships. The challenges arise from 1) mixing publicly regulated waste streams with private unregulated biomass materials, and 2) the establishment of a publicly owned biomass energy project that competes with the private sector. Is a publically-owned wastewater treatment/biodiesel facility in competition with a private biodiesel facility that utilizes the waste fats, oils and greases without entering the public wastewater treatment facility?

These challenges are not insurmountable. Some of these challenges have already begun steps toward the inevitable resolution that will be required before the AB 32 objectives can be met. Implementation of targeted projects will allow San Benito County to make a significant contribution to reducing its greenhouse gas emissions, and meet its energy needs locally, while providing economic stimulus to the local economy.

Appendix A: Biomass Energy Motivators

There are subtle differences between the scientific and political definitions of biomass.

Scientifically, biomass is carbon-based material derived from plants. Politically and legally there are more restrictions. A restrictive qualifier is that biomass is “recently” created. This eliminates fossil fuels (crude oil, natural gas and coal). Other qualifiers are related to traditional legal definitions of waste and remediating pollution. Some economic challenges are created because the legal definitions do not match the technical reality.

Under federal law, biomass is legally defined as, “any organic material that is available on a renewable or recurring basis.”³⁴ The Agriculture Title of the US Code of Regulation explicitly defines the term “biomass” to include:

...agricultural crops; trees grown for energy production; wood waste and wood residues; plants (including aquatic plants and grasses); residues; fibers; animal wastes and other waste materials; and fats, oils, and greases (including recycled fats, oils, and greases).

It also excludes paper that is commonly recycled, and unsegregated solid waste. California has a legal definition of *biomass conversion* that is related to solid waste diversion credit.³⁵ Physically and chemically paper and MSW are also biomass materials, but legally in California energy made from recyclable materials and solid wastes not listed above are referred to as a biomass *transformation* and does not count as a solid waste diversion credit.

The differences between these technical and legal definitions can be a barrier to biomass energy development. The greater the differences are, the more costly the adoption. Within the context of solid waste, the above legal definitions are still workable. Definitions of biomass conversion and transformation facilitate the documentation of solid waste diversion. However as the legal priorities shift to carbon mitigation, new statutes may take a precedence over the current legal prioritization. In this report, the focus is first on the technical possibilities for biomass energy, and less on the existing legal definitions. The policies and laws will shift and adapt over time.

A.1 Fundamental Biomass Characteristics

³⁴ USC Title 7, Chapter 107 - Renewable Energy Research and Development, Section 8101.
http://caselaw.lp.findlaw.com/cascode/uscodes/7/chapters/107/sections/section_8101.html

³⁵ California Integrated Waste Management Board (CIWMB), Biomass Diversion Credit website. The actual statutory language reference is at the bottom of the website
<http://www.ciwmb.ca.gov/LGCentral/Basics/Biomass.htm>

Biomass feedstocks have a specific and limited chemical footprint. Chemically there is relatively little difference between different kinds of raw plant materials. Virgin biomass has fewer risks and surprises than ancient fossil carbon. New biomass has even fewer risks than recycled or used waste carbon. Biomass: sugars, starches, fats and fibers; has mostly provided benefits like food and clothing to man for thousands of years.

The basic elements of various biomass materials are presented in Table A.1. These are: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), chlorine (Cl), and ash. But with the exception of ash content, the percent composition by dry weight is relatively similar across the different kinds of biomass.

Table A.1 Chemical properties of selected biomass (adapted from Robert Brown, 2003)³⁶

Biomass	Ultimate Analysis (% wt., dry)						
	C	H	O	N	S	Cl	Ash
Alfalfa Straw	46.76	5.40	40.72	1.00	0.02	0.03	6.07
Black locust	50.73	5.71	41.93	0.57	0.01	0.08	0.97
Corn cobs	46.58	5.87	45.46	0.47	0.01	0.21	1.40
Corn Stover	43.65	5.56	43.31	0.61	0.01	0.60	6.26
Corn Grain	44.00	6.11	47.24	1.24	0.14		1.27
Douglas fir	50.64	6.18	43.00	0.06	0.02		0.01
Manure (cattle, fresh)	45.40	5.40	31.00	1.00	0.30		15.90
Municipal solid waste	47.60	6.00	32.90	1.20	0.30		12.00
Oak bark	49.70	5.40	39.30	0.20	0.10		5.30
Orchard prunings	49.20	6.00	43.20	0.25	0.04		1.38
Hybrid poplar	48.45	5.85	43.69	0.47	0.01	0.10	1.43
Refuse-derived fuel	42.50	5.84	27.57	0.77	0.48	0.57	22.17
Sorghum stalks	40.00	5.20	40.70	1.40	0.20		12.50
Sudan grass	44.58	5.35	39.18	1.21	0.08	0.13	9.47
Switchgrass	47.45	5.75	42.37	0.74	0.08	0.03	3.50
Vineyard prunings	48.00	5.70	39.60	0.86	0.08		1.41
Wheat straw	43.20	5.00	39.40	0.61	0.11	0.28	11.40
Yard waste	41.54	4.79	31.91	0.85	0.24	0.30	20.37

It is when these materials or elements from these materials appear in the environment in excess of what can be assimilated, that there is an environmental problem. This is true even for the food that sustains us. If a truck-load of corn is dumped into a stream, it would kill the fish and create algal blooms just as dumping manure in the stream would. The elements of biomass are not

³⁶ Brown, Robert, *Biorenewable Resources: Engineering New Products from Agriculture*. Iowa State Press. Ames, IA 2003.

inherently toxic when in balance. When residual elements of biomass are out of balance, then there is a legitimate environmental challenge.

Conversion technologies influence emissions as much as the chemical composition does. Many of the hazardous materials that are air emission concerns are based on the industrial synthesis of chemicals or in the refining of fossil fuels. Conventional wastewater treatment discharges essentially all the material energy entering the technology, Figure A.1.³⁷ Landfills retain nearly all the solid waste entering the technology. The only emissions are ‘leakage’ (biogas and leachate).

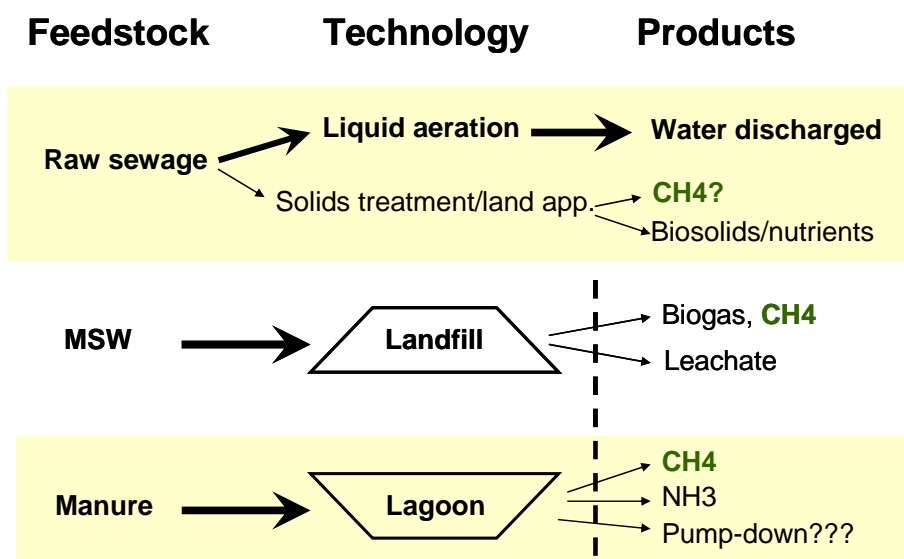


Figure A.1 Processes of waste treatment

These three components: feedstock quality, conversion technology, and products output; are the determinants of environmental risk associated with biomass emissions. The feedstocks and technologies both contribute to the risks and benefits of the associated outputs.

The three wastes described in Figure A.1 are based conceptually on traditional management of these three waste streams. Moving the technical aspects into the current policy (regulatory) process begins to complicate bioenergy opportunities. Bioenergy plants that interact with multiple technologies, do not fit the current permitting system well. For instance if gray water from Wastewater Treatment Facilities (WWTF) is used as a water supply to an energy project, or

³⁷ "Permission to Emit." Mark Jenner. Indiana Office of Energy and Defense Development, Pending.

methane generated at both the WWTF and energy project get channeled into a gasifier or other power generator; a single project can span air, water and likely solid waste permit authorities. The current regulations are not equipped to accurately define such risks and benefits.

Bioenergy projects like conventional ethanol and biodiesel facilities, tend to have less complex feedstocks and simpler technologies, lowering the emissions risks. Physically, chemically, and biologically biomass is simple, safe and provides significant economic, energy and environmental benefits. It will take time, continued research, and effort, for the existing permitting framework to adapt to the new bioenergy reality.

A.2 Energy Drivers

Not since the US Energy Crisis of the '70's, has the US had to face a new and increasing value of oil and conventional motor fuels. In just the last five years, spot prices for crude oil in Cushing, OK have risen from \$20 per barrel to \$100 per barrel (Figure A.2). That is a five-fold increase. The price of crude oil topped \$70 per barrel in 2005 due to hurricanes damaging the oil and gas infrastructure in the Gulf of Mexico, and pipeline damage in Alaska and Canada. Up to that time, \$40 per barrel had been used as 'upper limit' in all biomass energy economic analyses. With the energy price shocks of 2005, the feasibility of biomass energy snapped into focus.³⁸

While the price of crude oil has increased five times, the price of reformulated gasoline in California increased from \$1.20 per gallon in 2002 to nearly \$3.60 per gallon in 2007 (Figure A.3). The average price for reformulated gasoline in California stayed 20 to 50 cents per gallon higher than the average price paid across the country.

³⁸ While the energy price charts presented here span 5 years, from 2002 through 2007, in 2008 energy prices have continued to rise with crude oil reaching \$147 per barrel before declining.

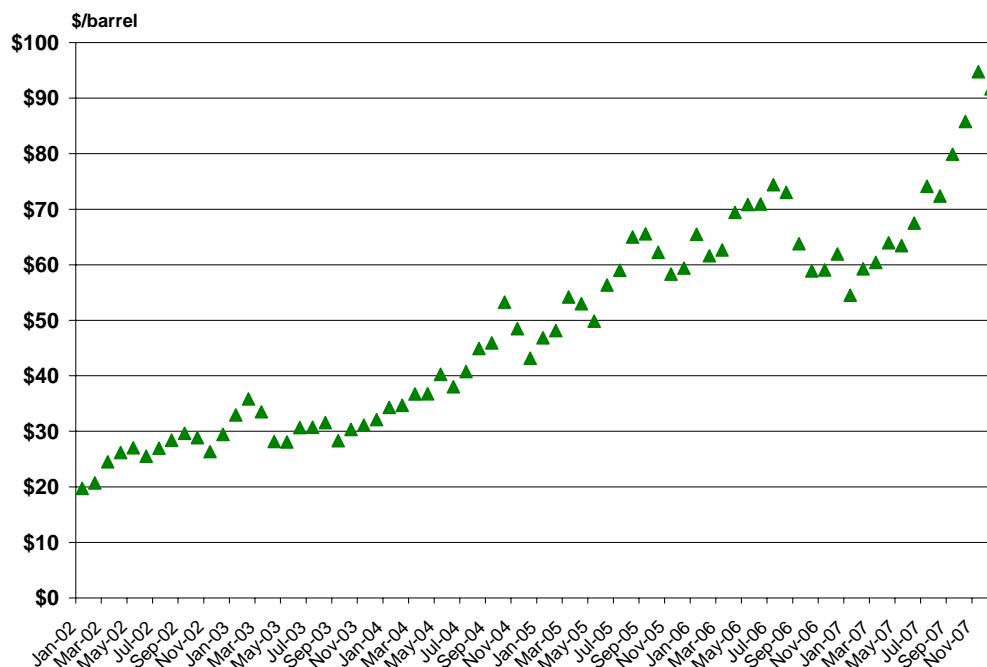


Figure A.2 Crude Oil Prices, Cushing, OK, 2002-2007, US EIA data

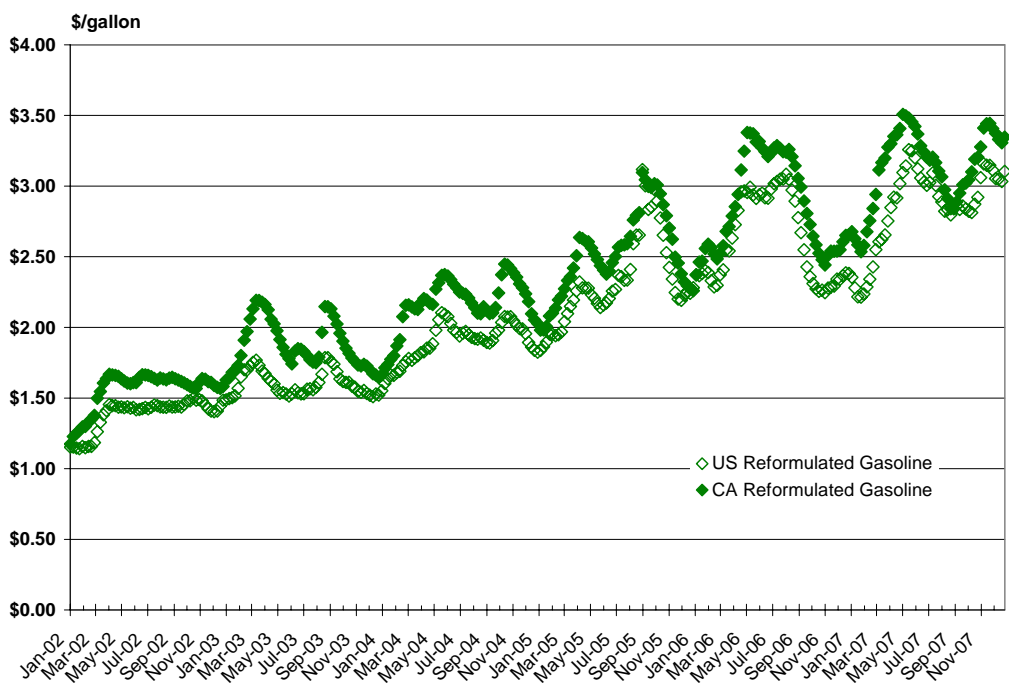


Figure A.3 US and CA Gasoline Prices, EIA data, 2002-2007

Bioenergy did not become the exciting economic wildcard until a few years ago, but we have been using biomass fuels since man learned to control fire. Until the industrial revolution the only solid and liquid fuels that were available were derived from wood, or plant oils and animal fats. As Henry Ford was developing engines for his early cars, he looked at using alcohol as a fuel.

Rudolph Diesel, father of the diesel engine, designed the diesel engine to run on vegetable oil, not fossil fuels. It was only later that the fossil-derived diesel fuel became more cost effective to produce and use.

During the energy crisis of the '70's, farmers experimented extensively with production gasohol on their farms (alcohol from grain). There were many challenges with this fledgling gasohol industry, the least of which was dealing with the very stringent alcohol production regulations. The modern ethanol industry was reportedly launched when President Jimmy Carter called the CEO of Archer Daniels Midland (ADM), and asked ADM to consider changing their planned food grade distillery in Decatur, IL to an industrial grade alcohol facility.³⁹ President Carter saw the opportunities for locally grown, corn-derived alcohol as part of the long term solution to the energy crisis.

The initial industrial ethanol production technology was referred to as a wet-mill process and produced many products besides ethanol. The prevailing ethanol technology in operation today is referred to as a dry-mill process. The technology is very specialized at producing ethanol with fewer byproducts. The cost of the dry mill technology is much lower than the more diversified wet-mill ethanol facilities. More detail on the biodiesel and ethanol processes are covered in Appendix D.

About the same time that the US oil and gas infrastructure was collapsing in 2005, California and other states across the country outlawed the use of the gasoline oxygenate, MTBE (methyl tertiary-butyl ether). The banned MTBE was replaced by adding ethanol to every gallon of gasoline. Nearly over-night, the demand for ethanol rocketed to a need for more than 4 billion gallons annual, just to fill the oxygenate uses. Investing in ethanol from 2005 until 2007 looked like a no-

³⁹ Martin Andreas, Retired Senior Advisor to CEO, ADM. "Lessons Learned & The Vision of the Future." Renewables on Parade, Washington, IA September 22, 2007.

lose business venture. Every community in the Midwestern Corn Belt was busy courting and citing ethanol plants. Even though the price of the prevailing ingredient in ethanol production, corn, is nearly double in California what it is in Iowa and Illinois, Californians needed ethanol also. Commercial ethanol plants began popping up in California also.

About August or September of 2007, the ethanol plant expansion crossed the level of production that was required to replace the MTBE oxygenate as a fuel additive. Again, almost overnight ethanol plants began shutting down. The price of corn rose to record levels. As the price of corn rose, livestock producers joined in the debate about the biofuel expansion creating an issue of food vs. fuel. By the end of 2007, the contraction of the ethanol and biodiesel production as well as difficult economic times, made the biofuel future look less than rosy.

The economic drivers are bigger than liquid fuels. In fact the environmental drivers discussed below are just as great or greater as the energy economic drivers. The prices of natural gas have been increasing at a steady but slower rate than the liquid fuels (Figure A.4). In this case, Californians have paid less than \$1 to \$4 per thousand cubic feet than the rest of the nation for natural gas.

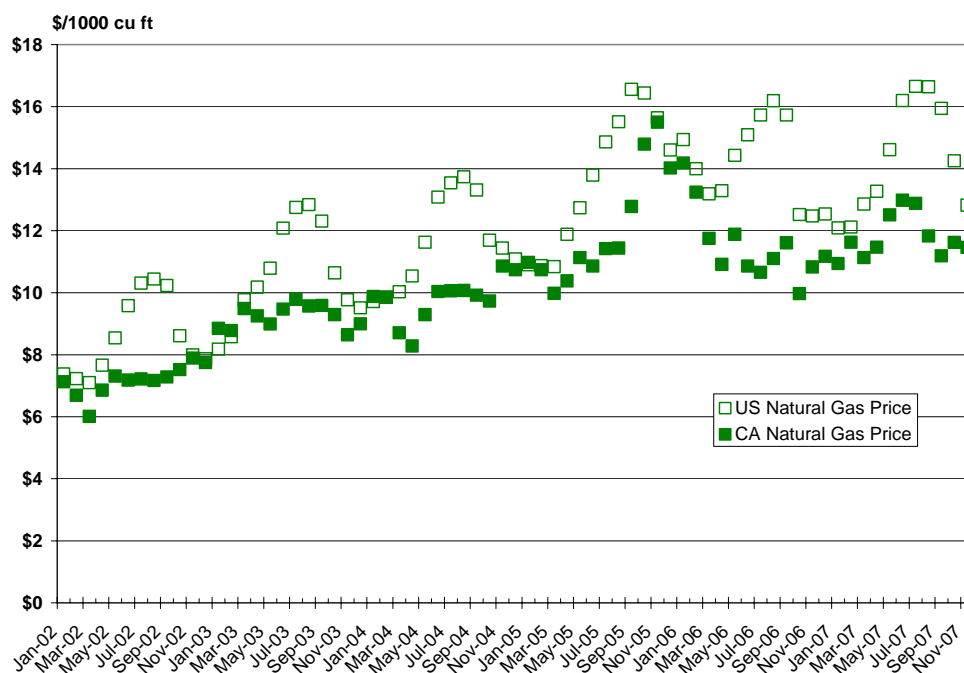


Figure A.4 Residential natural gas prices, US and CA, 2002-2007

Electricity prices in California have remained nearly constant for the last five years (Figure A.5). Although, a price of 12 cents per kilowatt-hour (kWh) is much higher than most of the nation, Californians have taken the electricity economics discussion to a new level. In the 1970's policies on building and appliance efficiency standards were implemented. Since then, appliances sold in California have become very efficient and cost effective. For appliances to be sold in California, they must meet more stringent efficiency standards.

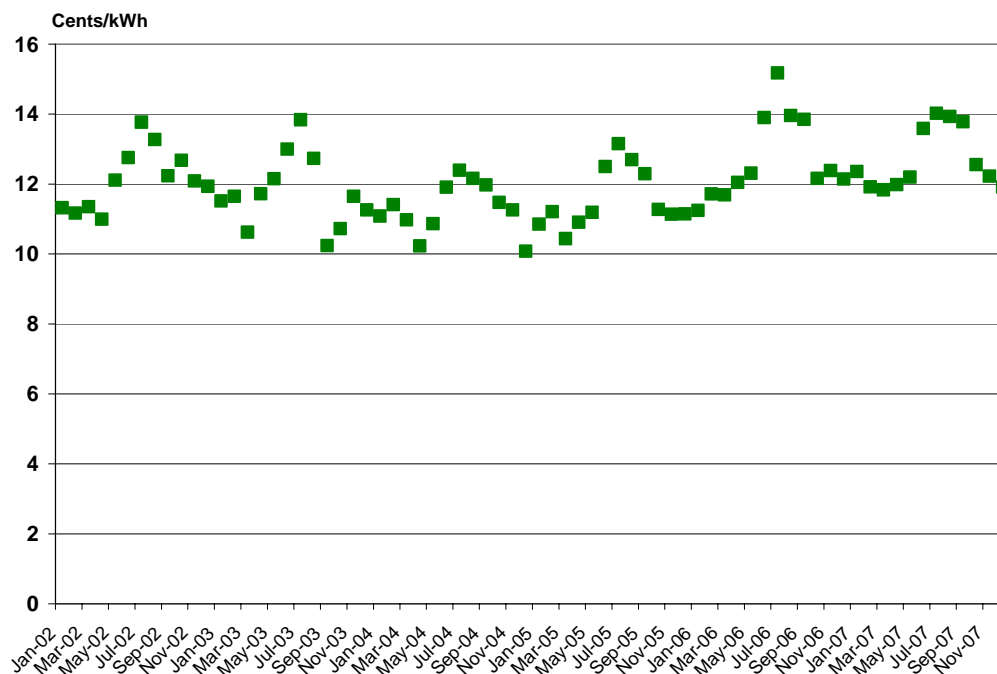


Figure A.5 California electricity prices, 2002-2007, Cents/kWh

Figure A.6 shows that on a per-person basis (per capita), the annual electricity use in California has been constant for nearly thirty years.⁴⁰ The average energy consumption per person for the rest of the country has continued to climb steadily. Another reason that California's per capita consumption has not risen as rapidly as other states is that until recently the population was clustered in large cities along the coast. Migrations inland and away from the fairer coastal climates are projected to put upward pressure on the per capita energy requirements.

⁴⁰ California Energy Commission 2007, 2007 Integrated Energy Policy Report, CEC-100-2007-008-CMF. http://www.energy.ca.gov/2007_energypolicy/index.html

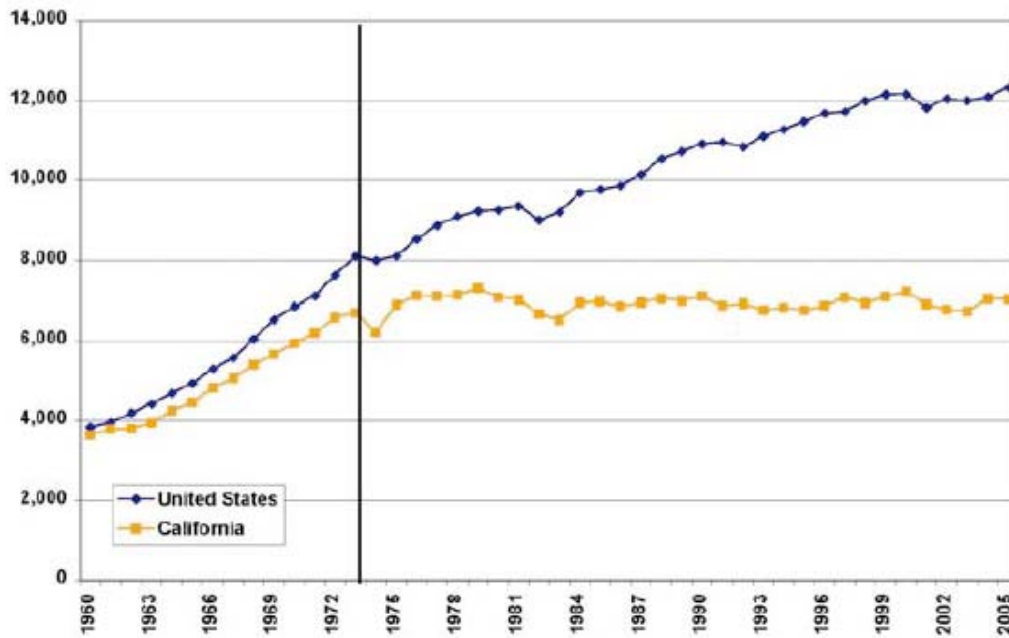


Figure A.6 Per Capita electricity sales, CA Energy Commission, IEPR

The electricity-use story gets even better for the residents of San Benito County. The State has 2005 data on electricity use by county. Dividing the reported use by the US Census Bureau county population numbers, San Benito County has the lowest electricity consumption per person in the State (Table A.2).⁴¹

⁴¹ Using the California Department of Finance population numbers, San Benito County becomes the second lowest county. At the time this report was submitted the county-level per-capita electricity sales were not available. It appeared that after upgrades, they would be available at this website. <http://energyvalmanac.ca.gov/electricity/index.html>

Table A.2 Per capita electricity consumption by county in California, 2005

County	KWh (millions)	KWh Rank	US Census 2006 Pop.	kWh/capita
San Benito, CA	302	14	55,842	5,408
Santa Cruz, CA *	1,375	30	249,705	5,506
Mariposa, CA	105	4	18,401	5,706
Marin, CA	1,421	32	248,742	5,713
Sonoma, CA	2,828	38	466,891	6,057
San Luis Obispo, CA *	1,584	34	257,005	6,163
Monterey, CA *	2,539	36	410,206	6,190
San Diego, CA	18,252	56	2,941,454	6,205
Sutter, CA	568	21	91,410	6,214
Riverside, CA	12,601	52	2,026,803	6,217
Calaveras, CA	299	13	47,722	6,265
Butte, CA	1,355	29	215,881	6,277
Mendocino, CA	566	20	88,109	6,424
San Mateo, CA	4,548	43	705,499	6,447
Nevada, CA	648	23	98,764	6,561
Yuba, CA	469	18	70,396	6,662
Orange, CA	20,171	57	3,002,048	6,719
El Dorado, CA	1,207	27	178,066	6,778
Los Angeles, CA	69,177	58	9,948,081	6,954
Ventura, CA	5,577	46	799,720	6,974
Napa, CA	944	24	133,522	7,070
Inyo, CA	128	5	17,980	7,119
Trinity, CA	103	3	14,313	7,196
Tehama, CA	446	16	61,686	7,230
Sierra, CA	25	2	3,455	7,236
Fresno, CA +	6,492	48	891,756	7,280
San Bernardino, CA	14,758	53	1,999,332	7,381
Solano, CA	3,044	39	411,680	7,394
Humboldt, CA	959	25	128,330	7,473
CALIFORNIA	272,464		36,457,549	7,473
Amador, CA	293	12	38,941	7,524
Alameda, CA	11,061	51	1,457,426	7,589
Sacramento, CA	10,574	50	1,374,724	7,692
San Joaquin, CA	5,197	45	673,170	7,720
Madera, CA	1,139	26	146,345	7,783
Tulare, CA	3,331	42	419,909	7,933
Contra Costa, CA	8,175	49	1,024,319	7,981
Lassen, CA	278	11	34,715	8,008
Santa Barbara, CA	3,214	41	400,335	8,028
Tuolumne, CA	459	17	56,855	8,073
Placer, CA	2,737	37	326,242	8,389
San Francisco, CA	6,243	47	744,041	8,391
Del Norte, CA	247	10	28,893	8,549
Yolo, CA	1,624	35	188,085	8,634
Imperial, CA	1,395	31	160,301	8,702
Shasta, CA	1,571	33	179,951	8,730
Kings, CA	1,286	28	146,153	8,799
Santa Clara, CA +	15,542	55	1,731,281	8,977
Plumas, CA	195	8	21,263	9,171
Lake, CA	622	22	65,933	9,434
Stanislaus, CA	4,837	44	512,138	9,445
Colusa, CA	236	9	21,272	11,094
Siskiyou, CA	560	19	45,091	12,419
Merced, CA +	3,054	40	245,658	12,432
Glenn, CA	363	15	28,061	12,936
Alpine, CA	17	1	1,180	14,407
Mono, CA	189	7	12,754	14,819
Modoc, CA	163	6	9,597	16,984
Kern, CA	15,370	54	780,117	19,702

* The Central Coast RMDZ includes Santa Cruz, San Luis Obispo, and Monterey Counties.

+ Other counties that boarder San Benito County include: Merced, Santa Clara, and Fresno County.

A.3 Environment

For most of the US, the primary biomass energy driver is energy and economics with the environmental benefits as a bonus. For California, the environmental benefits take a fundamental position. California has been setting environmental standards for the rest of the country for at least 30 years. And after all the environmental reform leadership implemented by California, air quality issues are still a constant concern. The existing restrictions will become more restrictive. This gives biomass energy production an advantage.

The greenhouse gas debate revolves principally around carbon. This is precisely why biomass energy plays such a significant role. The atmospheric carbon balance has been altered by the release of carbon dioxide from stored carbon fuels like coal and crude oil. As these complex carbon fuels (hydrocarbons) are burned, the levels of carbon compounds and related compounds continue to increase. This alters the atmospheric filter of solar energy striking the earth, changing the ambient temperatures enough to alter numerous ecological processes.

In the language of greenhouse gas discussions, traditional fossil-derived fuels are carbon positive. Using these fuels *adds* carbon to the working carbon cycle. AB 32 is a mandate to reduce emission back to 1990 levels. There are two ways to do that: reduce energy use, or find energy sources that remove carbon from the atmosphere. It will likely take a combination of both of those. Continuing to use carbon positive fuels at current levels will not work.

Renewable energy technologies that neither add-to or take-away-from the atmospheric carbon levels are carbon-neutral. These include solar, wind, hydroelectric, and geothermal energy. These must be part of the energy solution, because they off-set current carbon positive technologies. They neither add nor subtract carbon with use and will not make the carbon balance worse.

The foundation of the future energy supplies will need to be carbon negative. This is where biomass energy sources begin to come into their own. Plant roots and soil carbon tie up carbon and pull it out of the atmosphere. Growing more plants without harvesting them would pull more carbon out of the atmosphere faster. Biomass fuels sequester carbon, but current production practices rely on fossil fuels (ancient carbon), so they may be slightly carbon-positive or carbon-

neutral. Mixing biomass fuels with carbon-positive fuels will lower the additional carbon. The end result is that the traditional carbon positive fuel is still carbon positive, but the net additional carbon is lower. In the timeframe of 2020 mandated by AB 32, all of these options will play a role. Figure 2.7 summarizes carbon positive, carbon neutral and carbon negative fuel implications.⁴²

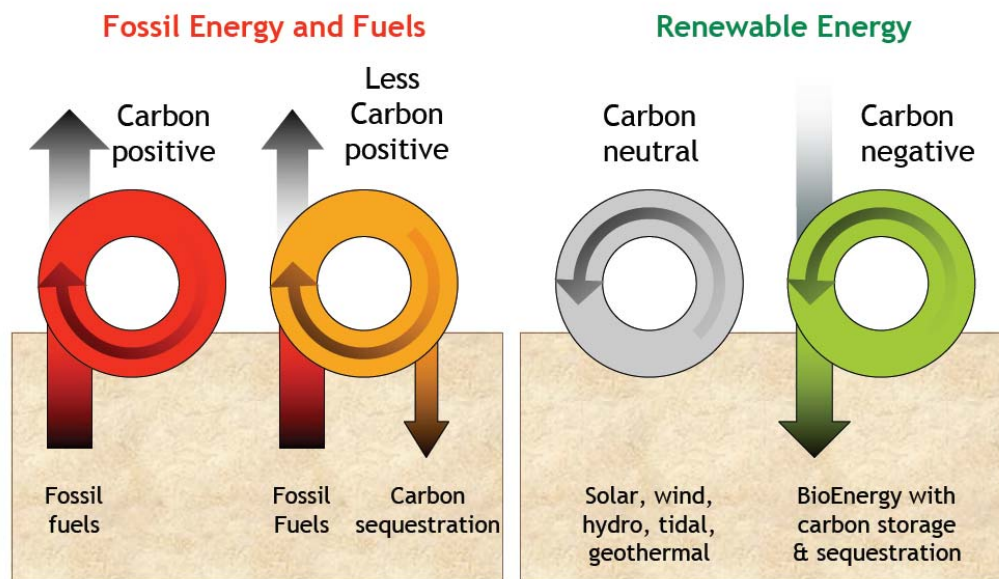


Figure A.7 The carbon balance comparison (BIOconversion/Biopact)

In California, AB 32, holds greenhouse gas emissions out in 2020 to the 1990 emissions levels. This is visually described by the California Energy Commission in Figure A.8.⁴³ To get back to the 1990 levels, it will require cleaner fuels, removal of carbon-based pollutants and the commercialization and deployment of efficient bioenergy technologies.

Cleaner bio-based fuels are part of the solution. It is recognized that ethanol, biodiesel, and gasification of biomass alone, or mixed with coal, have significant environmental benefits. It is also generally recognized that in some categories the emissions from biofuels can be greater than from fossil fuels, so biofuels are not an environmental ‘silver bullet.’

⁴² C. Scott Miller, BIOconversion Blog. <http://bioconversion.blogspot.com>, and Laurens Rademakers, Biopact Blog, <http://biopact.com/>.

⁴³ California Energy Commission 2007, 2007 Integrated Energy Policy Report, CEC-100-2007-008-CMF. http://www.energy.ca.gov/2007_energy_policy/index.html

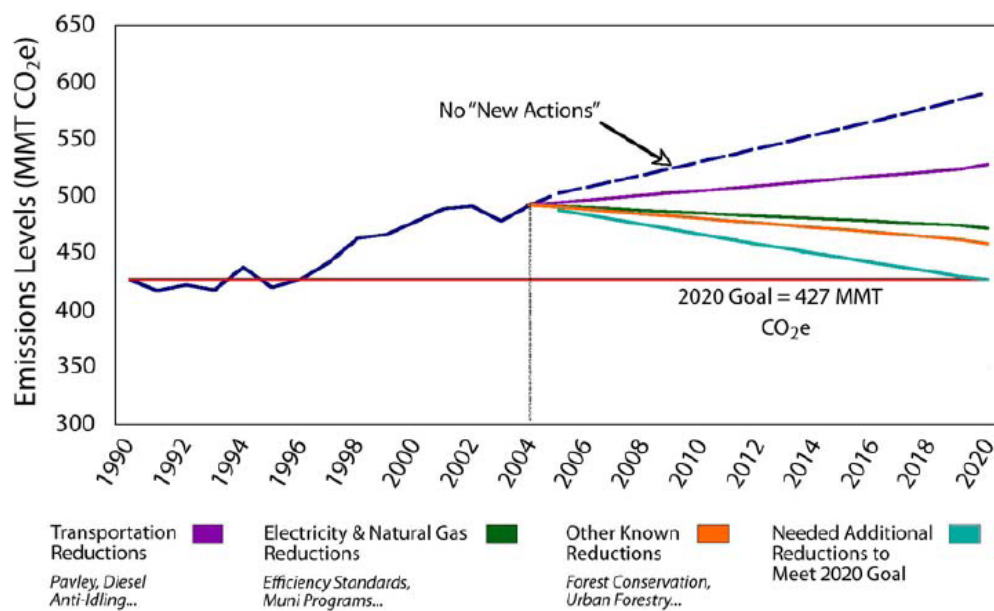


Figure A.8 Targeting AB 32, CA Energy Commission, IEPR

Gary Whitten, of Smog Reyes, credits the utilization of ethanol blended with gasoline as having a favorable air quality benefit in terms of fine particulate matter (PM_{2.5}), carbon monoxide (CO), air toxics (like benzene), and ozone.⁴⁴ It is the clean burning qualities of ethanol that have led to the replacement of MTBE as a fuel oxygenate, with ethanol blends. MTBE has been manufactured from natural gas and has been determined to be carcinogenic to humans.

Similarly, EPA recognizes biodiesel fuel and blends of biodiesel fuel with conventional diesel fuel as having significant air quality benefits in tail-pipe emissions.⁴⁵ This EPA report is an early study on biodiesel fuels derived from various feedstocks (soybeans, canola and animal fat). The report found significant reductions from 20 percent blends of soy-based biodiesel in particulate matter (-10%), hydrocarbons (-21%), and carbon monoxide (-11%, Figure A.9). The same fuel showed an increase in nitrous oxide of 2 percent. Variations in fuel source and technology influence quality of the output. For instance, animal fat-derived biodiesel had the smallest increase in nitrous oxide and the largest decrease in the other parameters.

⁴⁴ Gary Z. Whitten, PhD, Smog Reyes. Air Quality and Ethanol in Gasoline. February 4, 2004. http://www.ethanolrfa.org/objects/documents/69/nec_whitten.pdf

⁴⁵ A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. Draft Technical Report. EPA Air and Radiation. EPA420-P-02-001. October 2002. <http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf>

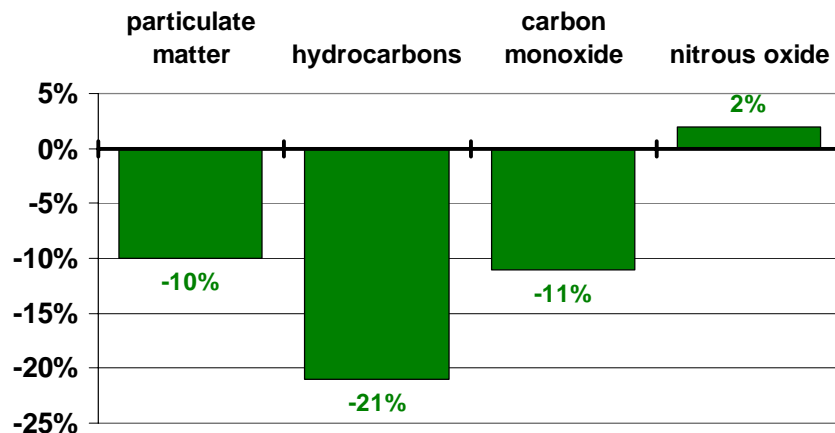


Figure A.9 Emissions from burning biodiesel fuel

The efficient, oxygen-controlled gasification processes also produce lower emissions than conventional fossil fuels. Data from tests conducted for the Rahr Malting, 20 MW biomass energy project in 2001, indicate that air quality emission reductions from gasifying biomass included reductions in sulfur dioxide, nitrous oxide, volatile organic carbons (VOC), and carbon monoxide.⁴⁶ Research at Texas A&M University has also demonstrated that co-firing dry-lot cattle manure with coal will provide reductions in both nitrous oxide and sulfur dioxide.⁴⁷

When atmospheric carbon is bound in the soil or underground – or even in permanent forests and prairies – it is considered sequestered from the atmosphere. Sequestering carbon refers to effectively removing it from the atmosphere. Like other aspects of biomass energy, the technical reality may or may not be the same as the political and legal policy framework. One principle difference between the technical reality and the policies are related to whether there is a relative gain in sequestration. Even if a landfill is burying tons and tons of carbon each year and destroying the methane gas produced, they may not get credit by generating electricity and offsetting coal-derived electricity generation if the generators were in place before 2001. This is because landfill gas power plants in place before 2001 are considered to be part of the background carbon balance.

⁴⁶ Rahr Malting 20 Megawatt Biomass to Energy Project, Feasibility Study. 2001 IN The BioTown, USA Sourcebook. Indiana State Department of Agriculture. 2006. Page 48.
http://www.in.gov/energy/pdfs/Biotown_Sourcebook_040306.pdf

⁴⁷ Manure to Energy: Understanding Process, Principles and Jargon. Saqib Mukhtar and Sergio Caparenda. Texas Cooperative Extension, The Texas A&M University System. E-428 11/06.
<http://tammi.tamu.edu/ManurtoEnrgyE428.pdf>.

Another difference has to do with whether the sequestered carbon is recorded in a voluntary carbon credit accounting system (currently in place in the US), or a mandatory system like the European Union has implemented. These carbon credit policies outline the kinds of materials and practices that are eligible and those that are not. Sequestering carbon on a technical level may not receive recognition on a legal or political level. These policies are still evolving.

A.3.1 Air Emissions California has been collecting data and quantifying emissions for several decades which provide an excellent starting reference to the opportunities and challenges in San Benito, California. Estimated air emissions for San Benito County provided by the California Air Resources Board in tons per day, are presented in Table A.3.⁴⁸ While all the categories have value, the category that is the most compelling in the biomass energy discussion is the summary of Reactive Organic Gas (ROG). The values shaded in green were listed as zero.

Table A.3 San Benito County, 2006 Estimated Annual Emissions, CA Air Resources Board

	Total Organic Gas tons/day	Reactive Organic Gas tons/day	Carbon Monoxide tons/day	Nitrous Oxide tons/day	Sulfur Oxide tons/day	Particulate Matter (PM) tons/day	PM 10 microns tons/day	PM 2.5 microns tons/day
Fuel Combustion	0.04	0.03	0.12	0.78	0.00	0.09	0.08	0.08
Waste Disposal	16.04	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	0.18	0.13	0.12	0.02	0.00	2.38	1.15	0.20
Petroleum Production	0.36	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Cleaning/Coating Surfaces	0.27	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Other Mobile Sources	0.99	0.89	5.02	1.56	0.01	0.09	0.09	0.08
Solvent Evaporation	1.30	1.23	0.00	0.00	0.00	0.00	0.00	0.00
On-Road Motor Vehicles	2.19	1.99	17.30	11.20	0.07	0.48	0.47	0.40
Farming/Managed Burning	19.51	3.26	42.43	1.40	0.01	23.51	14.55	5.40
San Benito Grand Total	40.88	8.09	64.99	14.96	0.09	26.55	16.34	6.16

Reactive Organic Gas is the most compelling in this discussion because the reactive organic gases, including methane and some volatile organic gases, can be converted into energy. When the ROG components are graphed by emission source, the significant contributors jump off the page (Figure A.10). In the conventional environmental regulatory environment, significant contributors are not a good thing. In the emerging bioeconomic environment, large sources of waste carbon are the ‘energy fields’ of tomorrow. **As underutilized, waste carbon gets pulled back into the economy as energy, it no longer represents an environmental liability.** This is exactly why bioenergy enterprises have a future – particularly if they utilize waste materials as feedstocks.

⁴⁸ 2006 Estimated Annual Average Emissions, San Benito County. CA Environmental Protection Agency. Air Resources Board. http://www.arb.ca.gov/app/emsinv/emseic1_query.php

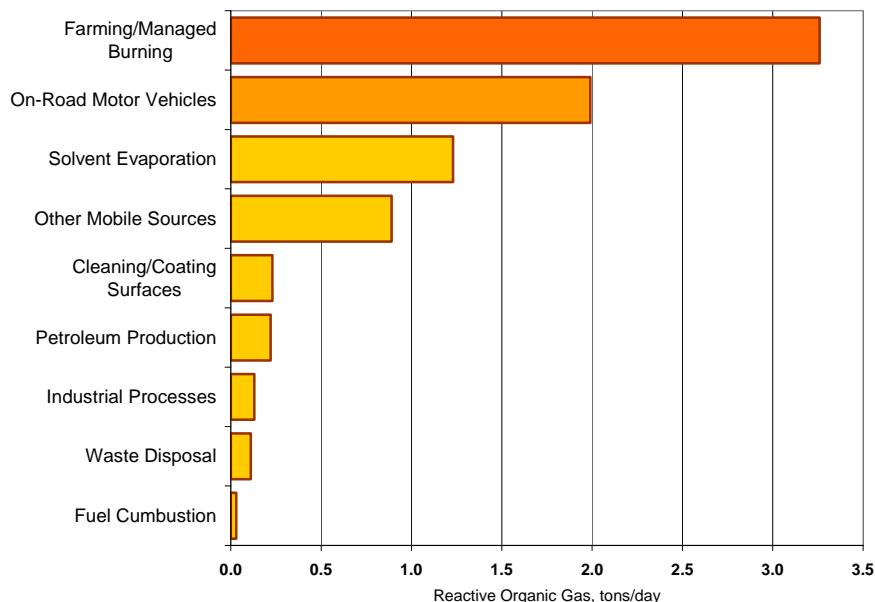


Figure A.10 Reactive Organic Gas Emission Source, CA Air Resources Board, 2006

Figure A.10 highlights that farming and managed burning are significant sources of ROG. Current sources of these ROG may be remediated through energy conversion technologies. As crop residues are combusted in field conditions, emissions occur that are more problematic than the emissions created from the controlled atmosphere of a gasifier. Converting agricultural residues from disposal burning to energy conversion will not be as simple as installing a gasifier, but there may be management alternatives that reduce ROG emissions while producing an energy product. Both On-Road Motor Vehicles and Other Mobile Sources also produce high levels of ROG. These will be reduced as biofuels become more available.

Not included in these emission numbers are the millions of acres of forest waste that have been burning across California. Wildfires could claim as much as 9 million acres in California this year.⁴⁹ These fires produce the same kind of ROG that are presented in Figure A.10. Harvesting the forest (hardwood) residuals in San Benito County would reduce ROG emissions, reduce the enormous cost of fighting fires, and provide locally available energy. The hardwood resources in San Benito County are discussed further in Appendix B.

⁴⁹ Wildfires burn through taxpayer dollars. Associated Press. Mercury News, San Jose, CA July 26, 2008. http://www.mercurynews.com/breakingnews/ci_10005687?nclink_check=1

A.3.2 Solid Waste Since the 1976 passage of the Resource Conservation and Recovery Act, solid waste agencies have been leading the way to source separation and reduction. Initial efforts to remove paper, cardboard, glass and aluminum have developed into million-dollar industry sectors built on recycled materials.

In California, since the 1989 (AB 939) the California Integrated Waste Management Act has been working on diverting materials from landfills.⁵⁰ This initial legislation created the California Integrated Waste Management Board. Diversion requirements were set at 25 percent in 1995 and raised to 50 percent diversion in 2000. As a result of the documentation of solid waste activities for the last 19 years, California has solid waste records that are not available in other states. The diversion rates attained each year since 1989 are presented in Figure A.11.⁵¹ The Estimated Statewide Diversion Tons rely on economic indicators. Those indicators changed in 2005. This is why the tons diverted are shaded differently in those two years. On the state level, diversion rates have passed the 50 percent level.

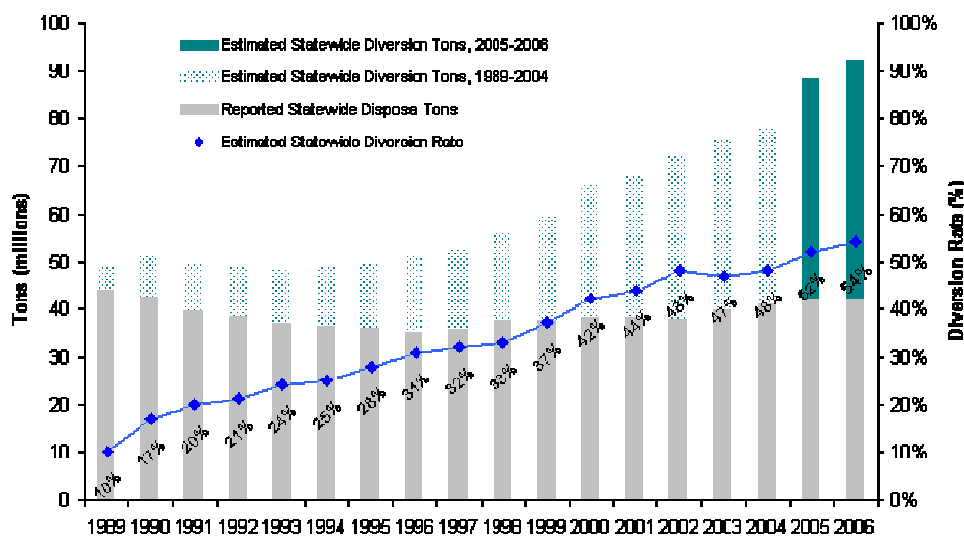


Figure A.11 Diversion and Disposal Tons in California, 1989-2006 (CIWMB)

⁵⁰ California Integrated Waste Management Board, Local Government Glossary. <http://www.ciwmb.ca.gov/LGCentral/Glossary.htm#IWMA>

⁵¹ California Integrated Waste Management Board, Local Government Central, Estimated Statewide Waste Tonnages and Rates. <http://www.ciwmb.ca.gov/LGCentral/Rates/Graphs/TotalWaste.htm>

The most detailed waste characterization data available for San Benito County is described for the 1999 waste stream. These broad waste categories are summarized in Table A.4.⁵² Tons and percentage for both residential and commercial waste streams are included. The top three categories: paper, other organic, and plastic; account for over 80 percent of the 1999 waste stream.

While plastic isn't generally included in biological assessments, it has a very high energy content (BTU) and should be included in this discussion.⁵³ It is not currently possible to pull out 100 percent of any of these three materials, but the 1999 Waste Characterization for San Benito County does provide a beginning reference from which to start.

Table A.4 San Benito County Solid Waste Stream (1999), CIWMB

	Household Tons	Household Percent	Commercial Tons	Commercial Percent	Total Tons	Total Percent
Paper	6,015	27.5%	7,446	32.6%	13,461	30.1%
Other Organic	9,860	45.0%	8,514	37.3%	18,374	41.1%
Plastic	1,938	8.8%	2,406	10.5%	4,344	9.7%
Metal	1,014	4.6%	1330	5.8%	2,344	5.2%
Glass	884	4.0%	643	2.8%	1,527	3.4%
Construction and Demolition	981	4.5%	1565	6.9%	2,546	5.7%
Household Hazardous Waste	71	0.3%	49	0.2%	120	0.3%
Special/Mixed Waste	1149	5.2%	890	3.9%	2,039	4.6%
Totals for all Types	21,912		22,843		44,755	
Totals for Carbon Waste	17,813		18,366		36,179	
Percent Carbon Waste	81.3%		80.4%		80.8%	

A.3.3 Wastewater Discharges Within San Benito County, the City of Hollister is in the midst of a major overhaul of Domestic Wastewater Treatment Plant (DWTP).⁵⁴ The Industrial Wastewater Treatment Plant (IWTP) is also included in the upgrade of treatment facilities. Municipal sewage is nearly all water which contains waste that is dissolved and suspended in the wastewater. Wastewater treatment facilities remove the waste and return the treated water to the environment. The industrial waste follows the same objective, but the waste composition is different.

⁵² California Integrated Waste Management Board (CIWMB) Waste Stream for San Benito County by material type in 1999. Residential
<http://www.ciwmb.ca.gov/WasteChar/ResComp.asp?I=625&SortBy=MatTypes> Commercial Waste Stream,
<http://www.ciwmb.ca.gov/WasteChar/wcabscrn.asp?Sector=MatlOverall&I=625&SortBy=Disposal>

⁵³ BTU = British Thermal Unit = 252 calories = 1.055 kilojoules.

⁵⁴ Long-Term Wastewater Management Program for the DWTP and IWTP. For City of Hollister, San Benito County, California. HydroScience Engineers, Inc. December 2005 .
http://www.hollister.ca.gov/site/html/gov/office/engr_wwtp.asp

The organic fraction, or carbon, is one of the primary treatment targets. Without treatment, microbial pathogens feed on wastewater organics. The conventional treatment of pathogens is directed at destroying the organics, or microbial food, to remove the threat of pathogens to humans. Aeration of the wastewater allows fast-growing benign microbes to consume the organics and prevent pathogen growth. The measure of organic “power” is biological oxygen demand (BOD) and represents the amount of biological activity in a fixed time period. There are other measures of wastewater quality, but BOD in this document will be used to discuss the organic energy component of the wastewater.

The wastewater characteristics of domestic and industrial influent are presented in Table A.5. This data is prior to the wastewater treatment facility upgrade from 2005. Not all the data has been presented, but with the facility upgrade completed the most compelling data will now be the flow into the facility (which also approximates the flow out of the facility) and the acres of land available for wastewater treatment.

Table A.5 Hollister Domestic and Industrial Waste Water Characteristics

Characteristic	DWTP Level	IWTP	IWTP
		Canning Season	Non-Canning Season
Raw Influent Flow	2.69 MGD (million gal/day)	6.10 MGD	2.60 MGD
Raw Influent Peak	4.00 MGD		
Raw Influent BOD	270 mg/L	1,200 mg/L	350 mg/L
Raw Influent TSS	315 mg/L	NA	350 mg/L
Percolation Beds - Number	15 beds		4 beds
Percolation Beds - Area	55.5 acres		36.1 acres

The initial DWTP wastewater treatment facility utilized algae to aerate and provide oxygen to the sewage. When the population of Hollister grew very rapidly over the last two decades, this low-energy, biological treatment technology was not sufficient. Although the initial design did not prove to be adequate, it was a very reasonable choice when it was initially selected as the treatment technology.

The new DWTP wastewater treatment plant has gone through a major public review and construction process. The new technology has just come on line in 2008. As the treated wastewater characteristics become established there may still be opportunities to further enhance

energy conservation and production. One possibility may be that the 90 acres of percolation ponds, could serve as an excellent container for intensive production of algae for biofuels.

A.4 Annual Energy Use of San Benito County

Just as California has set environmental benchmarks on air (greenhouse gas), solid waste (landfill diversion) and wastewater (BOD) benchmarks, it is important to have an energy consumption benchmark to target. A convenient measure for energy value is a BTU.⁵⁵

The US Department of Energy (DOE) does a nice job summarizing energy facts for each state. Table A.6 is based on the DOE data for California.⁵⁶ The electricity values are based on the documented electricity use in San Benito County (2005).

Table A.6 Estimated Annual Energy Use of San Benito County, million BTU (MMBTU, 2005)

Fuel	Annual Consumption	Energy Conversion	California MMBTUs	San Benito MMBTUs
Gasoline	381,301 thousand bbls	5,250,000 BTU/barrel	2,001,800,000	2,200,000
Distillate Fuel	96,902 thousand bbls	5,825,400 BTU/barrel	564,500,000	600,000
Liquified Gas	12,375 thousand bbls	3,834,600 BTU/barrel	47,500,000	100,000
Jet Fuel	104,612 thousand bbls	6,287,400 BTU/barrel	657,700,000	700,000
Natural Gas	2,292,056 million cu ft.	1,027 BTU/cu ft.	2,353,900,000	2,600,000
Residential Electricity	115,000,000 kW-hr	3,412 BTU/kWh		400,000
Commercial Electricity	187,000,000 kW-hr	3,412 BTU/kWh		600,000
Total Annual Energy Consumption				7,200,000

In Table A.2, San Benito County total electricity consumption in kWh was 0.11 percent State electricity consumption (kWh). This energy differential was multiplied by the liquid and gas fuel use documented at the State level to establish county-level values of energy use. Based on these assumptions, San Benito consumed 7,200,000 MMBTUs of liquid fuel, natural gas and electricity. While this value is based on the electrical use in San Benito County, rather than actual values of liquid fuels and natural gas, it serves as a basic starting place for energy replacement discussions in San Benito County. Without better data, the value could just as arguably be lower as well as higher.

⁵⁵ BTU = British Thermal Unit = 252 calories = 1.055 kilojoules. One million BTU = 1 MMBTU.

⁵⁶ US Department of Energy, Energy Information Administration, State & US Historical Data, California. http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA

Consumption of 7,200,000 MMBTUs will be challenging to replace. However, whatever percent of San Benito County energy is replaced by biomass energy will also bring reductions in air emissions, wastewater discharges and landfilled material, as well as off-set the fossil energy currently used to manage those activities.

The physical requirements to generate the estimated annual energy consumption of San Benito are listed in Table A.7. The facilities required to replace San Benito's energy use are tangible and could be replaced in with commercial units. Each energy option listed represents what it would take to generate 7,200,000 MMBTU for each kind of facility. The real challenge for San Benito County is how to generate the biomass fuel to power any of these options.

Table A.7 Equivalent biomass energy project required to generate 7,200,000 MMBTUs

Ethanol Capacity, million gallons per year	95
Biodiesel Capacity, million gallons per year	60
Power plant generation capacity, MW	270

In the Midwest, a productive acre of corn can produce about 500 gallons of ethanol. Two thousand acres could produce a million gallons of ethanol. So it would take about 185,000 acres of 180-200 bushel per acre corn to produce enough ethanol to offset the annual energy use of San Benito County. Soybeans produce just under 60 gallons of biodiesel fuel per acre. It would take 1,000,000 acres of soybeans to offset the County's annual energy use.

Using electricity as a reference, the current 26 operating biomass power plants in California produce nearly twice the County's energy use, so 13 biomass power plants would supply the annual energy needs. The electricity could be generated by landfill gas. An average landfill gas generator with 4 MW of generating capacity would require enough landfill gas to power 68 generators. Based on the national average for landfill gas power plants, that would require about 70 landfills.

Offsetting San Benito County's annual energy use with biomass will not be easy, but it is a worthwhile goal. Even offsetting 20 percent of the annual energy use would provide the residents of San Benito County with significant economic and environmental benefits – as well as a margin of energy independence.

Appendix B: San Benito County Land, Human and Biomass Resources

Biomass is considered to be recently created plant material, but biomass materials may not look like a plant any longer. These biomass resources may include solid waste, wastewater, and wood residuals. To gain a better perspective of biomass energy potential it is important to also review the land and human resources in addition to the biomass resources.

B.1 San Benito County Land Resources

An appropriate starting place is the land base of San Benito County. San Benito County has a surface area of 888,997 acres with 578,351 acres in farmland.⁵⁷ The USDA Census of Agriculture, land use category of 'Land Not in Farms' includes all non-private land that is not a farm. It includes the public, non-farm land, waste land, as well as the urban and industrial areas. Figure B.1 shows that cropland uses 9 percent of the county land. Rangeland uses 49 percent of the county. Other farmland makes up 7 percent, and Land Not in Farms is 35 percent of the county.

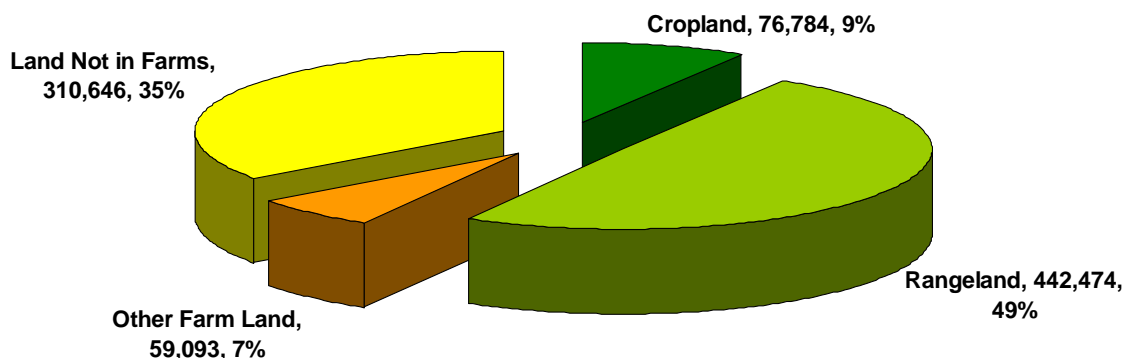


Figure B.1 Land use in San Benito County, 2002 USDA Census of Agriculture (acres, %)

San Benito County lies between the Central Valley to the east and the coastal environment to the west. As California counties go, San Benito's 888,997 acres account for 0.9 percent of the State's land mass, Table B.1. Out of the 58 counties in the state, San Benito is ranked as 35th largest in area, with 23 counties that are smaller. Considering the land in farms, San Benito accounts for 2.1 percent of the State's land in farms, and ranks in the top 18 counties in terms of county land in farms. In San Benito County, 65 percent of the county is in farms, while the state proportion of

⁵⁷ USDA, 2002 Census of Agriculture. <http://www.agcensus.usda.gov/Publications/2002/index.asp>

land in farms is only 28 percent. In 2002, San Benito County ranked 29th in county value of agricultural production. The 28 states with greater value of agricultural production grew 94 percent of the State's value of agricultural production.

Table B.1 San Benito Compared with the State of California (2002)

	San Benito	California	County Rank	Percent Of State
Land in farms (acres, 2002)	578,351	27,589,027	18	2.1%
County land area (acres, 2002)	888,997	99,813,971	35	0.9%
Proportion in farms (percent, 2002)	65.1%	27.6%	9	
Value of Ag products sold, 2002	\$197,894,000	\$25,737,173,000	29	0.8%

The vegetative cover for San Benito can be viewed graphically in Figure B.2.⁵⁸ The dark green acres are where the agricultural crops are grown. The light green is labeled vegetative, but it is reflective of the rangeland grasses. The orange land is shrub land and the brown land represents predominately hardwood acres. Most of the level cropland lies along the San Benito River at the north end of the county near Hollister and San Juan Bautista. As mentioned above, about half to the county is in rangeland. The hardwood stands are scattered throughout the county.

The soils of San Benito are presented in Figure B.3 by slope.⁵⁹ The darkest green areas are the flattest (less than 2 percent slope). As the shading in Figure B.3 turns a lighter shade of green, the steepness of the prevailing soil type slope increases. The intermediate green has between a 2 percent and 15 percent slope. The lightest shade of green goes from 15 percent to 30 percent slope. On these steepest soils, for every 10 feet traveled horizontally, 3 feet will also be traveled vertically. Any soils that had a predominant slope of greater than 30 percent are shown as an array of dots. The brown cross-hatched soils are predominately rock. While 49 percent of the county is in rangeland for agricultural purposes (Figure B.1), much of that land will not grow crops.

⁵⁸ California Department of Forestry and Fire Protection website, Multi-source Land Cover Data (v02_2), San Benito County. http://frap.fire.ca.gov/data/frapgisdata/download.asp?rec=fveg02_2.

⁵⁹ USDA, Natural Resource Conservation Service (NRCS), Electronic Field Office Technical Guide, Soil Data Mart, San Benito County, California. <http://soildatamart.nrcs.usda.gov/report.aspx?Survey=CA069&State=CA>

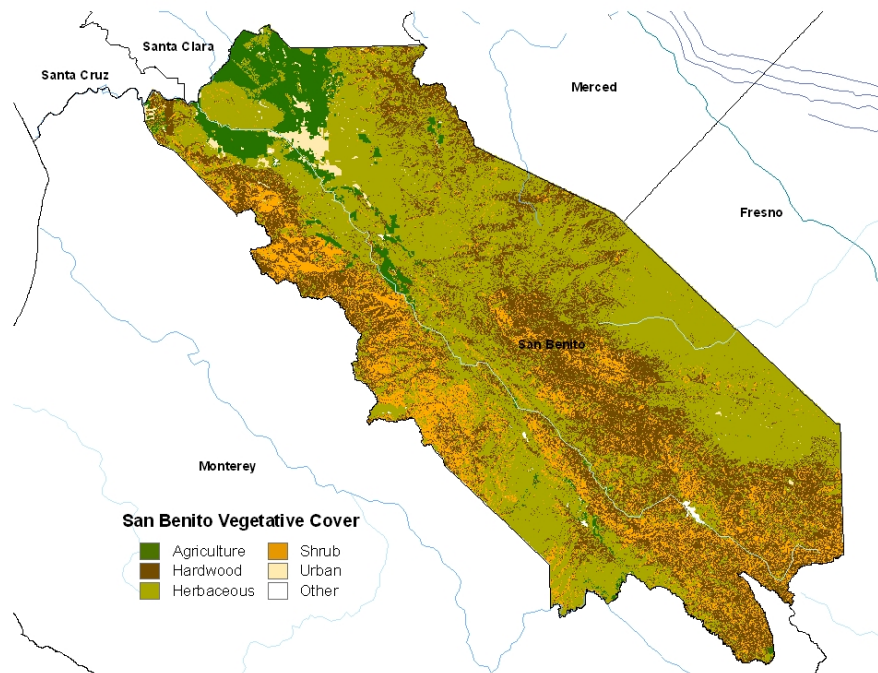


Figure B.2 Vegetative Cover of San Benito County

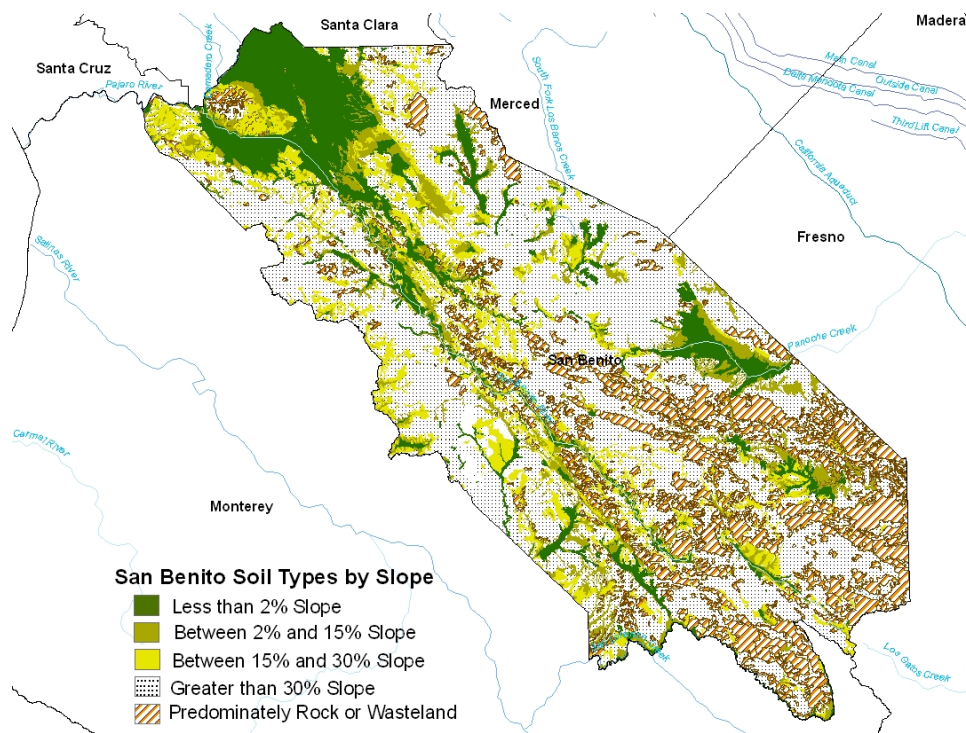


Figure B.3 San Benito Soil Types by Slope

Looking at the same information presented in Figure B.3 another way, 31 percent of San Benito County is arable with a slope of less than 30 percent (solid green shading, Figure B.4). Only 20 percent of the County has less than a 9 percent slope, and 11 percent of the County is flat. Another 18 percent is predominately rock or wasteland. And over half the County has a slope of more than 30 percent.

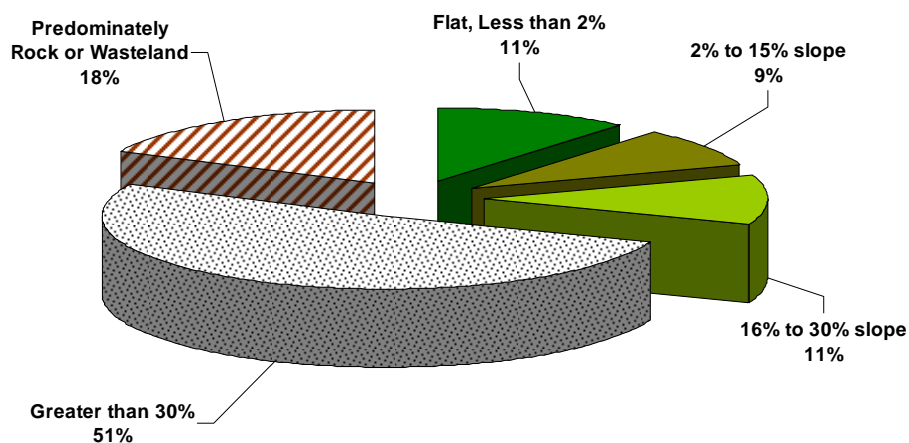


Figure B.4 San Benito Soil Types Distribution Based on Slope

San Benito County averages about 13.4 inches of rainfall during the year, with most of that falling over the winter months (Figure B.5).⁶⁰ The County also averages about 333 days of sunshine with temperatures that average between 60° and 70° Fahrenheit.

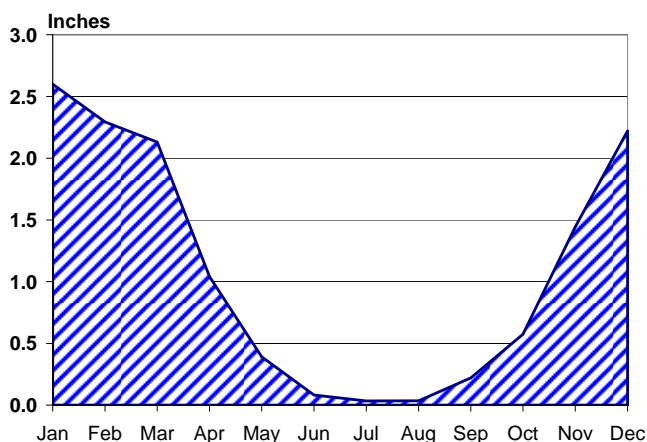


Figure B.5 Annual precipitation for San Benito County

⁶⁰ San Benito County Rainfall Records, San Benito Public Works
http://www.san-benito.ca.us/departments/dpw/rainfall_records.htm

B.2 San Benito County Human Resources

San Benito County is home to a population of 57,000 people. San Benito County is growing. Based on the US Census numbers in Table B.3, San Benito County has grown by 150 percent since 1980. The City of Hollister has grown by 180 percent and contained 62 percent of the County population in 2005.

Table B.3 San Benito County population changes 1980 to 2005.

Population	1980	1990	2000	2005
Hollister	12,473	19,212	30,387	35,452
San Juan Bautista	1,365	1,570	1,553	1,600
San Benito County	23,005	36,700	50,497	57,064

In comparison to the State of California, San Benito County has about 0.15 percent of the State population (Table B.4). This is just a fraction of one percent of the California population. The relatively small population of the county and area is likely an advantage when it comes to energy consumption. The categories in which San Benito County average statistics are higher than the State averages are highlighted in **bold green and indicated in** with the ‘>’ symbol in the last column. The other non-bold percentages indicate San Benito County statistics are smaller than the state value.

Table B.4 Selected Population and Business Statistics from the US Census Bureau.

	San Benito County	California	San Benito County as a % of State
People QuickFacts			
Population, 2006 estimate	55,842	36,457,549	0.15%
Population, percent change, April 1, 2000 to July 1, 2006	4.90%	7.60%	64.47%
Housing units, 2006	17,824	13,174,378	0.14%
Homeownership rate, 2000	68.20%	56.90%	>19.86%
Housing units in multi-unit structures, percent, 2000	11.90%	31.40%	37.90%
Households, 2000	15,885	11,502,870	0.14%
Persons per household, 2000	3.32	2.87	>15.68%
Median value of owner-occupied housing units, 2000	\$284,000	\$211,500	>34.28%
Median household income, 2004	\$57,595	\$49,894	>15.43%
Per capita money income, 1999	\$20,932	\$22,711	92.17%
Persons below poverty, percent, 2004	8.80%	13.20%	66.67%
Land area, 2000 (square miles)	1,389.06	155,959.34	0.89%
Persons per square mile, 2000	38.3	217.2	17.63%
Mean travel time to work (minutes), workers age 16+, 2000	33.7	27.7	>21.66%
	San Benito County	California	San Benito County as a % of State
Business QuickFacts			
Manufacturers shipments, 2002 (\$1000)	516,436	378,661,414	0.14%
Retail sales, 2002 (\$1000)	385,890	359,120,365	0.11%
Accommodation and foodservices sales, 2002 (\$1000)	46,459	55,559,669	0.08%
Federal spending, 2004 (\$1000)	172,960	232,387,168	0.07%

There are several compelling trends associated with this population data. First, with the explosion of population growth, there is a corresponding contraction in agricultural land and biomass production. Second, because San Benito is a quiet little community, residents of the County drive further on average than Californians in more densely populated areas.

B.2.1 Loss of Biomass Production As the San Benito County population rapidly grew in the '80's and '90's, land was required for more residences and municipal services. This growth resulted in a reduction of available farmland for agriculture and biomass production. Table B.5 shows that San Benito County lost 25,708 acres of farm land between 1987 and 1997.⁶¹ San Benito was not alone in the losses to agricultural land. San Luis Obispo lost five times the agricultural land during the same period. Monterey County also lost more agriculture land than San Benito County. Santa Cruz County did not make the list of top 20 counties that lost farmland. Population growth has slowed in San Benito County, but if the County is to move toward energy independence the conversion on farmland out of biomass production must be stopped.

Table B.5 Top 20 Counties Experiencing Agricultural Land Losses, 1987-1997

Rank	County	Acres lost
1	San Luis Obispo	-123,279
2	Riverside	-66,297
3	Kern	-47,672
4	San Diego	-44,635
5	Fresno	-43,017
6	Ventura	-41,702
7	Los Angeles	-37,450
8	Modoc	-34,009
9	Monterey	-33,706
10	Imperial	-33,198
11	San Benito	-25,708
12	Tehama	-23,279
13	Placer	-19,635
14	Sutter	-16,702
15	Butte	-13,663
16	Contra Costa	-13,663
17	Orange	-9,616
18	Yolo	-9,109
19	Sonoma	-9,009
20	San Joaquin	-7,591

⁶¹ Baseline Greenhouse Gas Emissions for Forest, Range, and Agricultural Lands in California. By Winrock International. California Energy Commission. Public Interest Energy Research Program. <http://www.energy.ca.gov/reports/CEC-500-2004-069/CEC-500-2004-069F.PDF>

Table B.4 also indicated that the travel time for San Benito County workers was 6 minutes, or 22 percent greater than average workers in California. Workers in San Benito County traveled 33.7 minutes each way to work while the average worker in the state traveled 27.7 minutes to work. That additional 6 minutes each way consumes more fuel, increasing the challenge of balancing biomass energy production with energy use.

Figure B.6 shows San Benito County in relationship to the surrounding metropolitan areas. Concentric circles have been overlaid in 10 mile increments radiating out from Hollister.

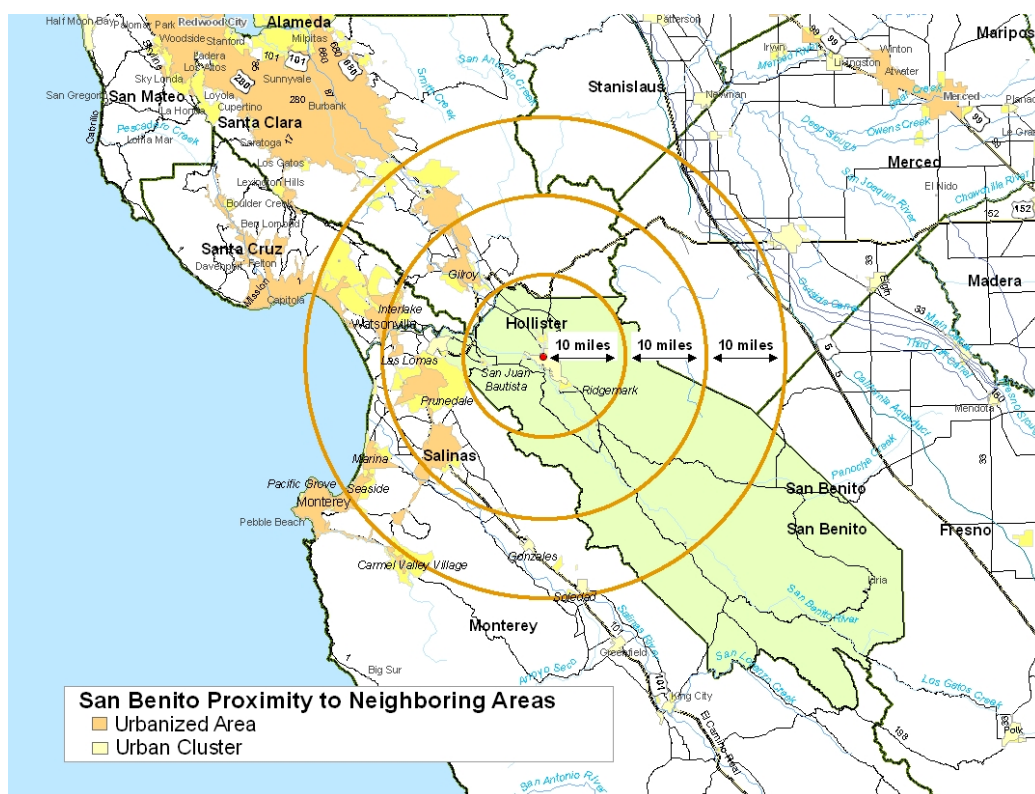


Figure B.6 Relative distances from Hollister, CA to surrounding metropolitan areas.

The separation from San Benito residents to surrounding population centers is not necessarily a negative. The neighboring communities could provide both virgin and residual biomass materials for conversion in San Benito County. Importing materials for biomass conversion may not be as self-contained in balancing energy production with energy consumption, but it should be kept open as an option. Most of the ethanol and some biodiesel plants being built in California will be importing corn and vegetable oil from other states.

B.3 San Benito County Biomass Resources

B.3.1 The Value of Agricultural Production. In 2006, the value of agricultural production in San Benito County was \$271 million dollars (Table B.6).⁶² Nine of the top 10 commodities sold in 2006 were composed of high valued nursery and food crops which had a value of \$184 million dollars and required 27,000 acres. The other commodity in the top ten was cattle. The 2006 sales of San Benito cattle had a value of \$11 million dollars and utilized 510,000 acres.

Table B.6 Value of San Benito County agricultural production, 2006

Nursery Stock	\$33,428,000	689	\$48,517
Peppers, Bell	\$28,418,000	1,696	\$16,756
Misc. Vegetables	\$25,781,000	4,787	\$5,386
Grapes, Wine	\$19,569,000	3,788	\$5,166
Lettuce, Romaine	\$18,329,000	3,057	\$5,996
Lettuce, Salad	\$18,233,000	5,159	\$3,534
Spinach	\$16,829,000	3,898	\$4,317
Onions, Dry Bulb	\$14,275,000	1,742	\$8,195
Pasture and Stockers	\$10,819,000	510,000	\$21
Lettuce, Iceberg	\$8,881,000	2,339	\$3,797
Total of Top 10 commodities	\$194,562,000	537,155	
Total of all commodities	\$270,940,000	568,889	
Top 10 as a Percent of Total	71.8%	94.4%	

With the exception of grazing cattle, the other high-valued, Top 10, agricultural commodities had an average return of \$6,800 per acre. This land is best used in its current use. The climate in San Benito County is an arid mountain climate, with sloping shallow soils and thirteen inches of annual rainfall over the winter months.

Figures B.7 and B.8 compare the distribution of commodities by value (B.7) and by acreage (B.8). In the first chart, vegetable crops account for \$168 million dollars and 62 percent of the total value of production. All cattle, on the other hand, account for \$21 million and only 8 percent of the value of production. In Figure B.8, the acreage by commodity is dominated by grazing cattle with 510,000 acres and 91 percent of the farmland. Vegetable crops only use 5 percent of the farmland (28,535 acres). The other commodities produced in San Benito County use the other 4 percent of the farmland to do so.

⁶² San Benito Count, Annual Crop Report 2006. Paul J. Matulich, Agricultural Commissioner/ Sealer of Weights and Measures, San Benito County, Hollister, California. May 2007.

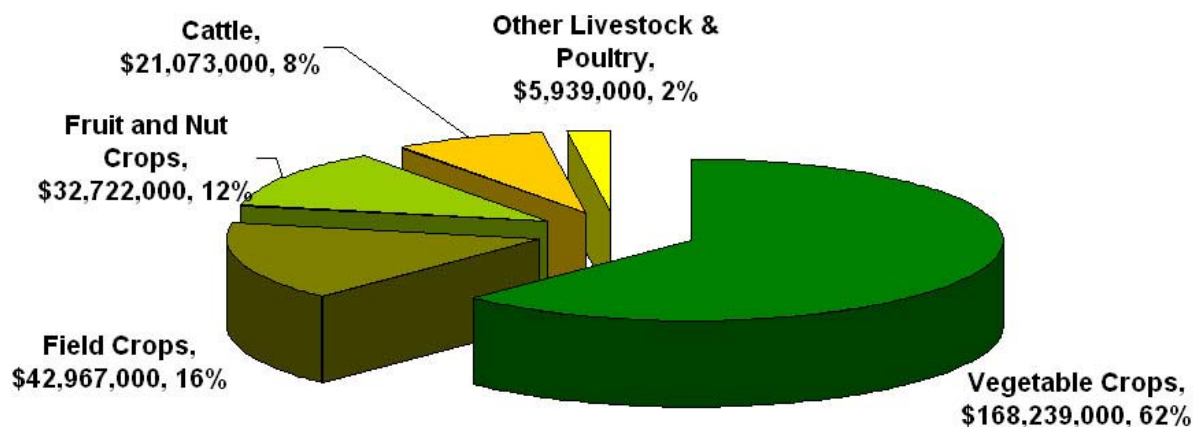


Figure B.7 Value of 2006 agricultural production in San Benito County

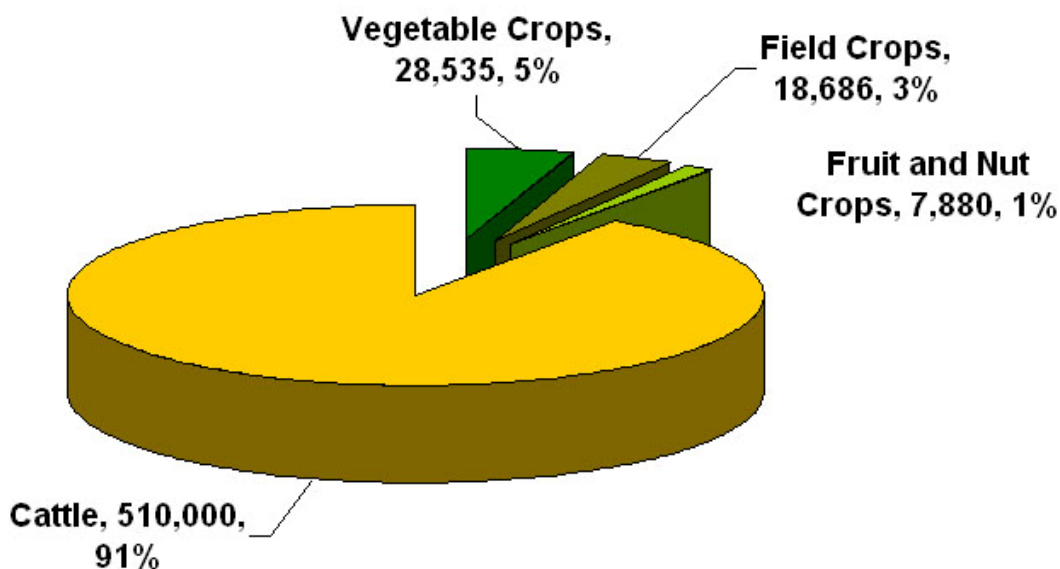


Figure B.8 Distribution of agricultural acres in San Benito (2006)

The fruit and nut crops (including wine grapes) are valuable for their respective fruits and nuts (Table B.7). San Benito County Apples, Apricots, Cherries, Grapes, Walnuts, and other fruits and nuts had a value in 2006 of \$32.7 million and used 7,880 acres. Table B.7 presents the 2006 fruit and nut crop in terms of tons per acre and also value per ton and acre.

Table B.7 2006 Fruit and Nut Production by acre and value

	Tons	Acres	Tons/acre	Value (\$)	\$/ton	\$/acre
Apples	6360	395	16.10	\$1,584,000	\$249	\$4,010
Apricots	2468	987	2.50	\$970,000	\$393	\$983
Cherries	2188	606	3.61	\$6,096,000	\$2,786	\$10,059
Grapes (wine)	15910	3788	4.20	\$19,569,000	\$1,230	\$5,166
Walnuts	1334	1905	0.70	\$2,010,000	\$1,507	\$1,055
Misc. Fruits & Nuts	---	199	---	\$2,493,000	---	\$12,528
	7,880			\$32,722,000		

In addition to the value of the marketable agricultural commodity, residuals from woody fruit and nut crops produce pruning and processing residue that can be used as biomass energy. The pruned limbs, fruit pits, and nut shells have high BTU values on a dry basis. Rotten and damaged fruit, as well as, unusable juice also has energy value as a liquid in a technology like an anaerobic digester. These residual energy opportunities will be discussed further in Appendix D.

B.3.2 Forest Biomass The California Biomass Collaborative has amassed county-level estimates of timber stands and biomass generated each year. Based on the estimates for San Benito County timber residuals amount to a total 82,000 tons of timber waste wood produced each year⁶³. Hardwood and scrub timber stand locations can be identified in the San Benito County map in Figure B.2. About half of this estimated to be technically usable (42,500 tons).

B.3.3 Municipal Solid Waste Of available sources of biomass in San Benito County, the most detailed waste data is characterized for the 1999 solid waste stream. This 1999, The California Integrated Waste Management Board (CIWMB) solid waste data was presented in Appendix A, Table A.4. That data reported 44,755 tons of residential and commercial solid waste entering the landfill.⁶⁴ The top three categories: paper, other organic, and plastic; account for over 80 percent of the 1999 waste stream (36,179 tons). While this material is not easy to separate out, it might be

⁶³ California Biomass Collaborative, 2005 County level biomass production level estimates.
<http://cbc2.ucdavis.edu/cbc/biomassResource/resourceByCounty.asp>

⁶⁴ California Integrated Waste Management Board (CIWMB) Waste Stream for San Benito County by material type in 1999. Residential
<http://www.ciwmb.ca.gov/WasteChar/ResComp.asp?J=625&SortBy=MatTypes> Commercial Waste Stream,
<http://www.ciwmb.ca.gov/WasteChar/wcabscrm.asp?Sector=MatlOverall&J=625&SortBy=Disposal>

reasonable to utilize 10 percent, or 3,618 tons. If it was possible to segregate 50 percent of the energy-laden solid waste stream for energy production, 18,090 tons could be used for energy.

An additional benefit of this direct diversion for energy production would be extension of the landfill life. If the waste stream was reduced by 10 percent, it would increase the life of the landfill by the same amount (10 percent).

B.3.4 Municipal Wastewater Treatment The newly, upgraded Hollister Wastewater treatment plant is nearing completion of the installation of new technologies. These technologies are very efficient, so some of the bioenergy opportunities from wastewater materials will be somewhat limited. There are two resources leaving the new treatment plant that may play a role in future biomass production. These are the treated water and the treated solids.

B.3.5 Waste Oil and Grease Area restaurants and groceries were queried on Yahoo Yellow Pages with the results presented in Table B.8. These facilities serve as an indicator of used vegetable oil from fryers and waste food. The ‘Restaurants’ include fast food restaurants, but they also have supplies of used oil. The first ‘Grocery Store’ column includes all groceries, including food sold at convenience stores. The second category, ‘Groceries w/ bakeries,’ represent larger stores with perhaps great quantities of food waste.

Table B.8 Local area restaurants and grocery stores

City	Restaurants	Grocery Stores	Groceries w/ bakeries
Hollister	70	20	4
Tres Pinos	4	1	0
San Juan Bautista	16	4	0
Watsonville	125	53	19
Gilroy	124	20	4
Salinas	283	88	30

This concept is being implemented in at least one neighboring community. Energy Alternative Solutions, Inc. is headquartered in Watsonville with their biodiesel plant in Gonzales, CA. Their website, www.bioeasi.com, indicates that they are also in partnership with Salinas Tallow Company, San Jose Tallow Company, and thousands of restaurants on the California Central Coast and in the San Francisco Bay Area.

This is an excellent illustration of the ease at which biomass materials can be imported and exported. Our food and fuel currently move around the globe. San Benito County would be hard pressed to consume all the vegetables it grows each year. Bringing biomass solids and liquids into San Benito County to be converted into liquid fuels, electricity, natural gas replacement, or simply as a heat source, should be included in the bioenergy possibilities. While striving for energy independence is an important goal, there are great benefits to finding economically competitive bioenergy solutions to the current fossil fuels like coal and crude oil.

B.4 Feedstock Quality and Handling

Biomass production, harvest, and storage are important components of biomass resource development. The Midwest is in the process of developing completely new harvesting and storage systems for corn stalks as a feedstock into cellulosic biofuels. One challenge is that at grain harvest, the corn stalks are much wetter than the corn. Harvesting them at the same time creates challenges for spontaneous combustion and rotting while being stored. If the corn stalks are left in the field too long after harvest, they begin to rot in the field and the energy value begins to decline very rapidly. Universities and private companies are redesigning harvest and storage systems to handle the corn stalks dry, while others are designing systems to store and handle them wet.

Most of the thermal conversion technologies discussed in Appendix D, like gasifiers, work best with very dry biomass materials. The biological and chemical conversion technologies generally work fine if there is moisture in the materials. If a thermal conversion technology like a gasifier were using corn stalks, drier corn stalks would have more value. If the conversion technology used was biological in nature like an anaerobic digester, higher moisture corn stalks would be an advantage. The key point to remember is that harvest and storage need to be considered when planning a biomass energy project.

B.4.1 Biomass Feedstock Handling and Storage Liquid and solid fossil fuels like gasoline, diesel fuel and coal are energy dense materials. Biofuel-equivalents are less dense than traditional fossil fuels, so greater attention must be paid to storage and handling of biomass feedstocks than the traditional fuels. Solid biomass feedstocks require a greater volume to achieve the same level of power as coal (Table B.9).

Table B.9 Energy values and volumes for selected fuels

	Heat Value BTU/lb	Density lb/cu ft	Energy Volume BTU/cu ft	Coal-BTU Equivalents	Replacement Volume
Coal, IL Basin	11,800	52.0	613,600	1.00	1.00
Soybean Oil (Central IL)	17,000	57.0	969,254	1.58	0.63
Number 2, Yellow Grease	15,400	48.0	738,535	1.20	0.83
Fuel Pellets	8,000	40.0	320,000	0.52	1.92
Shelled Corn	8,150	45.0	366,880	0.60	1.67
Recycled Cardboard	6,800	40.7	277,039	0.45	2.21
Compost	6,885	37.0	255,000	0.42	2.41
Sawdust	8,000	18.0	144,000	0.23	4.26
Wheat Straw	7,400	6.0	44,400	0.07	13.82
Mixed Grass Hay	7,500	11.0	82,500	0.13	7.44
Corn Stalks/Stover	7,800	11.0	85,800	0.14	7.15
DDGS	9,400	32.0	300,800	0.49	2.04

Table B.9 shows that various feedstocks and fuels vary both with energy content and in density. Looking first at the heating value (BTU/lb), Illinois coal is lower in energy value than Soybean Oil or rendered Number 2, Yellow Grease. It is higher in heating value than all the other biomass materials. The real difference comes in comparing the densities. Again, coal is less dense than Soybean Oil or Yellow Grease, but more dense than the biomass materials. On density alone it would take nearly 5 times the volume of corn stalks/stover to provide the equivalent weight in coal.

After combining the heating value and the densities, the differences are even greater. The column labeled BTU/cu ft is the heating value (BTU/lb) multiplied by the density (lb/cubic feet). This is the energy heating value of a volume of each fuel that has a volume of one foot by one foot by one foot. Coal is equivalent in energy to itself, so it has a Coal-BTU value of 1.0. A cubic foot of Soybean Oil has about 58 percent more energy than a cubic foot of coal. Because soybean oil has greater energy than coal, its Coal-BTU value is greater than 1.0 (1.58). Most solid biomass materials are less energy dense than coal. Shelled Corn (the grain) has only about 60 percent the energy content in a cubic foot of coal (a Coal-BTU value of 0.60). Other solid biomass crops like wheat straw, corn stalks and hay have even lower coal equivalent values.

The last column in Table B.9, Replacement Volume, indicates that for every cubic foot of coal required, it will take 7 cubic feet of Corn Stalks or Hay to replace the energy value. This has significant economic impacts. It means that to replace a semi-load volume of coal with Corn Stalks it will take 7 more trucks covering the same distance, and 7 times the storage space to store the

biomass. Fuel pellets will take 2 volumes for every one of coal to replace the same energy heating value. Wheat straw requires a replacement volume that is thirteen times greater than coal. This has a great influence on the economics of transporting and storing biomass.

The impact can be further illustrated by using some real applications. A small gasifier that is capable of powering a 1.5 MW capacity generator for instance requires 2 tons of biomass per hour (or 17,500 tons per year).⁶⁵ The commercial coal-fired, Alliant Energy 726 MW Chariton Valley power plant in Centerville, Iowa, intends to co-fire with switchgrass, using switchgrass to generate 35 MW of capacity will require up to 200,000 tons of biomass per year.⁶⁶

The smaller annual use of 17,500 tons per year is the equivalent of 35,000, large bales weighing 1,000 pounds each. The larger volume for the Alliant Energy plant would require the equivalent of 400,000 large bales at 1,000 pounds each. This is an enormous undertaking requiring 50,000 acres of land to grow. The Alliant Energy plant has developed a ‘collection and storage’ system that automates the removal of large square bales from semi-trucks and feeds them into a grinder in preparation for blending with coal. In addition to great space required to store the bulky biomass, it must be out of the weather, so it doesn’t absorb moisture.

Moisture contents may not interfere with the combustion process, but there is no energy value in water. So any fuel that is 20 percent moisture means that one fifth of the feedstock will not provide fuel value. Most of the wood waste used in the California biomass power plants is stored outside. The biomass boilers are able to operate with ambient moisture in the feedstocks. One challenge with the higher moisture biomass is that they tend to spontaneously combust if they get hot enough. Managing these fire risks is part of good management.

In most of the current energy discussions, the concept of bone dry tons (BDT) is used. This refers to the heat value without including moisture. Moisture adds no energy value, so BDT refer to useable energy within a solid biomass material.

⁶⁵ Coaltec Energy USA Test Burn Demonstration, Carterville, IL. November 17, 2005 (and 2006, BioTown™ USA Sourcebook).

⁶⁶ Chariton Valley Biomass Project, Goals and Objectives
<http://www.iowaswitchgrass.com/about~goals.html>

Agricultural biomass, forest products or liquid organic feedstocks, biomass materials cost less to transport and store when the conversion facility is located near the feedstock. Locating a conversion technology near the feedstock source limits both the transportation cost and lowers the negative carbon costs of using fossil fuel to transport the biomass great distances.

B.4.2 Feedstock Quality Feedstock quality becomes very important in biomass energy projects, because many of the emerging feedstocks and biomass resources are currently managed as wastes. Availability of a material like solid waste or manure, doesn't mean that it is automatically a great biomass feedstock. A case in point is that most of the US biodiesel plants have been built to run on virgin biodiesel fuel rather than used vegetable oil. More detailed economic reasons for this are discussed in Appendix C. Basically the adage of "Garbage in, Garbage out," holds true with biomass materials and projects also.

B.5 Future Crops and Biomass

This category shows promise for San Benito County. San Benito County has some significant resource crop production limitations when it comes to rainfall and available, flat, tillable acres. San Benito agriculture does very well with the valuable farm land it does have. But with water use pressures mounting in California, expanding available irrigation will become difficult.

Not all crops produce the same amount of energy per acre. The first generation energy crops in the US have been corn and soybeans. These are not really energy crops, although energy can be produced from them. Cellulosic ethanol is able to produce twice as much ethanol per acre as corn-based ethanol (Figure B.9). Soybeans are not an impressive liquid fuel feedstock on a per-acre basis. Again, corn and soybeans are not energy crops. On a per acre basis, corn can generate over 500 gallons of ethanol per acre.

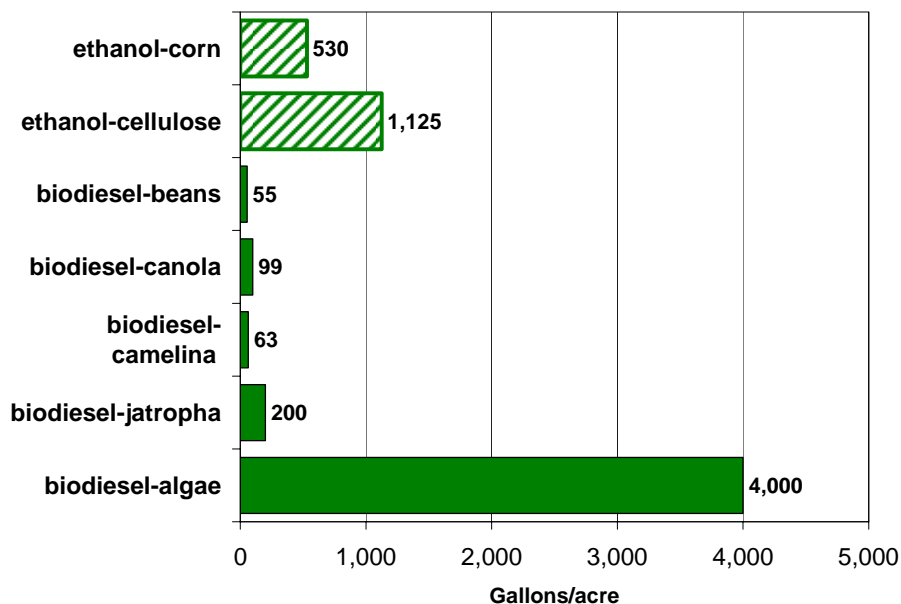


Figure B.9 Liquid biofuel production per acre for various crops

Soybeans produce about 19% oil by weight and 80 bean meal (protein). Soybeans yield about 25% of the bushels per acre that corn does, and so the number of gallons of liquid fuel per acre is much smaller. Biodiesel fuel has about 50 percent more BTUs per gallon than ethanol does, so on an energy content basis the yields are closer than on a straight liquid volume basis.

Canola, another common oilseed crop, will produce nearly twice the yield of oil that soybeans will. It does not produce the same volume of protein for animal feed, but will grow in cooler climates.

Several emerging crops yield significant amounts of oil and they can be grown in the San Benito climate. Two arid oil seed crops that have emerged recently in North America are camelina and the jatropha tree. Groups in Montana and Canada have been working in recent years to develop camelina commercially for oil production. The jatropha plant is a prolific shrub that produces inedible nuts that are loaded with oil. It is grown in Asia and Central America. It can do well in arid regions, but does not do well in areas that freeze. A third emerging energy crop that isn't widely considered a cash crop is algae.

As shown in Figure B.9, camelina is conservatively 'rated' at about 63 gallons of biodiesel per acre. If the growing conditions are optimal ample fertilizer, water and growing season, there is a belief

that it might grow two crops back-to-back in one season. Jatropha takes a few seasons to establish, but once it sets nuts they will come every year. Like the camelina output, the 200 gallons per acre 'rating' is at the low end because it has not been grown in San Benito yet. The last crop, algae is off the chart at 4,000 gallons per acre of biodiesel fuel. This number also is at the low end of the projections. It has appeared in enough places that it appears to be a reasonable estimate.

B.5.1 Camelina Camelina is an arid mountain crop that yields an amount of oil similar to soybeans. The Great Plains Oil and Exploration Company of Montana has a target of growing 100,000 acres of camelina and is paying growers a premium to produce it.

Camelina does well in areas with limited rainfall and it is a short season crop, (100 days or less). Its high oil content has 35 to 45 percent omega-3 fatty acids, which make it an excellent source of food-grade nutrients⁶⁷. The University of Montana is taking the US lead in agronomic research on camelina production⁶⁸

B.5.2 Jatropha Jatropha is a new oilseed crop that is being grown extensively in Asian countries like India⁶⁹. The jatropha plant is a hardy bushy shrub that produces nuts that are very high in oil and requires very little water. Jatropha research and production has reached the U.S. with research beginning in Florida, Hawaii, Texas and Missouri. In fact, Alternative Energy Solutions, a biodiesel company with a biodiesel plant in Gonzales, CA, is even looking at growing jatropha in the Central California region⁷⁰.

B.5.3 Algae and Other Aquatic Crops Water for crop irrigation is a very costly input in San Benito County. However there is an abundance of water that passes through the wastewater treatment facility that is currently not obligated for irrigation. This could provide a supply of water for energy crops that will not be used directly for food consumption. In addition the wastewater

⁶⁷ Is there room for Camelina? Khalila Sawyer. Biodiesel Magazine. BBI International. July 2008. http://biodieselmagazine.com/article.jsp?article_id=2475&q=&page=all

⁶⁸ Camelina Production in Montana. K. A. McVay and P. F. Lamb Montana State University Extension. Montana State University, Bozeman, MT. Revised 3/08. <http://msuextension.org/publications/AgandNaturalResources/MT200701AG.pdf>

⁶⁹ Centre For Jatropha Promotion. Rajasthan, India. www.jatrophaworld.org

⁷⁰ Central Coast biodiesel maker plans expansion. Mary Duan. Silicon Valley/San Jose Business Journal. November 23, 2007 <http://sanjose.bizjournals.com/sanjose/stories/2007/11/26/story12.html>

treatment plant has access to 90 acres of percolation ponds that could be used for aquatic energy crop production.

Algae is a kind of ‘Wonder Crop’ and has the capacity to remediate carbon dioxide (CO₂) emissions, produce energy, generate a source of protein for animal feed and even provide dietary and medicinal supplements for humans.⁷¹ After decades of trying to keep algae from spontaneous production in the wild from bursts of nutrient spills, now developers are rushing to find a way to grow it. In the blink of an eye algae technology is moving to an intensively managed, confined production system of algae.

Algae production technology developers are literally tripping over themselves and each other to be recognized as the first commercial production system of biofuel producing algae.

Table B.10 summarizes the most current algae production technology developers. Also listed in the table is the primary market that is being promoted, as well as other markets that the developer is also considering. The last column includes the website address of each company.

Table B.10 Current algae production system developers

Company	City	State	Primary Market	Other Interests	Website
GreenFuel Technologies Corp.	Cambridge	MA	CO ₂	Fuel, feed	http://www.greenfuelonline.com/
Solix Biofuels	Fort Collins	CO	Fuels	Climate, security, regulation	http://www.solixbiofuels.com/
XL Renewables	Phoenix	AZ	Fuels	Nutrients	http://xlbiorefinery.com/index.cfm?page=home
PetroAlgae, LLC	Melbourne	FL	Fuels	Bioplastics, chemicals, nutraceuticals	http://www.petroalgae.com/index.html
AlgaeWheel, Inc.	Indianapolis	IN	Wastewater treatment	Fuel, feed	http://www.algaewheel.com/index.cfm
Petro Sun Inc., HQ	Scottsdale	AL	Fuels	Heat	http://www.petrosuninc.com/
Solazyme, Inc.	S. San Francisco	CA	pharmaceuticals	Chemicals, fuel	http://www.solazyme.com/
Live Fuels, Inc.	Menlo Park	CA	Fuel	Environment	http://www.livefuels.com/
Aurora Biofuels	Alameda	CA	Fuel	Environment	http://www.aurorabiofuels.com/home.htm
Bioavitas, Inc.	Redmond	WA	Fuels	Nutraceuticals, environment	http://www.bionavitas.com/index.html
Valcent/Vertigro		TX	CO ₂	Fuel	http://www.valcent.net/s/Home.asp
Solena	Washington	DC	Fuels	Environment	http://www.solenagroup.com/html/home.asp
Blue Marble Energy	Seattle	WA	wastewater	Environment	http://www.bluemarbleenergy.net/

⁷¹ Algae - The Wonder Crop Of Tomorrow? Mark Jenner. Biomass Energy Outlook. BioCycle June 2008, Vol. 49, No. 6, p. 44

It is noteworthy that other aquatic plants have salt tolerance and are being explored for biofuels. Two of these are seashore mallow and cattails. Seashore mallow is a plant common to shorelines and estuaries. Cattails are freshwater weeds that have a high sugar content and some salt tolerance.

Research on the seashore mallow is occurring in Delaware with a focus on vegetable oil for use in biodiesel fuel.⁷² Research has been occurring in Texas and North Carolina using cattails for ethanol.⁷³

Another biomass energy crop that is not an aquatic plant, but does well in poorly drained and wetter soils is the hybrid poplar. Hybrid poplars are recognized for their environmental benefits.⁷⁴ Hybrid poplars are a softwood tree that is commercially under production by the pulpwood industry and is an excellent source of biomass energy.⁷⁵ Hybrid poplars can produce as much as 10 tons per acre of biomass annually.

⁷² "The Saltwater Soybean." Biodiesel Magazine. November 2007.
http://biodieselmagazine.com/article.jsp?article_id=1913

⁷³ "Beyond Corn." Ethanol Producer Magazine. July 2004.
http://www.ethanolproducer.com/article.jsp?article_id=1004&q=&page=4 and "Researchers Study Potential of Using Cattail Feedstock." Ryan C. Christiansen. Ethanol Producer Magazine. August 2008.
http://www.ethanol-producer.com/article.jsp?article_id=4540

⁷⁴ Licht, Louis A. and J.G. Isebrands. "Linking Phytoremediated Pollutant Removal to Biomass Economic Opportunities." http://www.ecolotree.com/pdf/5.0504_linkingopportunities.pdf

⁷⁵ "Biomass As Feedstock For A Bioenergy And Bioproducts Industry: The Technical Feasibility Of A Billion-Ton Annual Supply." Robert D. Perlack, Lynn L. Wright, Anthony F. Turhollow, Robin L. Graham, Bryce J. Stokes, and Donald C. Erbach. Oak Ridge National Laboratory. For the Department of Energy and Agriculture (DOE & USDA). December 2005.
<http://www.bcsmain.com/mlists/files/btvision.pdf>

Table B.11 Available Biomass Resources in San Benito County

San Benito County Resource	Yes	No	Maybe	Explanation
Current Agricultural Production		XXX	???	Nothing can (or should) compete with the high value of ag production. There are opportunities to develop some marginal land for arid energy crops and to use existing processing residuals for energy. Energy crop \$/acre would have to surpass food crop \$/acre value.
Forest Biomass	XXX			County hardwood stands should be managed for energy production from waste wood.
Municipal Solid Waste	XXX			There is potential to channel incoming carbon and plastic into energy conversion technologies. Any material diverted from the landfill will also lengthen the life of the landfill.
Municipal Wastewater			XXX	The new wastewater treatment plant has effectively met the needs of waste remediation. To the extent that the treated effluent, and percolation ponds can be utilized for aquatic energy crops like algae, it should be considered.
Waste Oil and Grease			XXX	There is not a great quantity of waste oil and grease in San Benito County. The quantities that are available could be developed for demonstration projects at the schools or organizations. Larger scale energy projects will require importing materials from surrounding counties
New Energy Crop Production	XXX			There is potential to grow non-irrigated, arid energy crops like camelina and jatropha in San Benito County. It will need to be addressed on a small scale initially, but even utilization of 10 percent of marginal land in the county will have a benefit to energy production.

Appendix C: Biomass Energy Conversion Fundamentals

C.1 Biomass Chemistry⁷⁶

Biomass is chemically composed of new and used plant carbohydrates. The fundamentals of biomass chemistry are not complicated. This brief discussion targets the conceptual level of biomass chemistry.

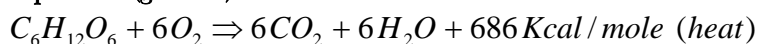
C.1.1 Stored Solar Energy One of the fundamental relationships in nature is the photosynthesis of carbon dioxide and water into carbohydrates and oxygen through sunlight absorbed through green plants (Equation 1). Quite simply, green plants store solar energy biochemically as sugars, starches, lipids and fibers.⁷⁷

Equation 1 Photosynthesis



Agriculture has always understood this process. All the value of our food and fiber commodities (corn, beans, wheat, cotton, timber, etc.) is based on photosynthesis. Shifting the market discussion from the hidden energy value of traditional commodities to biomass products is as simple as shifting from corn, beans, manure and timber to sugars, starches, lipids and fibers. The stored solar energy in green plants is accessible through the converse of photosynthesis, or respiration (Equation 2).⁷⁸

Equation 2 Respiration (glucose)



C.1.2 Understanding Carbohydrates and Other Carbon-Based Molecules Carbohydrates store energy in plant and animal life. Through photosynthesis solar energy is stored in plants. Carbohydrates include sugars, starches and fibers. Sugars form a basic carbohydrate unit. Starches and fibers are polysaccharides (many sugars) because they are formed from multiple combinations of simple sugars and other molecules.

⁷⁶ The fundamentals described in Chapter 4 are derived from and expanded on work completed for the BioTown USA Sourcebook. Mark Jenner. Indiana State Department of Agriculture 2006.
http://www.in.gov/oed/files/Biotown_Sourcebook_040306.pdf.

⁷⁷ From BioTown USA Sourcebook. Mark Jenner. Indiana State Department of Agriculture 2006.
http://www.in.gov/oed/files/Biotown_Sourcebook_040306.pdf.

⁷⁸ Darnell, James, Harvey Lodish and David Baltimore, Molecular Cell Biology 2nd Ed., Scientific American Books. New York. 1990 p. 37.

Various sugars are defined by the number and configuration of carbon molecules. Glucose is a six carbon sugar. Pentose is a five carbon sugar. These five and six carbon sugars are simple sugars or monomers (a single unit). They also have different shapes. Glucose and fructose are 6 carbon sugars, with a different configuration of the 6 carbon, 12 hydrogen and 6 oxygen molecules. Sucrose is composed of a glucose sugar plus a fructose sugar (less a water molecule).

Starches and fibers are combinations of either the same molecule of sugar, or they are combinations of different kinds of sugars.⁷⁹ The starches are much smaller molecules than the cellulose and hemicellulose molecules. Cellulose and hemicellulose molecules are the carbohydrates in fiber. Cellulose is composed of 'like' sugar molecules. Hemicellulose is composed of multiple kinds of sugars. The fact that these larger carbohydrate molecules are made from combinations of sugars is beneficial when trying to reduce them back down into sugars.

A principle carbon-based component contained in larger carbohydrates is lignin. Lignin is not a carbohydrate and is not composed neatly of different kinds of sugars. Lignin is not easy to separate from cellulose and hemicellulose. It is the biological glue that holds cellulose and hemicellulose together. Lignin is carbon-based and can be used to some degree as a biomass energy fuel. Efforts to chemically purify cellulose and hemicellulose by removing the lignin often corrupt access to the sugar molecules also.

Other important carbon-based, non-carbohydrates are proteins and fats. Proteins are carbon-based but contain nitrogen. They contain some stored energy, but technically they are not carbohydrates. Similarly, fats and oils also contain significant energy and play an important role in biomass energy production. Technically, they are not carbohydrates either.

Hydrocarbons are similar in function to carbohydrates, but may not contain an oxygen molecule. Hydrocarbon chemistry is well developed and is the chemistry of the fossil fuel energy system. Early efforts to transform biomass into energy began by converting carbohydrates into

⁷⁹ Brown, Robert, Biorenewable Resources: Engineering New Products from Agriculture. Iowa State Press. Ames, IA 2003.

hydrocarbons. This can be an energy intensive process. In time, biomass energy technologies may rely less on hydrocarbon chemistry.

C.1.3 Hydrolysis – Turning It All to Sugars. Hydrolysis is the process of breaking longer-chain carbohydrates (polysaccharides) into smaller carbohydrates, and eventually into simple sugars. It is based on passing hydrogen (like water, H_2O) over the carbon-based materials and so it is called, hydrolysis. Advancements in hydrolysis through the development of new enzymes, chemical, and physical processes are creating opportunities to convert large cellulose molecules to simple sugars.

Hydrolysis is most important for those energy conversion technologies that rely on sugar. If biomass energy conversion shifts away from hydrocarbon chemistry, hydrolysis of complex carbohydrates may play less of a role. Today, hydrolysis is an important concept to understand.

C.1.4 The Thermodynamics of Chemistry. It is important to recall that the carbohydrates and non-carbohydrates in this biomass energy discussion are rooted in balanced chemical equations. The photosynthesis equation is based on the balance of electrons and chemical bonds before and after the exposure to solar photons.

One of the fundamental pathways in transporting chemical energy is the synthesis of ATP (adenosine triphosphate) from ADP (adenosine diphosphate) and another phosphate.⁸⁰ Respiration frees the energy and shifts the ATP molecule back to an ADP molecule. It is the thermodynamics of biochemistry that transfers the stored solar energy as biomass chemical energy.

It is also important to point out that biomass chemistry is primarily the chemistry of carbon, hydrogen, oxygen, nitrogen (proteins) and phosphorus. Balancing these relationships is the key to turning surplus nutrients and organic wastes into valuable biomass energy products.

C.2 Biomass Physics

Energy is fixed in the universe. It can not be created or destroyed (First Law of Thermodynamics). All energy moves toward greater disorder (Second Law of Thermodynamics). Energy can only be

⁸⁰ Darnell, James, Harvey Lodish and David Baltimore, Molecular Cell Biology 2nd Ed., Scientific American Books. New York. 1990 p. 37.

conserved. It can not be recycled like nutrients. Solar energy strikes the planet and is captured and chemically stored in plants. If this chemical energy is not utilized as energy then it is released without economic benefit. There is a great deal of residual biomass energy that passes through unused in food waste, trash and all organic residuals. All organic residuals contain stored, underutilized solar energy.

Biomass has specific physical characteristics that are not difficult to understand and need to be reviewed. These include the affect of moisture content on combustion and the steps involved in the process of combustion.

C.2.1 Moisture and Combustion Biomass feedstocks, by their biological nature, have a moisture content associated with them. In the field, crops are dried to the extent that time and weather permit. Waste materials on the other hand, are often handled with water added for conveyance. There are efficient livestock production systems based on liquid manure handling technologies as well as efficient production systems that handle manure as a drier material.

When combusting biomass feedstocks to produce energy, the amount of energy used to prepare the feedstock for conversion to energy, should be as small as possible. By definition, a *calorie* is the amount of energy required to raise 1 gram of water, 1 degree Celsius.⁸¹ It takes energy to remove water. The greater the energy used to prepare the feedstock the less net energy that can be generated. Combusting materials that are not dry do not burn as well and may increase the water content of the resulting fuel – which is undesirable.

Moisture can be problematic in the transportation of the biomass feedstock. The higher the moisture content the more costly it is to transport, if the water itself is not used for conveyance. Water is added to liquid manure systems to aid in the transport of materials around the facility. Water is also added to sewage to assist in material transport. These are system design criteria and must be considered when assessing biomass utilization.

⁸¹ We generally think of calories in the context of dietary energy. Industrial energy is generally discussed in terms of joules. 1.0 calorie = 4.187 joules. The other energy convention is British Thermal Units (BTU). This Sourcebook includes all energy units in BTUs or million BTUs (MMBTU). 1.0 BTU = 1055 joules.

The presence of water or liquid feedstocks does not eliminate a feedstock from useful energy production. Anaerobic digesters operate on liquid feedstocks. Digesters strip off the methane (CH₄), retaining the nutrients and the moisture in the remaining effluent. As mentioned above, one of the constituents in the biogas coming off of anaerobic digesters is water. This water limits the utilization of the biogas generally to on-site uses. The raw gas is not easily compressed or transported off-site.

C.2.2 Burning Biomass Combustion is more involved than simply starting a fire. Brown (2003) describes combustion as a four step process: heating and drying, pyrolysis, flaming combustion and char combustion (Figure C.1).⁸² All four steps can occur very rapidly. So these four steps are a bit like a time-lapse image for the mind. Understanding these four steps helps understand the thermal conversion technologies discussed in Appendix D.

Process of Combustion

Heating and Drying As heat enters the solid fuel, water is driven off. The next phase, *pyrolysis* can not begin as long as the water remains.

Pyrolysis Elevated temperatures decompose organic compounds into volatile gases including: carbon monoxide, carbon dioxide, methane, and other compounds that condense into tar when cooled. The resulting char is more porous.

Flaming Combustion The introduction of oxygen (oxidation) ignites the volatile gases of *pyrolysis*. The ultimate products are carbon dioxide and water, but in the process many intermediate compounds combust. When conditions are right, the intermediates will be consumed in the process.⁸³

Char Combustion The solid core is oxidized in the last phase. Under optimal operating conditions, char combustion produces carbon monoxide and carbon dioxide.

⁸² Brown, Robert, Biorenewable Resources: Engineering New Products from Agriculture. Iowa State Press. Ames, IA 2003. Chapter 6.

⁸³ Incomplete combustion, due to improper design or management, can produce toxic pollutants.

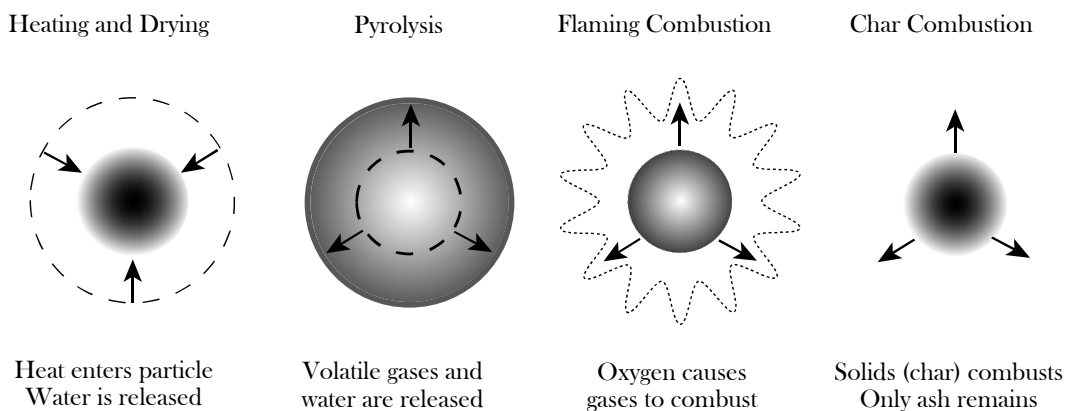


Figure C.1 Process Involved in Solid Fuel Combustions (Adapted from Brown)

C.3 Biomass Economics

Tracking the energy of production agriculture is a relatively new concept. U.S. agriculture has evolved on the basis of marketing commodities, not on the efficiency of energy utilization. It takes more energy to raise a pound of meat than a pound of grain. While the flavor of the pound of meat may be valued more highly than the flavor of 3 - 5 pounds of grain, production of the meat is not as thermodynamically efficient as producing grain. The traditional way of designing and managing production systems is evolving.

Biomass energy does not have well-developed supply systems and markets. There is no economic infrastructure, so there are a few caveats that describe biomass economics. After reviewing a few basics, significant biomass economic concepts like uncertainty and prices, economies of scale and scope, and biomass system profit, will be discussed.

C.3.1 Economic Basics Economics is balancing the supply of available goods with the amount of ‘stuff’ people want to buy. It is about balancing the supply with demand. In the emerging bioproduction ecosystem, pollutants that are in surplus quantities are being aligned with legitimate energy needs. The beauty is that the environment is enhanced, alternative energy forms are developed and the economy grows. While that is the vision, reality requires a few more steps.

C.3.2 Uncertainty and Prices The US economy in general works like it does because there is a lot of historical information on production, purchases, and prices. If something changes quickly, then all the analysts get nervous and there are ‘adjustments’ to compensate. In the bioproduction

ecosystem, there is insufficient historical data. This makes investing much more risky. Investors don't like to lose money so they may loan money for an anaerobic digester or a gasifier, but will charge higher interest rates. Startup costs are higher for new technologies, because it is difficult to estimate budgets without years of experience. Also data collection is expensive and sometimes data on test burns or on the feedstock quality will need to be measured for the first time.

C.3.3 All Prices Are Relative This is always true in economics. It is even more apparent in emerging market structures that do not have robust daily prices. Most biomass energy economic studies have been conducted by modeling a stand alone enterprise. The economics tend to reflect the retrofitting of an existing facility with new equipment, using product prices based on a similar existing market. These economic studies are excellent first steps into an industry that barely exists.

All studies are most relevant the minute they are complete. The more time that passes for most price-based economic studies, the less relevant they become. The anaerobic digestion studies done 20 years ago have little economic value today. For one thing, the livestock we are producing today are more efficient at converting feed to meat than they have ever been. We produce less manure per animal than we did twenty years ago. And in the case of anaerobic digesters, the digesters being installed today operate more consistently than the earlier digesters.

In addition, biomass energy studies conducted on an energy price assumption tied to \$40 a barrel crude oil, will have a significantly different result when crude oil sells for \$130 a barrel.

All biomass energy markets must be contractually established or used internally at the production site. There are no terminal markets (grain elevators or stockyards) for a producer to deliver a load of biomass energy to sell. This is a profoundly different marketing strategy than existed for grain and livestock 50 years ago. If a facility intends to develop a biomass energy or alternative market, it must first find a buyer/client – and sign a contract.

C.3.4 Data Collection On the bioenergy frontier, the risks of failure can be capitalized into a proven, turn-key system – or each valuable lesson-learned can be pieced together from scratch. Data collection is very expensive, but one way to lower the risks of failure is to collect the best data

available on the frontend. If a project fails for lack of good preliminary data, then the cost of not collecting that real-time data becomes very high.

Kinds of data that need to be collected fall into three basic categories: input quality, technology emissions, and product quality (relative to the intended market). Technology providers that offer turn-key conversion technology systems may charge more for their services than it appear to merit, but they are trying to recapture their costs of collecting all the data to make their technology work. It is possible to independently develop a commercial biomass conversion technology from scratch, but then the independent developers must collect the input quality, emissions and product quality data themselves.

One caution about using historically tabled data. It is possible to find data tables on manure and biomass quality and energy content. These are excellent starting points for preliminary planning. They are used extensively throughout this document. However once money begins to be invested in any project, it is time to begin collecting project-specific data. Unfortunately, there are millions of dollars that get spent on investments that are made on the average data that has been created for planning, and too often the site-specific inputs do not have the same quality characteristics as the average tabled data. When the project advances to the point where money is being spent on the project, it is time to collect project-specific data.

C.3.5 Project Size or Scale Another way to offset the lack of data is to begin on a very small scale, or size, and gradually work up to a commercial scale project. The basic economic sizes are laboratory scale, pilot scale, commercial scale or industrial scale. These scales are set by the intended goal or purpose rather than by specific size. For instance, a commercial biodiesel plant might be as small as 3 million gallons per year, while a pilot cellulosic ethanol plant might be more than 3 million gallons of production capacity per year. It is more about whether the biodiesel plant can make money or the pilot cellulosic ethanol plant is being used to gather data for a larger plant.

The scale categories can be defined as:⁸⁴

- A laboratory-scale project is small enough to fit on a lab tabletop. The purpose of this size is to perfecting the process; there are no commercial economic considerations.
- Pilot-scale projects are the intermediate step between laboratory and commercial. Technology developers need confidence in their technologies - a proof of concept - to attract investors and clients. The scale of these pilots is large enough to test the equipment at a rigorous level, but small enough to minimize economic risks to the developer.
- The purpose of a commercial-scale plant is to be economically viable. These projects are economic experiments. Hundreds of millions of dollars are on the line. Public grants and loans do not guarantee success, but provide some risk protection. Once the “first of its kind,” commercial-scale project risks are removed, subsequent projects should operate without public assistance.
- Finally, industrial-scale projects are replications of the successful “first” commercial-scale projects. A key factor in the rapid expansion of the dry-mill corn ethanol industry was that investors knew the established technologies were replicable.

C.3.6 Large and Specialized (Industry) or Small and Diversified (Sustainable Ag)? Both business models work, but the ‘large’/‘small’ designations are political terminology. For biomass energy projects to succeed over the long-run, they will need to avoid playing political games for as long as possible.

In economics, specialization is referred to as *economies of scale*. By specializing, firms spread capital investments over more units of production output. This means they get larger and focus on a single output. The result is a lower per-unit cost of production and more competitive cost structure. In agriculture we talk about farms getting larger and fewer in numbers. This is due to economies of scale.

Diversification of an asset, means that assets have multiple uses and produce multiple outputs. This is referred to as *economies of scope*. A ‘diversified’ farm produces multiple commodities. The ‘conventional’ corn-based, dry mill ethanol plant was designed to produce ethanol and manage the byproducts of distillers grains (DDGS) and carbon dioxide (CO₂). Since energy costs continue to rise, this fledgling industry continues to innovate combining biomass gasification or anaerobic digestion for fuel sources. They are cultivating research in new markets for the DDGS,

⁸⁴ Scaling the biomass energy Mountain. Mark Jenner. BioCycle Magazine. Biomass Energy Outlook. July 2007. Vol. 48. No. 7. p. 60. http://www.jgpress.com/archives/_free/001380.html

reusing municipal wastewater, developing CO₂ product enterprises, and finding new ways to utilize the waste thin stillage. Highly specialized biofuels facilities are diversifying.

Combining economies of scale (specialization) and scope (diversification) are creating exciting new realities. This is happening across the nation. Landfills are pumping their methane to manufacturing facilities for a fuel source. Large livestock facilities are diversifying into energy production from methane digesters. Ethanol, biodiesel and fuel pellet mills are all continuing to innovate to be large enough to capture economies of scale, but diversify into multiple product lines to reduce waste and increase revenue. Large efficient, facilities are nesting lesser enterprises within the umbrella of the specialized enterprise to more completely utilize company resources.

Economies of scope imply that the sum of the total system is greater than the sum of the parts (individual enterprises).

C.3.7 Profit - The Business of Making Money The evolution of the valuable environmental benefits and the increasing value of producing energy have created some confusion about whether it is better to save the environment, or have economic growth. The right answer is both, and that is possible with well planned bioenergy enterprises. Just as the specialized, ethanol plants are learning the benefits of diversification, businesses built on making a profit are learning the economic value of environmental remediation. Many waste management businesses are watching the economic excitement associated with biofuels and are adjusting their cost-minimizing business models to operate more like profit centers.⁸⁵

Biofuels facilities are planned and built as profit centers. Corn-based ethanol, biodiesel, and fuel pellet mills are producing fuel for profit. Because of they have a proven technology and financial success at producing clean, renewable energy, these young industry sectors pass the economic litmus test of commercial maturity - they are able to get financing.

⁸⁵ New Bioenergy - Profit Meets Waste Remediation. Mark Jenner. BioCycle. Biomass Energy Outlook. August 2007. Volume 48, Number 8. page 50. http://www.jgpress.com/archives/_free/001400.html

Waste remediation projects can generate a profit, but that profit is based on remediation services rather than commodity production. Biomass methane energy projects (landfills, wastewater treatment digesters and manure digesters) have evolved as energy (commodity) enterprises with in a waste treatment facility. The facility's primary function is to remediate the waste and stabilize the carbon. Then they attempt to recover some costs by developing methane gas utilization. The first goal is to remediate waste and the cost recovery benefit from energy is an afterthought.

Cost recovery is not the same as a profit center. Waste treatment functions minimize liabilities and costs. The highest value of a cost-minimizing project is zero cost. Zero costs (without profits) do not excite investors and bankers. Even when costs are zero, a profit only occurs if there is also revenue (profit = revenue - costs).

Waste treatment industries have a legal, health and environmental mandates that impose enormous costs. They are offsetting some of those expenses through bioenergy production. Bioenergy profit centers in turn are learning to more efficiently utilize their resources similar to the cost recovery management of waste treatment facilities. The two different business models are merging into a single, very efficient low-cost profit center.

As waste remediation moves toward energy production, a second benefit emerges. Waste remediation shifts from a service-oriented industrial sector to a product-producing industrial sector. In addition to remediating waste, with more frequency energy production is also occurring. According to the 2002 Economic Census, California generates \$6.4 billion dollars in receipts to make the waste 'go away.'⁸⁶ As waste biomass moves more into biomass energy, composting and recycling, that \$6.4 billion dollar sector will continue to provide services to remediate the waste; but in addition they will produce energy and other marketable products also. Once again the benefits of environment, energy and economics are apparent.

C.3.8 The Price Impact of Recycling Recycling enhances efficiency, but it is not without its impacts. In the case of paper recycling, increased efficiencies gained by salvaging used paper

⁸⁶ 2002 Economic Census. Administrative and Support and Waste Management and Remediation Services, California. http://www.census.gov/econ/census02/data/ca/CA000_56.HTM

created a greater supply of paper from the original supply of pulp wood. The excess supplies of waste biomass feedstocks exist because these waste materials are under developed and so they have a negative value. As the supply of paper increased from recycling, the price also dropped.

Inputs will have more competition. The feedstock price will move upward as competition for undervalued feedstocks increases. Corn for ethanol, for instance became more expensive when corn for animal feed became less available. As more industries compete for the same materials, though, they will put pressure on keeping their own input costs down. As bioenergy, chemical and fiber products become more reliant on biomass feedstocks, each firm will compete for the least cost input into the process, driving biomass feedstock prices down. Even though there are contradictory forces on feedstock prices, this is part of the challenge of establishing a bioeconomy.

C.4 Non-energy Biomass ...or Summing the Parts of the System

Many biomass utilization enterprises are only marginally profitable. Doing a specific process by itself may not make economic sense. By utilizing economies of scope a system of marginally profitable enterprises can share the same capital asset and work. Not all biomass enterprises need to be energy projects. There are non-bioenergy projects that may even be more profitable than the energy component. While only a partial list, non-biomass energy topics of crop fertility, soil amendments and compost; building materials; and industrial chemicals and products, are discussed below.

C.4.1 Crop fertility, Soil Amendments and Composting One of the great ‘undersights’ of the commercial U.S. livestock industry has been neglecting the impact of under-managed, under-utilized manure nutrients. As the livestock facilities grew in size and concentration over the last three decades, the accumulation of under-managed nutrients became more noticeable. Now in 2008, with skyrocketing energy prices have come skyrocketing fertilizer prices. Farmers are looking for opportunities to use organic nutrients if they will offset the high cost of conventional fertilizers.

Manure nutrients have always been utilized in crop fertility programs. In the US since WWII, commercial fertilizer has been cheap and easy to manage. In most areas of the country, crop production

has become less connected to livestock production, and manure utilization has been less intensively managed.

The range-raised beef in San Benito County is a self maintaining manure management system. It is an excellent use of the manure. There may be other opportunities with stables, or with imported manure, to work to the benefit of San Benito County. Biological technologies such as anaerobic digestion and composting conserve the biomass nitrogen much better than the thermal gasification and combustion technologies. Most biomass energy conversion technologies preserve the phosphorus in the conversion byproducts.

Depending on one's political view, land-applied biosolids has become politically charged in California. The passion of the publically contested high-profile cases like Hinkley, CA and Kern County, CA interfere with application of the very practical and beneficial uses of composted and treated, land-applied biosolids. With any biomass energy project or affiliated biomass project it is vital to establish excellent communication and transparency before the project progresses very far.

New markets for composted materials have developed. Residential construction has gained a new appreciation for compost in establishing yards for new housing. Also state and federal transportation agencies are using compost to remediate erosion and water quality regulations on road construction sites. These new uses are rapidly increasing the demand – and the value of consistent, quality composted products. In California the Association of Compost Producers is actively cultivating new markets for compost (<http://www.healthysoil.org/>).

C.4.2 Building Materials: Resins, Fibers and Composites The fibrous nature of biomass can not be overlooked. Wood composites like plywood and fiberboard are low-cost, durable building materials. Use of plant fibers for traditional fiber uses is expanding for ropes and twines using both traditional and new fiber crops.⁸⁷ Research at Iowa State University has included exploring

⁸⁷ Shri Ramaswamy, “Natural Fibers Application and Composites - Potentials for Alternative Non-Wood Fibers.” ISU, Growing the Bioeconomy, Ames, IA August 30, 2005.
http://www.valuechains.org/bewg/Conf2005/Presentations/Shri_Ramaswamy.pdf

production of resins and composites from plant proteins and fibers.⁸⁸ Initial work included the use of manure as both fiber and a binder for the fibers in the composite. Other research has been conducted in biocomposites at the University of Maine by Stephen Shaler.⁸⁹

Dr. Shaler lists Non-Structural Biomass Panel Attributes as:

- Medium Density Fiberboard, Particleboard, Strawboard
- Used where reduced moisture resistance is needed
- Produced using compression molding
- Dry process
- 3-10% adhesive based on dry material weight

The use of these green building materials is becoming popular. Green buildings are constructed on practices that are environmentally responsible and resource efficient.⁹⁰ To accredit and set standards on green buildings, the US Green Building Council has created the Leadership in Energy and Environmental Design (LEED) system.⁹¹ These standards have taken efficiency to new levels. Energy efficient subdivisions and other residential dwellings are moving toward both energy efficient and zero energy levels. One community near San Benito County is the Vista Montana community in Watsonville, CA. Using solar energy and efficient insulation; these homes reduced energy consumption by 50 percent.⁹²

Craig Shore, President of Creative Composites, Brooklyn, Iowa, is building his company on the market for light, sound-dampening insulating biocomposites (Figure C.2).⁹³ In addition to building the infrastructure and market for the biocomposites, their long-run business plan also includes building a market and production capacity for kenaf.⁹⁴ This is an excellent example of how new industries are springing up on new uses for biomass crops.

⁸⁸ Teddi Barron. "From cow chips to cow barns" Inside Iowa State. May 19, 2000. <http://www.iastate.edu/Inside/2000/0519/cowchips.html>

⁸⁹ Stephen Shaler, "Natural Fibers and Composites." ISU, Growing the Bioeconomy, Ames, IA August 30, 2005. http://www.valuechains.org/bewg/Conf2005/Presentations/Stephen_Shaler.pdf

⁹⁰ Green Buildings. US EPA. <http://www.epa.gov/greenbuilding/pubs/about.htm#1>

⁹¹ US Green Building Council, LEED resources. <http://www.usgbc.org/DisplayPage.aspx?CategoryID=19>

⁹² Vista Montana homes, Watsonville, CA. US DOE, EERE. <http://www.nrel.gov/docs/fy04osti/35305.pdf>

⁹³ Craig Shore "Commercialization of Natural Fiber Composites." ISU, Growing the Bioeconomy. Ames, IA. August 30, 2005. http://www.valuechains.org/bewg/Conf2005/Presentations/Craig_Shore.pdf

⁹⁴ A new annual fiber crop called kenaf, *Hibiscus cannabinus* L., <http://www.hort.purdue.edu/newcrop/proceedings1993/v2-402.html>



Figure C.2 Biocomposites from Creative Composites of Brooklyn, IA

C.4.3 Industrial Chemicals and Products Just as with the use of biomass materials in building and construction, chemicals and industrial products are already being made with bio-based products. Robert Brown lists the top 60 organic chemicals with the implication that this is a target list of products that can be made from biomass materials.⁹⁵ Table C.1 is a much broader list of products that have been designated as Biobased BioPreferred Products for Federal Procurement.⁹⁶ As part of the 2002, Farm Security and Rural Investment Act (FSRIA) mandate, the U.S. Department of Agriculture was directed to develop and implement a comprehensive program for designating biobased products.

⁹⁵ Brown, Robert, Biorenewable Resources: Engineering New Products from Agriculture, Iowa State Press. Ames, IA 2003. Table 5.4. Page 127-128.

⁹⁶ USDA BioPreferredSM Website. <http://www.biopreferred.gov/Default.aspx>

Table C.1 Approved Designated BioBased Items for Federal BioPreferred Program

2-Cycle Engine Oils	Fiber-Based Furniture	Metal Cleaners
Adhesive and Mastic Removers	Films	Metalworking Fluids
Adhesives	- Non-Durable	- General Purpose Soluble, Semi-Synthetic, and Synthetic Oils
Ag Spray Adjuvants	- Semi-Durable Films	- High Performance Soluble, Semi-Synthetic, and Synthetic Oils
Air Fresheners and Deodorizers	Filters	- Straight Oils
Air Tool Lubricants	Fingernail/Cuticle Products	Microbial Cleaners
Aircraft Cleaners	Fire Retardants	Mulch and Compost
Allergy and Sinus Relievers	Fire Starters	Multi-Purpose Cleaners
Animal Care Products	Firearm Lubricants	Multi-Purpose Lubricants
Animal Repellents	Floor Cleaners and Protectors	Oral Care Products
Aquaculture Products	Floor Coverings (Non-Carpet)	Other
Aromatherapy	Floor Strippers	Oven and Grill Cleaners
Artistic Supplies	Fluid-Filled Transformers	Packaging Materials
Asphalt and Tar Removers	- Synthetic Ester-Based	Paint Removers
Asphalt Restorers	- Vegetable Oil-Based	Paints and Coatings
Automotive Care Products	Food Cleaners	- Exterior
Bath Products	Foot Care Products	- Interior
Bathroom and Spa Cleaners	Forming Lubricants	Papers
Bedding, Bed Linens, and Towels	Fuel Conditioners	- Non-Writing
Biobased Pallets	Fuel Oil	- Printing and Writing
Biodegradable Foams	Fungicides	Parts Wash Solutions
Bioremediation Materials	Furniture Cleaners and Protectors	Penetrating Lubricants
Blast Media	Gasoline Fuel Additives	Personal Insect Repellents
Body Powders	Gear Lubricants	Plastic Insulating Foam for Residential and Commercial Construction
Building Materials	Glass Cleaners	Plastic Products
Candles and Wax Melts	Graffiti and Grease Removers	Polyurethane Coatings
Carpet and Upholstery Cleaners	Greases	Pond and Aquarium Cleaners
- General Purpose	- Food Grade	Power Steering Fluids
- Spot Removers	- Multipurpose	Printing Chemicals
Carpets	- Rail Track	Rock Drill Oil
Chain and Cable Lubricants	- Truck	Roof Coatings
Clothing	Hair Cleaning Products	Rope and Twine
Composite Panels	Hair Removal Products	Sanitary Tissues
- Acoustical	Hair Styling Products	Sealants
- Interior Panels	Hand Cleaners and Sanitizers	Sewage System Maintenance Products
- Plastic Lumber	- Hand Cleaners	Shaving Products
- Structural Interior Panels	- Hand Sanitizers	Shipping Pallets
- Structural Wall Panels	Heat Transfer Fluids	Slide Way Lubricants
Compost Activators and Accelerators	Herbicides	Soil Conditioners
Concrete and Asphalt Cleaners	Household Cleaners	Solid Fuel Additives
Concrete and Asphalt Release Fluids	Hydraulic Fluids	Sorbents
Concrete Curing Agents	- Mobile Equipment	Specialty Precision Cleaners and Solvents
Concrete Repair Patch	- Stationary Equipment	Sun Care Products
Corrosion Preventatives	Industrial Cleaners and Solvents	Thermal Shipping Containers
Corrosion Removers	Industrial Enamel Coatings	Topical Soreness Relief
Cosmetics	Ink Removers and Cleaners	Total-Loss Lubricants
Cuts, Burns, Rashes and Skin Condition Ointments	Inks (Specialty)	Toys
De-Icers - General Purpose	Insect Control Products	Transmission Fluids
Deodorant	Insecticides	Turbine Drip Oils
Dethatchers	Interior Wall and Ceiling Patch	Wastewater Systems Coatings
Diesel Fuel Additives	Intermediate Feedstocks	Water Tank Coatings
Dishwashing Detergents	Lab Chemicals	Water Turbine Bearing Oils
Disposable Containers	Laundry Products	Women's Health Products
Disposable Cutlery	- General Purpose	Wood and Concrete Sealers
Disposable Tableware	- Pretreatment/Spot Removers	- Membrane Concrete Sealers
Durable Foams	Lavatory Flushing Fluid	- Penetrating Liquids
Durable Tableware	Leather, Vinyl, and Rubber Care Products	Wood and Concrete Stains
Dust Suppressants	Lip Care Products	Woven Fiber Products
Electronic Components Cleaners	Lithographic Offset Inks	
Engine Crankcase Oil	- Heatset	
Erosion Control	- News	
Expanded Polystyrene Foam Recycling Products	- Sheetfed	
Facial Care Products	Lotions and Moisturizers	
Fertilizers	Machine Oils	
	Marine Products	
	Massage Oils	

Appendix D: Biomass Energy Conversion Technologies

Biomass conversion technologies, in California, take on some what of a different meaning than in the rest of the country, because conversion technologies are defined in the solid waste regulations. The solid waste regulatory definitions do not control all biomass conversion, but it is important to acknowledge that these regulations exist.

For the purposes of communication in this Chapter, the starting point will be the broader category of science that does not depend on the regulations. This Chapter begins with a discussion of thermal conversion technologies, followed by biological conversion, biochemical conversion, and ends with a discussion on integrated systems.

D.1 Combustion

Combustion is the burning of organic material in the presence of oxygen creating a flame. Wood stoves, fireplaces, and industrial burners are examples of biomass energy by combustion.

“Combustion is defined as the oxidation of the fuel for production of heat at elevated temperatures without generating commercially useful intermediate gases, liquid, or solids.”⁹⁷ Fundamentally combustion is unrestricted oxidation of fuel.

D.1.1 Raw Industrial Solid Biomass Fuel California has a great story to tell about biomass power. In the 1980’s California had more than 60 biomass power plants that had a generating capacity of nearly 1,000 MW.⁹⁸ Changes in pricing policies, utility regulation and normal wear and tear have taken its toll on the California biomass power generation industry. Currently there are only 26 operating biomass power plants with a generation capacity of 550 MW (Table D.1).⁹⁹

Table D.1 Status of Current and Former Biomass Power Plants in California

Status	Number of Plants	Generating Capacity (MW)
Operating	26	550

⁹⁷ Technology Assessment for Biomass Power Generation - UC Davis. Draft Final Report. Rob Williams and Bruce Vincent. California Biomass Collaborative website, October 2004. http://biomass.ucdavis.edu/materials/reports%20and%20publications/2004/2004_Assessment_SMUD_ReGEN.pdf.

⁹⁸ Status of Biomass Power Generation in California, July 31, 2003. G. Morris for National Renewable Energy Laboratory (NREL) Golden, CO. December 2003. <http://www.nrel.gov/docs/fy04osti/35114.pdf>

⁹⁹ Biomass to Energy. Biomass and Conversion Technologies. CIWMB website [Http://www.ciwmb.ca.gov/Organics/Conversion/BioEnergy](http://www.ciwmb.ca.gov/Organics/Conversion/BioEnergy)

Idled	17	217
Dismantled	14	97
Converted to Gas-Fueled	5	111
Total	62	975

The larger of these industrial biomass power plants burn over 1000 tons of bone dry biomass per day. Siting near the biomass source is a major economic factor regarding transportation costs.

D.1.2 Solid Fuel Densification¹⁰⁰ At the other end of the spectrum from the bulk, raw feedstocks, are the densified fuel products like wood pellet and larger cubes. These biomass pellet and cube projects generally focus on producing a usable, transportable fuel for use away from the pelleting mill. Creating pellets and cubes standardizes the quality of the wood and biomass feedstocks so they will perform consistently in multiple locations. The creation of pellets and cubes generally relies on an extrusion process, so the final product is more compact and dense. Densifying wood and other biomass materials facilitates economic transportation of bulky biomass.

Figure D.1 show the continental US pellet manufactures during the 2005-2006 heating season.¹⁰¹ Pelleting wood and biomass is an economical way to move biomass produced in one location to use as a heating fuel in another location. The US pellet manufacturing industry is exploding. In 2005-2006, the US production of fuel pellets was about 1 million tons. With the expansion of the pellet fuel manufacturing projects, it could be nearly double that capacity by the end of in 2008. There are several very important factors that have driven the expansion of pellet fuels.

- The increasing price of energy – both domestically and internationally.
- Large available quantities of waste wood from pest infestation and natural disasters
- New California Air Resources Board rules that restrict the use of wood stoves unless pellet fuels are used (this is generally because the newer pellet stoves burn more efficiently.

¹⁰⁰ “*densification*” means to make more dense, less fluffy.

¹⁰¹ Pellet Fuels Institute website. <http://www.pelletheat.org/3/residential/fuelAvailability.cfm>

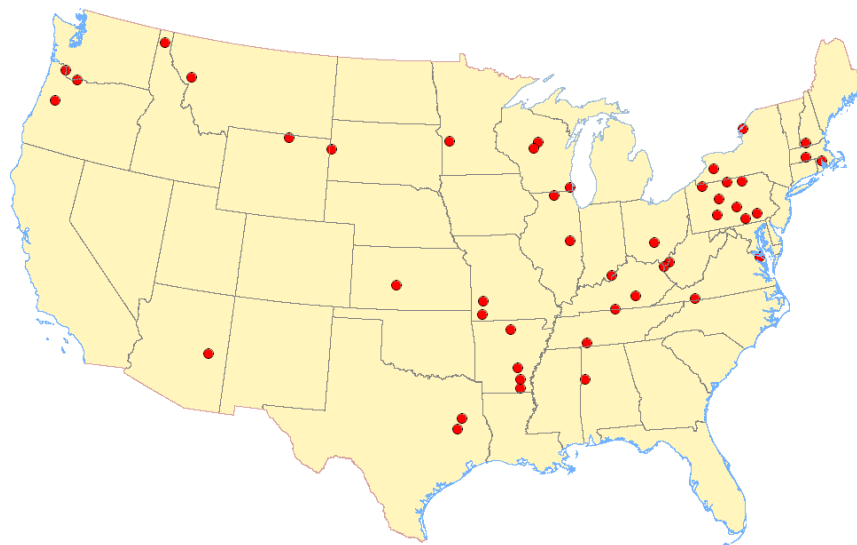


Figure D.1 Fuel Pellet Manufacturers, 2005-2006 heating season (Pellet Fuels Institute)

Pellet fuel projects evolved in cooler forested regions of the US, but that is no longer the case. Pellet fuel projects are developing all over the US. Very large industrial pellet manufacturing facilities have moved into Florida and Alabama. Green Circle Bio Fuels, a recent large pellet mill, opened in Florida in June 2008. It has an annual production capacity of 500,000 tons of fuel pellets. This single facility alone will produce what was half the US pellet fuel supply from three years ago. They are targeting the more lucrative markets of Europe and Asia.

The pellet fuels industry has developed some pretty strict standards for fuel pellet quality. Premium fuel pellets have less than 1 percent ash content with controls on fines and chlorides. They are fairly dense at 40 lbs per cubic foot and do not crumble, so they transport well. Certification of fuel pellet quality is determined by laboratories that have been approved by the Pellet Fuels Institute.

Fuel pellet prices have remained fairly constant during the last heating season (2007-2008). Figure D.2 shows the prices reported across the country on the Hearth.com website.¹⁰² These prices are not aggregated statistically, but are based on entries from volunteers around the country. The

¹⁰² Hearth.com pellet fuel prices. <http://www.hearth.com/econtent/index.php/fuels/viewwoodpellets/P0/>

prices presented here are generally posted in \$ per ton. If the pellets are not sold in bulk, they usually sell in 40 pound bags.

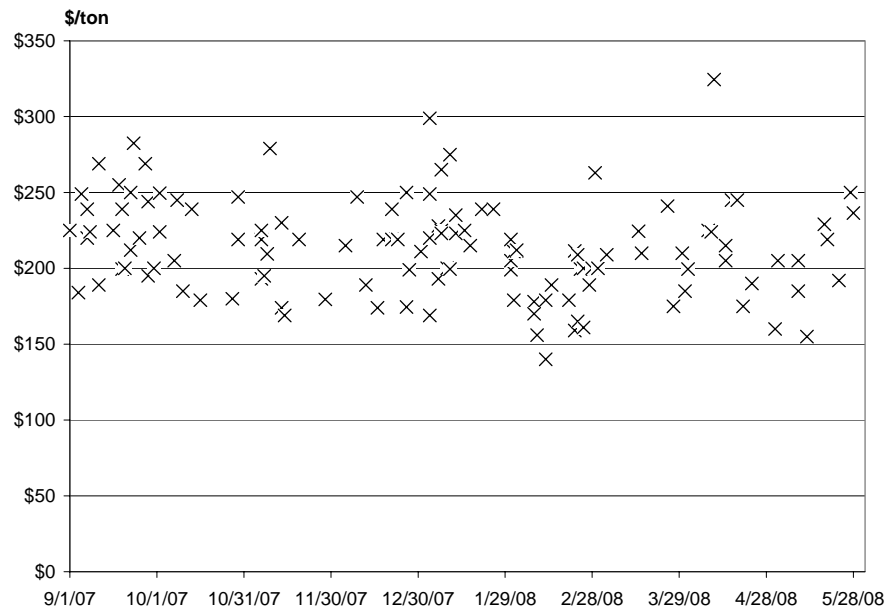


Figure D.2 US Fuel pellet prices for 2007-2008 winter heating season

D.1.3 Non-traditional Solid Biomass Fuels Converting waste wood to premium quality fuel pellets has been a strength of the pellet fuels industry. However, nearly any biomass material that can be extruded – and will burn – is being examined as a feedstock into pellet fuel production. Common materials are derived from wood, agricultural residues, and paper. Many wood processing and paper mills produce their own energy from waste wood. A brief list of facilities that are using solid fuels are provided in Table D.2. Examples of different pellets are shown in Figure D.3.

Table D.2 Selected California and US solid biomass boiler applications

Feedstock	Project	Technology	Output	City	State	Status
Wood, biomass	Most of CA 26 biomass power plants	biomass boiler	>500 MW	---	CA	Operational
MSW pellets	Soy Energy biodiesel plant	biomass boiler	heat	Marcus	IA	Planned
Manure	Fibrominn	biomass boiler	55 MW	Benson	MN	Operational
Manure	Mesquite Lake (GreenHunter Energy)	biomass boiler	18 MW	El Centro	CA	Operational
Paper, wood	NW Missouri State University	biomass boiler	heat	Maryville	MO	Operational
Cherry pits	various cherry orchards	natural fuel pellet	heat	---	MI	Available



Figure D.3 Premium wood fuel pellets (left) and larger paper pellets used in NW Missouri State University's biomass boiler, Maryville, MO (right)

D.2 Gasification

Gasification is the liberation of volatile, gaseous compounds at high temperatures with the controlled restriction of oxygen.¹⁰³ This creates a flammable producer gas ready to combust. One of the challenges with a gasifier is that this producer gas does not substitute directly for natural gas. In addition the composition of the gas varies with the feedstock entering the gasifier.

While the Department of Energy does not distinguish between combustion and gasification, the CIWMB does.¹⁰⁴ This distinction between combustion and gasification is important, because it influences the release of emissions. Fundamentally on a technical level, gasification pulls the volatile organic gases out of the solid fuel without combusting those gases (oxidation). This is described in the first two stages of the combustion process in Appendix C, Figure C.1. At the technical level the release of the volatile gases from the solid biomass are very similar for both gasification and pyrolysis.

The California legal definition of gasification goes beyond the technical definition by qualifying the feedstocks permissible in an approved gasification process. According to California Public

¹⁰³ From BioTown USA Sourcebook. Mark Jenner. Indiana State Department of Agriculture 2006. http://www.in.gov/oed/files/Biotown_Sourcebook_040306.pdf.

¹⁰⁴ DOE, Energy Efficiency and Renewable Energy, Biomass Program, Thermochemical Conversion Processes, Gasification. http://www1.eere.energy.gov/biomass/thermochemical_processes.html. The CIWMB definition of gasification is tied to the solid waste diversion credit regulations <http://www.ciwmb.ca.gov/Organics/Conversion/Gasification/>.

Resources Code (PRC), Section 40117 of the, if the biomass materials entering the conversion technology can be reduced, recycled or composted, it is not legally gasification. Since San Benito County falls under the California Code it is important to be aware that there are some constraints on conversion technology adoption. The PRC, Section 40117 definition of gasification sends a confusing message about whether firms should comply with the solid waste diversion rules or those rules which encourage biomass energy production.

Gasifiers produce three products: heat, producer gas, and ash. To operate as an efficient system, beneficial uses need to be developed for all three products. Many processes require heat or drying. If the heat can not be used directly by the gasifier operators, there may be opportunities to market it to a nearby school or industry. The ash contains phosphorus and may be developed into a soil amendment or plant fertilizer.

The producer gas contains many valuable organic compounds. These can be used to produce power directly, or can be used to develop further refined products like: chemicals and fertilizers and liquid fuels.¹⁰⁵ To fully utilize the gasifier producer gas for any kind of power generation, additional equipment is necessary.

D.2.1 Benefits and Liabilities of Gasification Gasifiers are very good at converting the lignin (25-30% of the biomass) into useful products of the producer gas. Lignin has an energy value, but it is often difficult to separate it from the simple sugars for efficient recovery. Gasification converts most biomass feedstocks into a clean producer/synthesis gas.

Low air emissions are another significant benefit of gasification relative to combustion. Gasification emissions tests, as mentioned for the Rahr Malting plant gasifier in Minnesota (Appendix A), showed significant reductions over coal and diesel fuel. Research in Texas found that mixing small amounts of beef feedlot manure (7-15%) with coal before gasification reduced

¹⁰⁵ Gasification Products and Applications, Gasification Technologies Council
http://www.gasification.org/what_is_gasification/products.aspx

the nitrous oxide emissions levels with potential to reduce energy costs of delivering less coal to the power plant.¹⁰⁶

Other benefits of gasifiers are:¹⁰⁷

- Reduction of waste volume by over 90%, reducing it down to ash content.
- Gasifiers generally have few moving parts.
- Gasifiers are built for specific application after testing response of feedstock in a test burn.
- There are heat and ash co-products, in addition to the energy-rich gas, that also have value.

The University of Minnesota is building a gasifier at their Morris, UMN experiment station.¹⁰⁸

The University will be feeding corn stover, wheat straw, soybean residue, native grasses and hybrid poplar. In addition they plan to develop best management practices, templates for pricing structures and contracts and templates for environmental permitting.¹⁰⁹ On-site operation of the gasifier will provide power to the University of Minnesota Morris facilities and allow research in biomass collection and storage.

Technical barriers for gasification are:

- Feed processing and handling – The handling and storage of biomass feedstocks is a challenge (Appendix B). Maintaining consistent feedstock quantities and qualities are not easy. Various gasifiers feed some kinds of biomass materials in more easily than others, so switching biomass feedstocks may also have limitations.
- Producer/syngas cleanup and conditioning – the gaseous compounds leaving the gasifier do not meet standards for other more conventional fuels, like natural gas, and must be further treated or cleaned up to meet those standards. Cleanup and conditioning are required to remove tar, particulates, alkali, ammonia, chlorine, and sulfur. This challenge is further compounded by economic, and environmental performance standard criteria.
- The gas produced by gasifiers can not be stored. It must go directly into the next process.
- System integration – as mentioned earlier it is important to integrate all feedstocks and products with existing enterprises and operation. Anything less than full utilization will not be efficient.

¹⁰⁶ John M. Sweeten and Kalyan Annamalai, “Gasification & Combustion of Cattle Feedlot Manure,” BioEconomy Conference, Iowa State University, Ames, IA August, 30 2005.
http://www.valuechains.org/bewg/Conf2005/Presentations/John_Sweeten.pdf

¹⁰⁷ BioTown USA Sourcebook, Mark Jenner. Indiana State Department of Agriculture 2006.
http://www.in.gov/oed/files/Biotown_Sourcebook_040306.pdf

¹⁰⁸ University of Minnesota, Morris News. August 9, 2007.
<http://www.morris.umn.edu/greencampus/BiomassGroundbreaking.html>.

¹⁰⁹ NRCS USDA Awards \$12.6 million for biomass research and development
www.nrcs.usda.gov/technical/grants.html

- Material design – there are often issues in dealing with abrasive ash and containment vessel, this includes development of sensors and analytical instruments necessary to optimize systems.

D.2.2 Plasma-Gasification Plasma gasification or Plasma-arc gasification is a legitimate technology that is discussed frequently as a tool for converting biomass into energy. It is essentially a gasifier but an electrical current is run through the gasifier taking the operating temperature up to temperatures as high as 25,000 degrees Fahrenheit. Until recently plasma gasification has not been commercialized because the expense of building a commercial plasma gasification facility far outweighed the economic benefit of adding the electrical current.

Today that appears to be changing. The list below, in Table D.3, describes biomass gasification systems. The gasification projects that have indicated the use of plasma gasification are marked as such. Two of the three proposed gasification projects for California are plasma arc gasification projects. The project in Watsonville, CA is a pilot plant they plan to bring in on a trailer. The project in Gilroy, CA will be a commercial facility producing 70 percent A-1 jet fuel and 30 percent naphtha. Both of these projects will use MSW as a feedstock.

Table D.3 Biomass gasifiers - proposed and operational

Company	City	State	Plasma	Current Phase	Feedstock	Capacity	Output
Process Heat Supply							
Chippewa Valley Ethanol Co	Benson	MN		Operational	assorted biomass		heat
Panda Ethanol Inc.	Hereford	TX		Approved	cattle manure		heat
Pilot Plants							
AdaptiveARC	Watsonville	CA	X	Proposed	MSW		electricity
Florida Syngas LLC	Grant	FL		Proposed	glycerin	1 MW	electricity
Ze-gen Inc	New Bedford	MA		Proposed	C&D Waste		syngas
BGP	Raleigh	NC		Operational	hazardous waste		pathogen control
Coskata, Inc	Madison	PA	X	Proposed	assorted biomass	0.04 million gal	ethanol, cellulosic
University of South Carolina	Columbia	SC		Proposed	wood chips		steam, electricity
Vermont Electric Cooperative	Derby Line	VT		Proposed	wood chips	1 MW	electricity
Coaltec USA	Wardensville	WV		Operational	poultry manure		heat
Commercial Scale Plants							
Community Power - BioMax	Truckee	CA		Operational	wood chips	0.015 MW	electricity
Community Power - BioMax	Winters	CA		Operational	walnut shells	0.050 MW	electricity
Liberty Energy	Lost Hills	CA		Proposed	organic waste	20 MW	electricity
Solena Group	Gilroy	CA	X	Proposed	MSW	17 million gal	biofuels
MaxWest	Sanford	FL		Proposed	biosolids		heat, gasifier
Green Power Systems LLC	Tallahassee	FL		Proposed	landfill, MSW		electricity
BFC Gas & Electric Co.	Cedar Rapids	IA		Operational	assorted biomass	7.5 MW	electricity
Dow Corning	Midland	MI	X	Construction	assorted biomass		syngas and HCL
SunCrest Energy	Monroe	MI	X	Proposed	MSW	100 MW	electricity
University of Minnesota	Morris	MN		Proposed	corn stalks		steam
Rural Energy Marketing	Vermillion	SD		Proposed	corn stalks	15 million gal	biodiesel
Farm Power	Spokane	WA		Construction	grass, straw		electricity
Grand Meadow Energy LLC	Stratford	WI		Construction	cheese permeate	6 million gal	ethanol/biodiesel

D.3 Pyrolysis (also known as Fast Pyrolysis)

The fast pyrolysis technology concept is a bit confusing because ‘pyrolysis’ is a step discussed in the combustion process (Appendix C). The process, ‘pyrolysis,’ used in that four-step combustion process actually occurs with both gasification and fast pyrolysis. The technology, ‘fast pyrolysis,’ condenses the volatile gases liberated by the process ‘pyrolysis’ and rapidly condenses them into a bio-oil.

Fast pyrolysis occurs at lower temperatures than gasification (400-600⁰ C or 750-1,100⁰ F).¹¹⁰ Volatile carbon-based materials are turned into a gaseous state and liberated from the remaining char. Once the gaseous organic materials leave the reaction chamber, they are condensed into a liquid, pyrolytic bio-oil (Figure D.4).

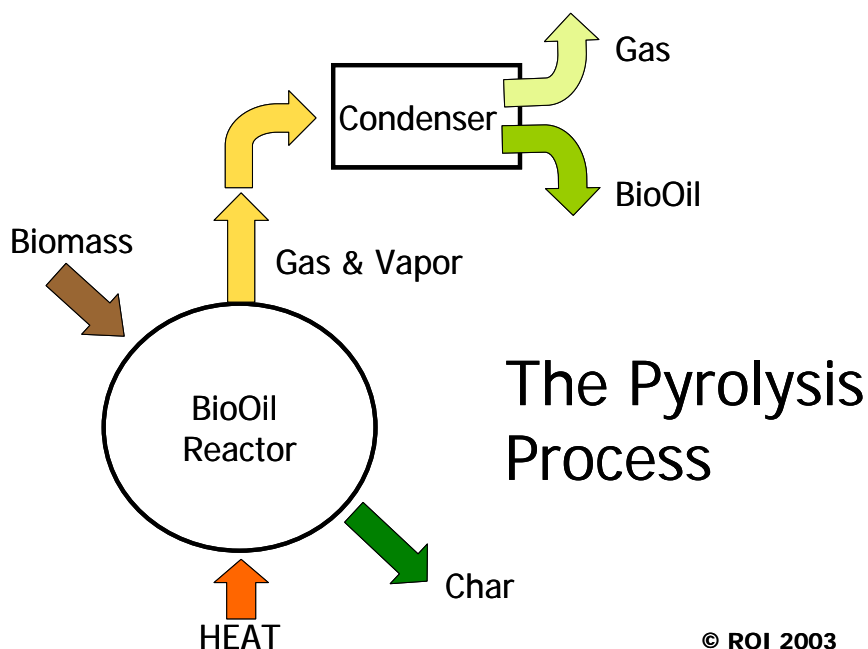


Figure D.4 The Pyrolysis Process (Renewable Oil International)

When the feedstock is dried to less than 10 percent moisture, pyrolytic bio-oil will yield 60 – 75 percent with about 13 – 25 percent resulting in char. Assuming a conversion of 72 percent of the biomass feedstock to liquid by weight, pyrolytic bio-oil will yield about 148 U.S. gallons per ton.¹¹¹

¹¹⁰ Brown, Robert, *Biorenewable Resources: Engineering New Products from Agriculture*. Iowa State Press. Ames, IA 2003.

¹¹¹ “Fast Pyrolysis,” BioRefining Process. Wisconsin BioRefining Development Initiative. <http://www.wisbiorefine.org/proc/fastpyro.pdf>

Fast Pyrolysis is an energy intensive process, but recycled combustible gases can supply about 75 percent of the required energy.

Fast Pyrolysis is a technology that is in the initial stages of commercialization. A fairly current summary of North American commercial-scale fast pyrolysis plants is provided in the Wisconsin BioRefining Development Initiative, Fast Pyrolysis document referenced above:

- The Dynamotive Corporation has reached the commercialization stage. They have two operating commercial-scale plants in Canada (West Lorne & Guelph) and have announced a 5,000 ton biooil plant to be constructed in Missouri
- Renewable Oil International, is an Alabama company that is commercializing a fast pyrolysis technology. A 3-4 ton per day ROI plant is in the works with the location to be announced.
- Ensyn reports 1989 and 2008, they have built and commissioned 7 commercial plants in the US and Canada.
- The Biomass Technology Group (BTG) is a commercial technology that has pyrolysis sites in Europe and Asia.

D.3.1 Benefits and Liabilities The benefits of fast pyrolysis are similar to gasification. Fast pyrolysis reduces the volume of the feedstock significantly. Fast pyrolysis, however, is unique from gasification in that it can be condensed at the feedstock production site and then transported more cost-effectively to another central facility for further-processing. Conventional liquid fuels have a high energy density. Bio-oil is appealing because it produces also produces an energy-dense liquid fuel. There are significant environmental benefits in reducing air emissions and waste.

The liabilities and risks are high due to a fledgling-level of the commercialization of this technology. The bio-oil is similar to heating oil, but differs in character depending on the biomass feedstock used. Like the producer gas of gasification, fast pyrolysis bio-oil is not directly usable in many applications, but can be cleaned and used in conventional liquid fuels. The limited number of commercial fast pyrolysis plants translates into a lower confidence and a higher risk for lenders.

D.4 Biological Conversion

Biological conversion is the process of converting carbohydrates into energy using living organisms. The biomass energy discussions here are limited to the very specific microbiological processes of anaerobic digestion and fermentation of carbohydrates.

D.4.1 Anaerobic digestion Anaerobic digestion is the cultivation of methagenic bacteria in the absence of oxygen. Methagenic bacteria live in an aquatic environment. This is intuitive when thinking about manure and municipal sewage waste streams. This is also true for landfill gas methane. So the basics of anaerobic digestion described here also apply to landfill gas generation.

Intensively managed methane generating technologies, like anaerobic digesters, are very complex microbiological ecosystems. The efficiency of conversion of manure or sewage to methane gas depends on many factors like quality of the feedstock or waste material entering the digester and the intensity of digester management. This latter intensity includes things like: the retention time of manure in digester, temperature of the digester, and whether it is continuously loaded or not.

Increasing the management intensity an anaerobic digester increases the conversion efficiency, but also increases the possibilities of the digester system being upset. The opposite is also true with the lowest levels of digester management. Decreasing digester management to a low level of management, like a landfill, produces a very stable, low volume output of biogas and methane. As management level drops, so does the methane conversion rate.

Because a digester is a biological ecosystem, there is some stability in the buffering ability of the digester. Natural buffers will compensate for small fluctuations in the chemical nature of the liquid material within the digester.

Anaerobic digesters are similar to the rumen (digestive system) of cows. In fact, a great deal of US anaerobic digester microbiology evolved from research conducted by ruminant physiologists. When a cow eats plant material, it gets broken down into smaller molecular units (sugars starches and fibers) by physical, biological and chemical processes.

In a digester, high moisture biomass, or wastes (used biomass) that enters the digester contain partially digested plant parts (Figure D.5).¹¹² These plant parts may take the form of unused food, paper, wastewater, or oils. Acid forming bacteria feed on carbohydrates and produce volatile

¹¹² BioTown USA Sourcebook, Mark Jenner. Indiana State Department of Agriculture 2006.
http://www.in.gov/oed/files/Biotown_Sourcebook_040306.pdf

organic acids. These acids are what the methane-forming bacterial eat. As these methagenic bacteria respire, they release methane. While this is described here as a linear process, all these steps are happening at the same time.

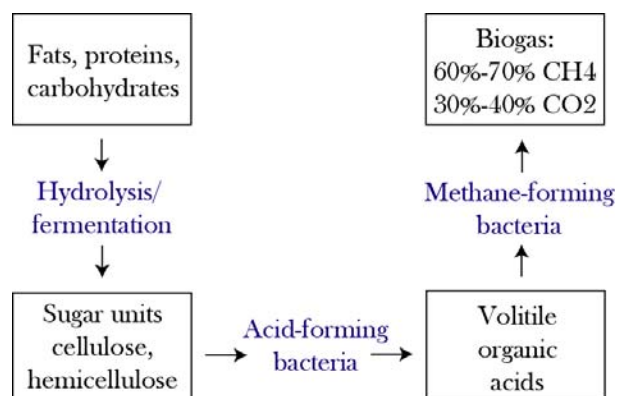


Figure D.5 Microbiology of an Anaerobic Digester

The operating temperatures of digesters are divided into three categories: psychrophilic (less than 68° F), mesophilic (95° to 105° F) and thermophilic (125° to 135° F).¹¹³ The psychrophilic digesters are not heated. Mesophilic digesters are heated to about 100 degrees. The thermophilic digesters are heated even more. They are the most efficient, but also the most sensitive to shocks within the digester system. Anaerobic lagoons (outside earthen containers) are also digesters. The operating temperatures of these earthen, anaerobic lagoons fluctuate with the season. They will warm up in the summer, and during the winter methane production is reduced.

In San Benito County the confined livestock sources of biomass like manure are limited. More probable sources of methane are from municipal sewage or landfilled waste. Methane bioenergy projects do not traditionally yield high amounts of energy. This is because the systems that have been designed historically have been designed to mitigate or remediate a waste – rather than process a marketable resource. The summary of California and US methane-powered electrical generators are presented in Table D.4.

There are some very notable things contained in Table D.4. First, landfill gas projects provide about 90 percent of all methane-generated electricity (in CA it is 89 percent). Municipal

¹¹³ Joseph Kramer, Agricultural Biogas Casebook – 2004 Update. Resource Strategies, Inc.
<http://www.mrec.org/pubs/AgriculturalBiogasCasebook2004Update.pdf>

wastewater digesters produce about 10 percent of the methane (in CA). Manure digesters to-date have only provided about 1 percent of the methane produced (in both CA and the US).

Table D.4 Methane-powered electrical generation for California and the US

	California Projects	MW Capacity	MW per Facility	National Projects	MW Capacity	MW per Facility
Landfill gas projects^a	113	304	2.69	442	1550	3.51
Metropolitan sewer digesters^b	29	34	1.18	106	114	1.08
Farm manure digesters^c	16	4	0.25	90	21	0.24
Total MW electrical generation		342			1,685	

a Landfill gas project data was derived from the EPA, Landfill Methane Outreach Program (LMOP) database. <http://www.epa.gov/lmop/proj/index.htm>

b Methane projects for municipal sewage anaerobic digesters is from EPA, Combined Heat and Power Partnership program document: *Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities*. Eastern Research Group, Inc. December 2006. http://www.epa.gov/CHP/documents/chp_wwtf_opportunities.pdf

c Methane projects using manure in manure digesters came from the EPA AgStar program, Anaerobic Digester Database. <http://www.epa.gov/agstar/operational.html#addatabase>. Some numbers may vary on all three dataset due to interpretation of what is the most representative data.

Intensively managed digesters while more efficient than landfills currently do not cash-flow as well as the low management landfills energy projects. A landfill gas generator has about 10 times the electrical generation capacity of the average farm manure generator. In California the average size landfill-gas power plant has a 2.7 MW capacity per unit. With manure-digester power plants the average generating capacity in California is 0.25 MW per unit. It costs about 2-3 times more to install a landfill-gas generator, and it yields 10 times more electricity (due to the sheer volume of material in the landfill rather than conversion efficiency). This is only a problem using traditional methodologies. With the emerging wastewater and manure digester technologies, there are more marketable products are available from the technology like digester solids, organic nutrients, and carbon credits.¹¹⁴ The return on a new wastewater/manure digester is different than the return on investment from a landfill gas project.

There is a revolution going on in manure energy projects. They are moving from a farm-scale digester to an industrial scale digester that utilizes more than manure. One of the technical benefits from manure/industrial digesters is that the technology can process more than one kind of

¹¹⁴ Carbon credits are the accounting and trading of carbon dioxide equivalent emissions. In California, the California Climate Action Registry (CCAR) is developing carbon sequestration protocols that facilitate carbon emissions trading. <http://www.climateregistry.org/tools/protocols.html>.

waste at one time. The legal challenge is that multiple wastes are generally regulated by multiple permits and multiple agencies in which there are limited incentives to coordinate a multi-waste digestion project. Even so, there are several commercial scale digesters that are effectively generating significant methane using multiple waste streams.

As bioenergy production becomes more common, landfills will look for ways to segregate solid biomass from entering the landfill. Landfill methane, just like wastewater/manure-derived methane, grows in aquatic conditions. It takes enormous amounts of landfilled solid waste to generate a tiny amount of methane. The 1,550 MW generating capacity of the existing US landfills is an accomplishment to be proud of. However, there are more efficient ways to utilize that residual carbon than burying it in a landfill. Biomass or carbon within the solid waste stream is being examined as a feedstock into cellulosic ethanol production, gasification for electricity and heat, and sometimes, even developing solid fuel such as fuel pellets or cubes.

Table D.5 uses the basic numbers provided by EPA's LMOP dataset (referenced in Table D.4). The 1,550 MW of existing generation capacity is produced from a resident landfill tonnage of 3.7 billion tons of solid waste. That means that with the current landfill-gas electricity generating base it takes a million tons of buried waste to supply a 0.4 MW generation capacity. This is not an efficient conversion rate.

Table D.5 Generation capacity based on tons of buried solid waste

442	US landfill gas electricity generating facilities
1,550	MW of generation capacity
3,700,744,518	Tons total buried solid waste
4.18835E-07	MW/ton of buried waste
0.418834641	MW/million tons of buried waste

To be fair, the solid waste industry is also examining more efficient technologies to generate energy revenue than the first generation landfill gas generators. The new systems being installed today are likely much more efficient than the early landfill gas generators. As opportunities emerge to segregate and divert the biogenic materials from the solid waste stream, it will be much more efficient to convert a ton of biomass into liquid and solid fuels than to wait for millions of tons to accumulate in the landfill so it can begin to run a generator. There are also movements within

California to ban organics completely from landfills. If these evolve into law there will be even greater incentives to use the solid waste fuel for something besides landfill gas generators.

The conversion rate of wastewater generation capacity to million gallons per day (MGD) of influent is 22.22 kW per MGD. This is remarkably consistent for all 106 reported metropolitan wastewater treatment facilities reported in Table D.4. For a 4 MGD wastewater treatment plant, this means it could power an 88.8 kW generator.

D.4.2 Further Processing of Methane Gas While the gas referred to as methane that is produced in anaerobic digesters is largely methane, it also has other components. One of the problematic components is water vapor. In order for digester-produced methane to be compatible with natural gas and other common gas and liquid fuels, it must be refined or further processed.

The publication, “Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California,” is a comprehensive discussion of what is necessary to further process methane digester gas and make it commercially available in energy forms that are in demand.¹¹⁵ “Biomethane from Dairy Waste” describes seven processes that can be used to remove the hydrogen sulfide from the biogas and more than six processes for removing water vapor from digester biogas.

All of these processes add more steps and costs to the utilization of anaerobic digester gas output, but the end product also has a significantly higher value. The Sourcebook on “Biomethane from Dairy Waste” also describes several gaseous product forms: blending with natural gas and compressing the purified biomethane. Three liquid fuel products are described also: methanol synthesis (for biodiesel), Fischer-Tropsch (for gasoline) and liquefied biomethane.

D.4.3 Benefits and Liabilities There may be a place for methane generation in San Benito County, because it is a great way to manage some liquid resources. Since water is at a premium it

¹¹⁵ Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California. Prepared for Western United Dairymen by Ken Krich, Don Augenstein, JP Batmale, John Benemann, Brad Rutledge, and Dara Salour. July 2005
<http://www.westernuniteddairymen.com/USDA%20Grant/USDAgrantfinalreport.htm>.

will likely make economic sense to process as much biomass as possible as solid biomass.

Anaerobic digesters have many benefits.

- Odor control
- Greenhouse Gas reduction
- Heat and Electricity production
- Fly, weed seed, and pathogen reduction (manure digesters)
- Enhanced manure nutrient availability
- Carbon-credit revenue

The list of anaerobic digester liabilities is equally as exciting.

- Manure and wastewater treatment digesters haven't always worked. Current technologies have track records of success. But the hard reality is that in the last 20 years a lot of digesters that have been built are no longer running. There are legitimate reasons for this. One good reason is that we know a lot more about building and running digesters than we used to.
- Revenue from the sale of methane-generated electricity may not provide any economic security. It is difficult to obtain a good price for electricity. New policies are being developed, and things are changing, slowly.
- Raw methane gas generated from an anaerobic digester can not be stored. It has to be used as it is produced or flared off into the atmosphere. Or else it must be cleaned and processed for use in the natural gas, or further-processed market.
- The existing single-focused environmental regulations do not accommodate the mixing of materials that are regulated by separate agencies. This needs to change for anaerobic digestion to move from a waste-treatment technology to a commercial energy production technology.
- It is less costly and more efficient to build a digester that is designed from the ground up as an integrated component of the livestock operation and buildings.
- Digesters, as with other energy conversion technologies, are difficult to just 'try it out' for a while. Once you make the commitment to build and operate a digester, it is a long term decision.

D.5 Biological Fermentation of Alcohol

Conversion of corn into ethanol by fermentation has been one of the bright stars of the biomass renewable fuels industry. As of July 2008, there are over 160 existing US ethanol plants currently listed on the Renewable Fuels Association (RFA) website with expansion or new construction planned at 49 more facilities.¹¹⁶ Ethanol production in 2007 was 6.5 billion gallons (Figure D.6).

Indeed the expansion of the ethanol industry has been so rapid, it has created numerous conflicts. The industry has grown 200 percent since 2002. The greatest driver in this growth domestically

¹¹⁶ Renewable Fuels Association <http://www.ethanolrfa.org/industry/locations/>

has been the switch from using the oxygenate MTBE (methyl tertiary-butyl ether) to ethanol as an oxygenate. The rapid growth has created an increased demand for corn and the price of corn is nearly triple its traditional price. This is a principle reason for the current ‘Food vs. Fuel’ debate.

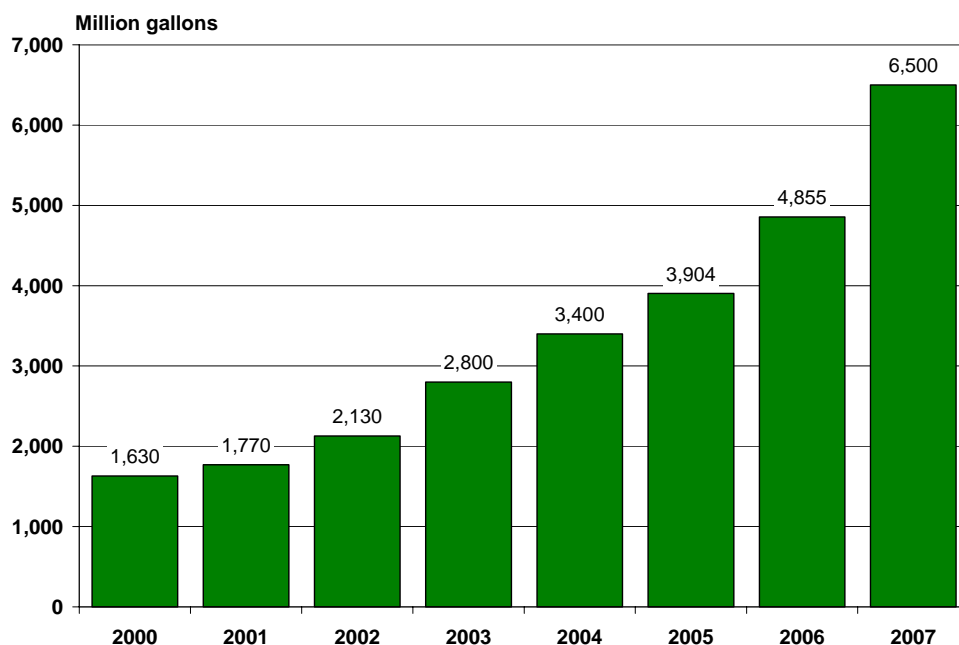


Figure D.6 US Ethanol Production, 2000 to 2007

Ethanol prices hit a low last fall (2007) around \$1.50 per gallon, when the demand for ethanol as an oxygenate was finally met (Figure D.7).¹¹⁷ The steady increase in the price of crude oil has pulled the price for ethanol steadily up also, so it approached \$3.00 per gallon. Multiple studies have been released in 2008 that indicate the volume of domestically produced ethanol is high enough now that it is keeping the price of gasoline 30 to 40 cents per gallon lower.¹¹⁸ About the first week of July the price of ethanol broke and through July 2008, it has continued to fall.

¹¹⁷ USDA Agricultural Marketing Service (AMS) Livestock & Grain Market News. National Weekly Ag Energy Round-up <http://www.ams.usda.gov/nmreports/lswagenergy.pdf>.

¹¹⁸ “The Impact of Ethanol Production on U.S. and Regional Gasoline Prices and on the Profitability of the U.S. Oil Refinery Industry.” Xiaodong Du and Dermot J. Hayes. Working Paper 08-WP 467. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa. April 2008. <http://www.card.iastate.edu/publications/DBS/PDFFiles/08wp467.pdf>

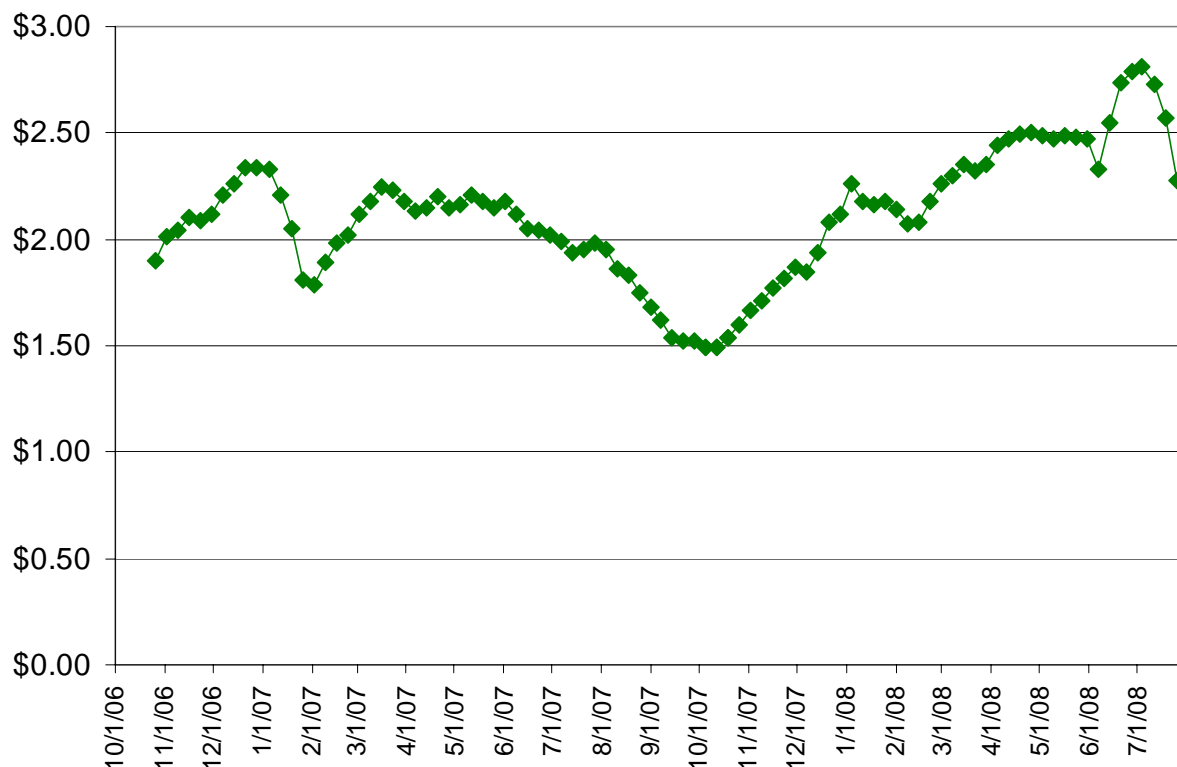


Figure D.7 Iowa Ethanol Prices, October 2006 through July 2008, USDA-AMS

Currently there are three ethanol plants with a total production capacity of 76.5 million gallons in California. They are: ¹¹⁹

- Golden Cheese Company of California, Corona, CA, using cheese whey, producing 5 million gallons of ethanol per year.
- Pacific Ethanol, Madera, CA, using corn, producing 40 million gallons of ethanol per year.
- Phoenix Biofuels, Goshen, CA, using corn, producing 31.5 million gallons ethanol per year.

Other ethanol plants have begun construction or announced plans to build they are:

- Calgren, Pixley, CA, using corn, to produce 55 million gallons per year.
- Cilion Ethanol, Keyes, CA, using corn to produce 50 million gallons per year.
- Pacific Ethanol, Stockton, CA, using corn to produce 50 million gallons per year.

When these proposed projects come on-line they will provide an additional 155 million gallons of ethanol in California annually.

¹¹⁹ Renewable Fuels Association <http://www.ethanolrfa.org/industry/locations/>

The ethanol industry has successfully commercialized the dry-mill process of converting a bushel of corn into ethanol (2.5-2.6 gallons/bu.), dried distillers grains and solubles (17 lbs DDGS/bu.) and carbon dioxide (16 lbs. CO₂/bu.).¹²⁰ Successful ethanol projects find the highest value for all of these products, which add to the total revenues for the project.

The dry-mill process is more specialized than the other commercial ethanol process, the wet-mill process (Figure D.8). The wet-mill process produces other valuable co-products, such as high fructose corn syrup and corn gluten, but is also far more costly to build. Another emerging ethanol process is dry fractionation, which increases the value of non-starch components before fermentation and reduces the quantity of distiller's grains after fermentation. As new adaptations emerge, ethanol processors will become more efficient at utilizing all the components of a kernel of corn. Facilities are even beginning to install biodiesel operations at ethanol plants to convert the corn oil to biodiesel fuel.

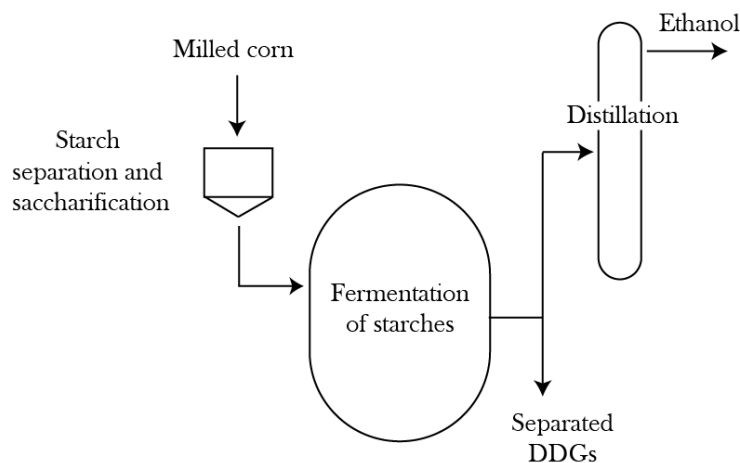


Figure D.8 Schematic of Dry-Mill Ethanol Plant (modified from Brown)

D.6 Chemical Conversion

Like all the energy conversion technologies presented here, there are nearly always a combination of technologies in the conversion of biomass to energy. The principle chemical processes are the hydrolysis of cellulosic fiber into sugars, and the esterification of vegetable oil into biodiesel fuel.

¹²⁰ Brown, Robert, *Biorenewable Resources: Engineering New Products from Agriculture*. Iowa State Press. Ames, IA 2003.

D.6.1 Hydrolysis: Ethanol Fermentation Process (Cellulose/Fiber). Hydrolysis is technically the breaking down of large molecules by splitting a water molecule into a hydrogen (H) molecule bonded to one product and a hydroxyl (OH) bonded to the other product.¹²¹ Here we are referring to the break down of large cellulosic fibers into smaller sugars. The two chemical processes are using acid and using enzymes.

One of the leading cellulosic technology developers is Iogen, a Canadian-based Company. They had initially been awarded a US DOE grant to design and build a cellulosic ethanol plant. Recently they decided to build their first commercial plant in Canada. Another commercial cellulosic technology developer is BlueFire Ethanol, who was also awarded a DOE commercialization grant. BlueFire Ethanol is building their first commercial plant in California. Their chemical hydrolysis process includes the acid hydrolysis process. BlueFire Ethanol is using MSW as their feedstock.

The process for making ethanol from cellulosic fibers is similar to the process of making ethanol from corn (Figure D.9). The difference is a pre-treatment process that reduces the fibers to sugars. This means that the biochemical hydrolysis process can be used to condition or pre-treat the cellulose. This will create sugars that can be fermented like the existing corn-based ethanol plants.

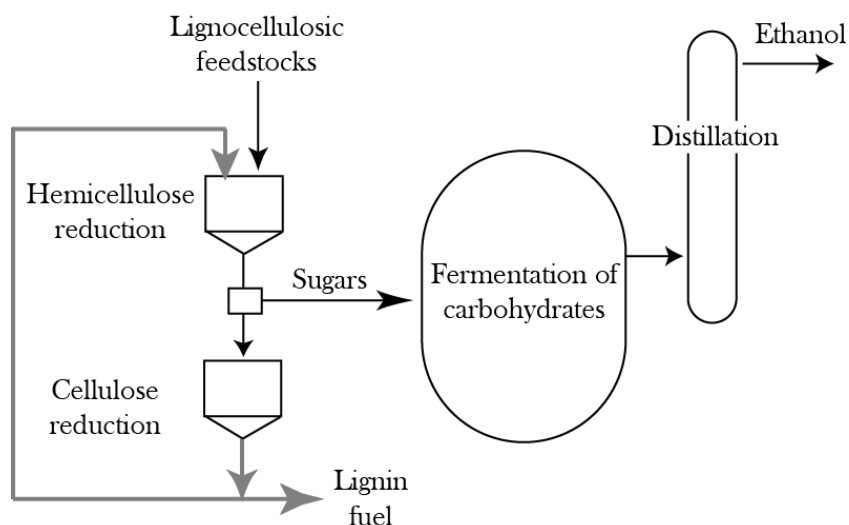


Figure D.9 Schematic of Cellulosic Ethanol Plant (modified from Brown)

¹²¹ Brown, Robert, Biorenewable Resources: Engineering New Products from Agriculture.

Technologies that are being commercialized that use acid hydrolysis are:¹²²

- BlueFire Ethanol is building both a pilot and commercial scale plant in California.
- Genahol, like BlueFire, specializes in using MSW as a feedstock (possibly Indiana).
- Masada/Oxynol is out of Alabama, but building a project in New York.

Biochemical hydrolysis is not the only way to break down long-chain cellulosic fibers. Biomass can be gasified in a thermal technology and then converted to alcohols or hydrocarbon fuels through a process call the Fischer-Tropsch (F-T) process.¹²³

D.6.2 Transesterification of Vegetable Oil (Biodiesel) The soybean oil that is used as a feedstock in commercial biodiesel production process has already been processed from soybeans. So unlike corn ethanol plants that accept the grain itself, biodiesel plants start with processed soybean oil. Soybeans contain about 18.5 percent oil which is separated from the high-valued protein soybean meal.¹²⁴ A 60 pound bushel of beans yields about 11 pounds of oil and 48 pounds of meal.¹²⁵ The oil and soybean meal (protein) are separated at a soybean processing facility and the meal and oil supply two completely different markets.

The National Biodiesel Board (NBB) estimates there is currently the capacity for producing 2.24 billion gallons per year in the U.S.¹²⁶ The NBB points out that capacity is not the same as actual annual production. With the same 2.24 billion gallons of capacity, the production volume for 2007 reported by the NBB is only 450 million gallons of biodiesel fuel (Figure D.10). Biodiesel plants will operate at full capacity only when it makes economic sense to do so. Production of 450

¹²² Williams, Robert B. "Biofuels from Municipal Wastes Background Discussion Paper, March 28, 2007. University of California, Davis and the California Biomass Collaborative. [http://biomass.ucdavis.edu/materials/reports%20and%20publications/2007/2007 Annual Forum Background Paper.pdf](http://biomass.ucdavis.edu/materials/reports%20and%20publications/2007/2007%20Annual%20Forum%20Background%20Paper.pdf)

¹²³ Williams, Robert B. "Biofuels from Municipal Wastes Background Discussion Paper, March 28, 2007. University of California, Davis and the California Biomass Collaborative. [http://biomass.ucdavis.edu/materials/reports%20and%20publications/2007/2007 Annual Forum Background Paper.pdf](http://biomass.ucdavis.edu/materials/reports%20and%20publications/2007/2007%20Annual%20Forum%20Background%20Paper.pdf)

¹²⁴ Dirk E. Maier, Jason Reising, Jenni L. Briggs, Kelly M. Day & Ellsworth P. Christmas. "High Value Soybean Composition." Grain Quality Task Force. Fact Sheet #39. Purdue University. November 23, 1998. <http://www.ces.purdue.edu/extmedia/GQ/GQ-39.html>

¹²⁵ The standard test weight of soybeans is 60 pounds at 13% moisture, while the standard test weight of corn is 56 pounds at 15.5% moisture.

¹²⁶ National Biodiesel Board. "U.S. Biodiesel Production Capacity." January 25, 2008. http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf

million gallons when the capacity is 2.24 billion gallons means that on average the biodiesel industry is only utilizing 20 percent of its capacity.

The cost of vegetable oil, the principle ingredient in biodiesel fuel, is also increasing very rapidly (Figure D.11). This is a fairly accurate indicator that food is more important than fuel. About the first week of July 2008, the price also broke on vegetable oil. The price of vegetable oil has increased to the point that the fuel uses can only compete at the lowest levels.

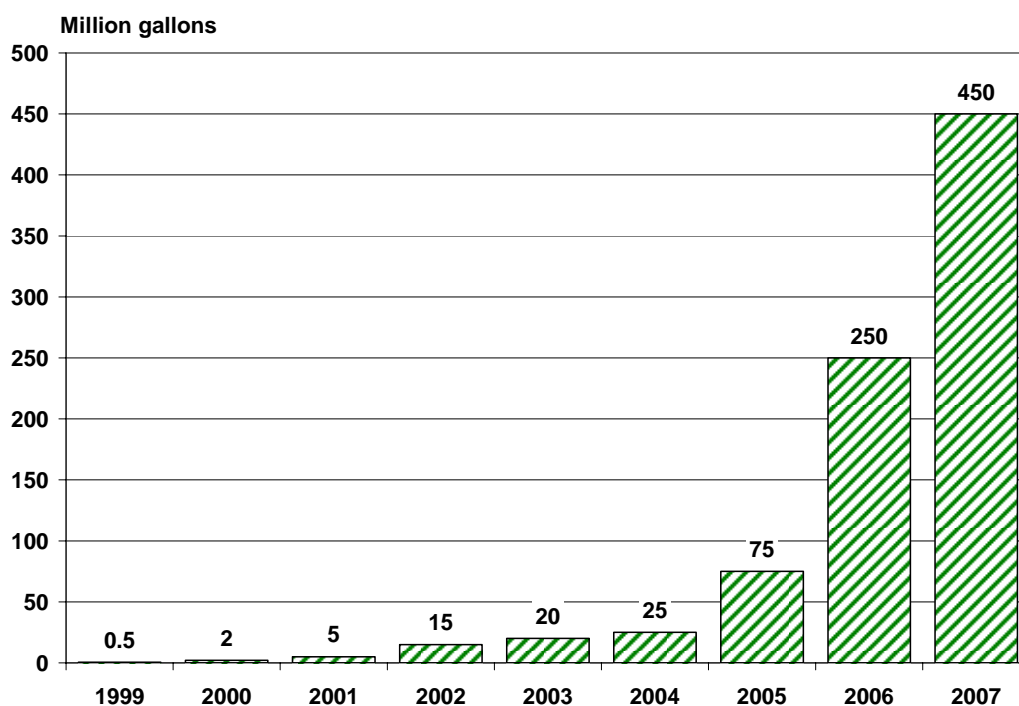


Figure D.10 US Biodiesel Annual Production (NBB)

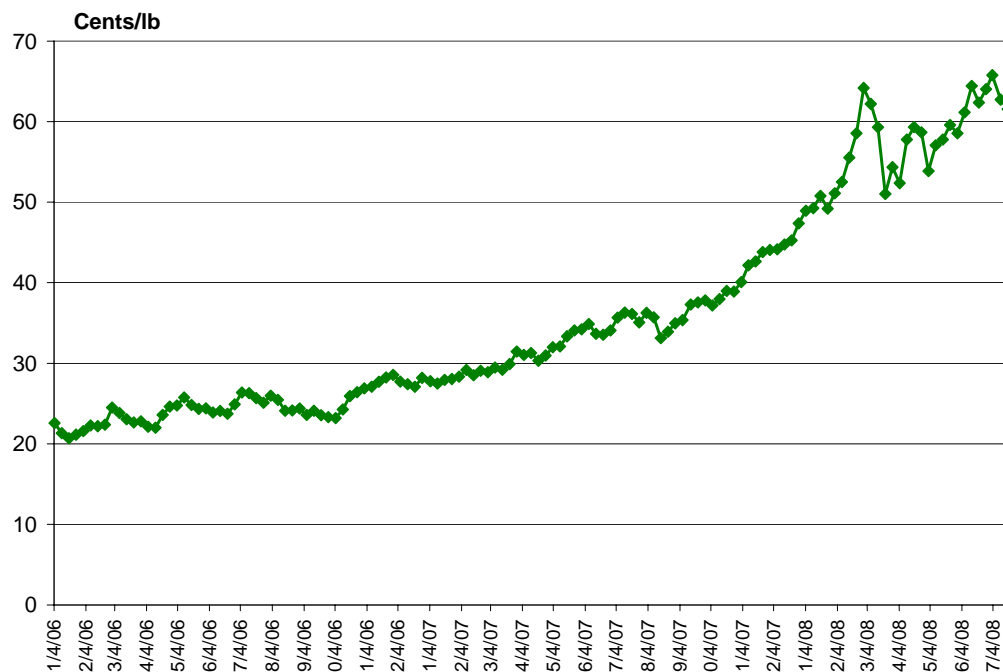


Figure D.11 Price of vegetable oil January 2006 through July 2008

The conversion of vegetable oil to biodiesel is relatively simple chemical reaction that results in nearly a complete conversion of vegetable oil to biodiesel fuel. About 10 percent of the material leaving the process is glycerin (Figure D.12). Glycerin has market value but the quantities produced through the biodiesel conversion process are so large that it creates marketing (disposal) challenge for a biodiesel plant.

The National Biodiesel Board (NBB) describes the primary commercial transesterification process as:¹²⁷

“A fat or oil is reacted with an alcohol, like methanol, in the presence of a catalyst to produce glycerin and methyl esters or biodiesel. The methanol quickens the conversion process and is recovered for reuse. The catalyst is usually sodium or potassium hydroxide which has already been mixed with the methanol.”

¹²⁷ Biodiesel Production. National Biodiesel Board.
http://www.biodiesel.org/pdf_files/fuelfactsheets/Production.PDF

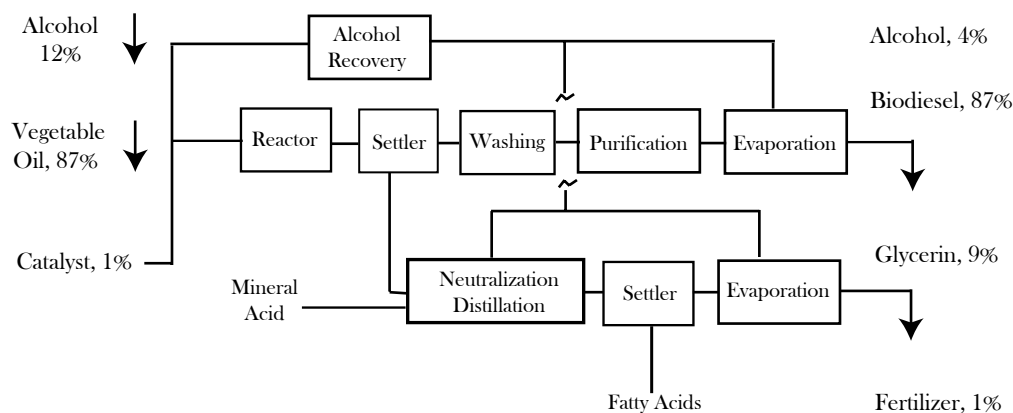


Figure D.12 Process Flow Schematic of Vegetable Oil Conversion to Biodiesel (NBB)

San Benito County is not well suited for soybean production. Soybeans would grow very well in the irrigated San Benito cropland, but the San Benito irrigated land is far too valuable with its current uses. For a soybean oil biodiesel plant to operate in San Benito, all the feedstock oils would need to be brought in to the county. Small amounts of oilseed crops can be grown on the non-irrigated acreage in the County.

As discussed in Appendix B, camelina and jatropha oil crops are theoretically possible in San Benito County. Additional production on non-irrigated land would provide an excellent source of biodiesel feedstock that would not compete with existing food uses.

The greatest advantage of using virgin vegetable oil in the biodiesel conversion process is cost associated with feedstock variability. Because the oil quality of fresh vegetable oil is relatively consistent, biodiesel plants can move large quantities of consistent oil through large facilities. The more specialized a facility is, the lower the costs of the processing operation. The trade off is that the fresh vegetable oil has many other uses and is more costly.

While using virgin vegetable oil as a feedstock into biodiesel production has many benefits, it is not the only source of biodiesel feedstocks. Used vegetable oils, animal fats, Number 2 Yellow Grease and Brown Grease from restaurant grease traps, can all be converted into biodiesel fuel. These used materials are extremely variable and may not provide the biodiesel yield that using fresh vegetable oil does. The economic trade-off with used oil and fat is that it is considered waste material and suppliers (used-oil generators) have had to pay to have it collected.

Increasing prices for virgin vegetable oil are driving the commercialization of used oil feedstocks in the production of biodiesel fuels. An early leader in establishing a business model and developing a used oil technology is Piedmont Biofuels of Pittsfield, North Carolina.¹²⁸ They are a multi-service cooperative that offers biodiesel fuel from used oils. They also offer education and training opportunities in setting up a facility. Piedmont Biofuels has been composting the glycerin.

While Piedmont Biofuels was one of the first waste oil to biodiesel commercial facilities they are not the only ones. Table D.10 lists California biodiesel products. According to the National Biodiesel Board, nine biodiesel plants representing 30.8 million gallons of biodiesel capacity exist in California. These facilities in Table D.10 are the top nine listed. Below the horizontal line are another 6 that are listed as under construction (40 million gallons of capacity). The last three entries in Table D.10 are projects that have been in the news, but were not yet listed on the National Biodiesel Boards website.

Energy Alternative Solutions, Inc. facility in Gonzales, CA is producing biodiesel fuel just outside San Benito County from used vegetable oil and animal fat. These same materials are being used in Watsonville, CA to generate methane by anaerobic digestion.

Table D.10 California biodiesel facilities that are operating (top) and planned (bottom)

Facility	City	Capacity	Feedstock	Date	Website
Bay Biodiesel, LLC ^a	San Jose	3,000,000	Multi Feedstock	Mar-07	www.baybiodiesel.com
Blue Sky Bio-Fuels, Inc. ^a	Oakland	8,000,000	Multi Feedstock	Jan-07	www.blueskybio-fuels.com
Central Valley Biofuels, LLC ^a	Orange Cove	2,000,000	Multi Feedstock	May-07	www.cvbiofuels.com
LC Biofuels ^a	Richmond			Dec-07	
Energy Alternative Solutions, Inc. ^a	Gonzales	1,000,000	Multi Feedstock	Dec-06	www.bioeasi.com
Imperial Valley Biodiesel, LLC ^a	El Centro	3,000,000		Dec-07	www.imperialvalleybiodiesel.com
Imperial Western Products ^a	Coachella	8,000,000	Multi Feedstock	Oct-01	www.biotanefuels.com
Wright Biofuels, Inc. ^a	San Jacinto	5,500,000	Multi Feedstock	Sep-07	www.wrightbiofuels.com
Yokayo Biofuels, Inc. ^a	Ukiah	300,000	Used Cooking Oil	Apr-06	www.ybiofuels.org
Biodiesel Industries of Port Hueneme ^b	Port Hueneme	20,000,000	Full Spectrum	Dec-08	www.biodieselinindustries.com
Central Valley Biofuels, LLC ^b	Orange Cove	5,000,000	Multi Feedstock	Aug-08	www.cvbiofuels.com
Community Fuels ^b	Stockton	7,500,000	Multi Feedstock	2Q 2008	www.communityfuels.com
GeoGreen Biofuels, LLC ^b	Vernon	3,000,000	Used Cooking Oil	1Q 2008	www.geogreenbiofuels.com
Greener Tomorrow ^b	Chino		Used Cooking Oil	2Q 2008	www.GreenerTomorrow.us
Noil Energy Group ^b	Commerce	5,000,000	Multi Feedstock	Apr-08	
Sacramento Biofuels, LLC ^c	Sacramento	60,000,000		Mar-08	
Crimson Renewable Energy ^c	Taft	30,000,000	Multi Feedstock		
	Pacifica	3,000,000	Used Cooking Oil		

a www.biodiesel.org/pdf_files/fuelsheets/Producers%20Map%20-%20Existing.pdf

b www.biodiesel.org/pdf_files/fuelsheets/Producers%20Map%20-%20Construction.pdf

c www.biomassrules.com

¹²⁸ Piedmont Biofuels. <http://www.biofuels.coop/>

D.6.3 Benefits and Liabilities of Conversion of Vegetable Oils and Animal Fats to Biodiesel Fuel

Benefits

- The conversion of oil and fat to biodiesel is a proven and profitable technology investment with nearly over 171 plants operating and another 60 under construction.
- Biodiesel conversion is a relatively simple and very compatible with conventional diesel fuel.
- Engines burning biodiesel emit no sulfur dioxide, and less carbon monoxide, hydrocarbons and particulates. Biodiesel also adds lubricity.
- Recycling used vegetable oil and animal fat, especially Brown Grease from restaurants reduces environmental pressures from disposal of organic wastes.

Liabilities

- Vegetable oil is very valuable already. Converting millions of gallons of vegetable oil into biodiesel fuel has raised the price of vegetable oil for all uses.
- Marketing or disposal of the co-product glycerin is not automatic, but markets exist if the glycerin is managed well.
- Burning biodiesel in engines has been reported to increase the nitrogen oxide levels slightly. Recent work by Bob McCormick of the National Renewable Energy Laboratory indicates that the influence on nitrogen oxide levels may be lower than previously reported. Engine design and emission test method impact the effect of biodiesel nitrous oxide emissions.¹²⁹

D.7 Integrated Systems

Biomass energy production systems are composed of complementary conversion technologies.

Nearly every project contains more than one technology when the non-biomass technologies are also considered. There are two additional production systems that do not fit into the technologies discussed to this point. The first technology, **thermal depolymerization**, is a combination of thermal conversion technologies. The second technology, the **integrated ethanol plant/feedlot**, is a system of biological technologies.

D.7.1 Thermal Depolymerization Thermal depolymerization is basically the use of high temperatures and pressures to replicate the ancient, natural decomposition of prehistoric plant material into crude oil. Changing World Technologies, Inc. (CWT) is commercializing a Thermal Depolymerization process (TDP).¹³⁰

A CWT pilot scale TDP plant was built in 1998 in Philadelphia, PA. In 2000, ConAgra Foods partnered with CWT to form a new company, Renewable Environmental Solutions, LLC (RES).

¹²⁹ Bob McCormick, "Effects of Biodiesel on NOx Emissions," National Renewable Energy Laboratory Golden, CO, ARB Biodiesel Workgroup, June 8, 2005 <http://www.nrel.gov/docs/fy05osti/38296.pdf>

¹³⁰ Renewable Environmental Solutions, LLC, press release www.res-energy.com/press/presskit.asp

RES established a commercial scale TDP plant in Carthage, MO using the turkey fat and offal from a ConAgra turkey processing plant. This plant became fully operational in February, 2005.

A 200 to 250 tons per day plant, like the Carthage, Missouri plant will produce about 200 barrels of oil, 150 barrels of fatty acids, 275 MMBTU of fuel gas, 10 tons of dry fertilizer (11% P, 13% CA), 6000 gallons of liquid fertilizer and 25,000 gallons of water, each day.¹³¹ As with all new technologies, this commercial-scale technology is still under development. The first year of operation required many revisions beyond the data available from the pilot-scale research.

Another process using high temperatures and pressures is under development by agriculture engineers at the University of Illinois, Urbana-Champaign (U of I).¹³² The U of I process produced an oil product similar to a pyrolysis oil. Professor Yuanhui Zhang continues to develop the process and has recently begun tests converting cellulosic fiber from miscanthus into oil.¹³³

D.7.2 Integrated Ethanol Plant/Feedlot Another integrated biomass energy system is ethanol plant with an attached feedlot. This model has been in development for years. Initially, Prime Technologies, Inc. made a drive toward a commercial production model in 2001 in Pierre, South Dakota. In the end they were not able to get funding. Some of the principals of Prime Technologies, Inc. reorganized as E3 Biofuels. The E3 Biofuels facility opened in June of 2007 and included a 25 million gallon ethanol plant with a 28,000 head beef feedlot.¹³⁴

This facility included a number of energy and cost savings. First, wet distiller's grains would be fed as part of the beef ration without needing to be dried or transported. Beef manure would then be added to an anaerobic digester along with waste ethanol from the ethanol plant to supply the ethanol production facility with 90 percent of its energy needs (Figure D.13).

¹³¹ Paul Halberstadt, "Commercialization of the Thermal Conversion Process: Agricultural Residues into Renewable Fuels." 2004 National Poultry Waste Management Symposium. Memphis, TN. October 24-26, 2004.

¹³² B.J. He, Y. Zhang, Yin, G.L. Riskowski, and T.L. Funk. "Thermochemical Conversion of Swine Manure: A process to Reduce Waste and Produce Liquid Fuel." ASAE/CSAE Annual International Meetings, Toronto, Ontario, Canada. July 18-21, 1999.

¹³³ Yuanhui Zhang. "Thermochemical Conversion of Biomass to Fuel and Other Value-Added Chemicals." Biomass Energy Crops for Power and Heat Generation in Illinois." University of Illinois, Champaign-Urbana. January 12, 2006.

¹³⁴ E3 Biofuels, Mead, Nebraska facility. <http://www.e3biofuels.com/press/official-launch.php>

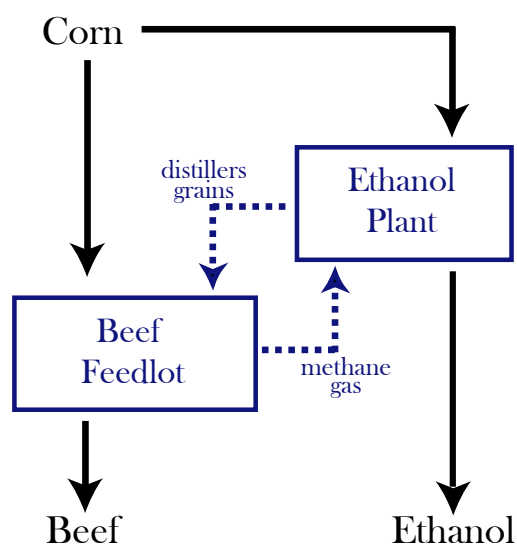


Figure D.13 Material Flow in an Integrated Ethanol Plant/Feedlot

Unfortunately in November 2007, E3 Biofuels filed for bankruptcy. The E3 Biofuels model is an excellent example of efficiency. It also is a painful reminder that not all well designed projects succeed economically.

Appendix E: Biomass Energy Opportunities In San Benito County

So what do all these biomass resources and conversion technologies mean for San Benito County, California? At the end of Chapter 2, the annual energy use for San Benito County was estimated to be 7,200,000 MMBTU (million BTUs). That is a pretty big number but to put it in perspective, the annual national energy use is calculated to be right at 101.6 quadrillion BTUs. San Benito's 2005 energy use could be written as 0.0072 quadrillion BTUs.

As a nation, biomass energy use has risen from 2.817 Quads (quadrillion BTU) in 2003 to 3.615 Quads in 2007.¹³⁵ On the one hand that is a 28 percent increase in five years or an average of nearly 6 percent growth each year. In the big picture though, biomass energy provided 3.615 Quad of energy in 2007, or only 3.6 percent of the US, 101.6 Quad energy use.


A goal of this project was to identify as much available and potential biomass materials as possible to replace the 7,200,000 MMBTU of estimated annual energy use from fossil fuels (ancient biomass). AB 32 calls for reduction of greenhouse gas emissions back to 1990 levels by 2020. Some renewable energy sources like solar and wind do not add carbon to the atmosphere. They are carbon neutral. They offset the fossil fuel sources of energy that add carbon to the atmosphere, or are carbon positive. Biomass energy sources can be used with fossil fuels to lower the carbon emissions. They can use as much carbon as they produce, so they too can be carbon neutral. Or they can sequester carbon and remove it from the atmosphere. Biomass energy can be carbon negative.

Achieving the reductions outlined in AB 32 will utilize both carbon neutral and carbon negative kinds of energy fuels. It will also require more conservation. Technology is helping with this by providing newer cars that have greater fuel efficiency, houses that require fewer emissions to build and that are better insulated requiring less energy (fewer emissions) to maintain. Certainly biomass energy production will play a significant role.

E.1 General Biomass Energy Production

For most people, 7,200,000 MMBTU of energy is just a number without much relevance to everyday life. To give it some perspective, this amount of energy can be replaced with the

¹³⁵ Renewable Energy Consumption and Electricity Preliminary 2007 Statistics, Table 1: US Energy Consumption by Energy Source, 2003-2007. Energy Information Administration. Department of Energy (DOE). May 2008. http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table1.pdf.

production of 55 million gallons of biodiesel fuel. Alternatively, this equivalent amount of energy could be generated by a 268 MW electrical power plant. These facilities are within the technological scope of commercial energy production. There is little preventing a facility of either size from being constructed in San Benito County. The difficult part comes from trying to feed local materials into projects of this .

This biomass inventory relies heavily on the coefficients and assumptions based on the California Biomass Collaborative.¹³⁶ The Collaborative goes into great depth collecting the best local data and using the current understanding of biomass energy production to create their state and county level estimates. As presented in Table E.1 San Benito County produces the second smallest quantity of biomass that is appropriate for thermal conversion in the State (just 0.25 percent of the State's biomass).

Using the California Biomass Collaborative numbers and some other fairly reasonable assumptions, it is possible to identify raw biomass heating values in San Benito County that add up to 1,717,503 MMBTU of energy. This number is about 24 percent of the 2005 estimated annual energy use. Energy is lost or consumed in the process of converting raw materials into usable forms of fuel, so the usable energy will be lower due to conversion efficiencies.

In 2005 San Benito County had the lowest per-capita electricity consumption in the State. It also has one of the lowest levels of county biomass production. To get to the 1,717,503 MMBTU number, we will look at the 2007 heating values calculated by the California Biomass Collaborative and then make additional assumptions about energy from San Benito solid waste, cultivation of energy crops and conversion of waste oil from local restaurants.

¹³⁶ The California Biomass Collaborative/Tools/Biomass Resources Data (2007).
<http://biomass.ucdavis.edu/bfrs.html>.

Table E.1 County estimates for California biomass production (2007, CA Biomass Collaborative)

County	Total Biomass	Biomass for Thermal Conversion	Biomass for Conversion (Percent)
Alpine	33,700	33,000	0.127%
San Benito	80,100	64,100	0.247%
Marin	106,800	67,500	0.260%
Mono	112,200	108,400	0.417%
San Francisco	144,600	109,900	0.423%
Solano	169,000	121,400	0.467%
Inyo	147,200	136,500	0.525%
Santa Cruz *	147,600	137,300	0.528%
San Mateo	186,800	153,300	0.590%
Amador	162,000	154,400	0.594%
Del Norte	168,800	160,900	0.619%
Mariposa	172,100	164,800	0.634%
Yolo	199,400	177,900	0.685%
Sierra	196,100	193,800	0.746%
Santa Barbara	232,800	193,900	0.746%
Contra Costa	290,100	195,400	0.752%
Yuba	227,700	213,400	0.821%
Napa	224,100	214,000	0.824%
San Luis Obispo *	252,500	215,900	0.831%
Sutter	235,400	228,000	0.878%
Monterey *	288,100	234,200	0.901%
Ventura	293,700	238,300	0.917%
Imperial	444,300	254,600	0.980%
Glenn	287,300	254,800	0.981%
Kings	495,500	257,600	0.992%
Calaveras	269,400	260,100	1.001%
Merced +	708,500	274,500	1.057%
Lake	291,900	287,700	1.107%
Alameda	367,400	293,600	1.130%
Placer	341,000	322,900	1.243%
Nevada	328,600	323,800	1.246%
Colusa	348,000	340,600	1.311%
Sacramento	474,900	345,900	1.331%
Stanislaus	672,700	347,700	1.338%
Tuolumne	387,400	371,500	1.430%
Santa Clara+	467,000	380,000	1.463%
Tehama	406,200	382,200	1.471%
Madera	527,300	405,100	1.559%
Modoc	456,800	435,200	1.675%
Sonoma	555,600	482,200	1.856%
San Joaquin	759,100	535,200	2.060%
Butte	584,500	570,300	2.195%
El Dorado	587,700	578,300	2.226%
Tulare	1,290,500	595,400	2.292%
Plumas	675,900	670,900	2.582%
Orange	1,023,400	673,200	2.591%
Lassen	706,200	691,600	2.662%
Riverside	1,019,700	709,500	2.731%
Trinity	742,300	740,800	2.851%
Kern	1,060,000	805,800	3.102%
Fresno+	1,317,800	934,900	3.599%
Shasta	955,900	937,000	3.607%
San Diego	1,210,900	955,100	3.676%
San Bernardino	1,359,600	1,034,100	3.980%
Siskiyou	1,137,100	1,116,600	4.298%
Mendocino	1,291,100	1,281,300	4.932%
Humboldt	1,363,600	1,331,700	5.126%
Los Angeles	2,822,900	2,192,400	8.439%
State Total	32,055,000	25,980,000	100%

* The Central Coast RMDZ includes Santa Cruz, San Luis Obispo, and Monterey Counties.

+ Other counties that boarder San Benito County include: Merced, Santa Clara, and Fresno County.

E.2 California Biomass Collaborative Data for San Benito County

The California Biomass Collaborative data is very impressive. Based on the publications list on their website, their data has been evolving since about 2003. It uses the most accurate data available from various state and federal agencies. Using county-level reported units (acres, animals, etc.) the real data is transformed first into Gross Biomass. Gross Biomass includes all raw biomass (residuals) that are available at a county level.

The Technical Biomass is the amount of Gross Biomass that is available for energy use. This takes into account agronomic and ecological requirements, terrain limitations, and political constraints.¹³⁷ It also factors in physical constraints on harvesting, transport, storage, and handling of the biomass materials.

According to the 2007 California Biomass Collaborative data for San Benito County, there were 1,241,474 bone dry tons produced that were also technically available (Table 6.2). This includes municipal sources from wastewater treatment and solid waste, manure from livestock, other agricultural residuals generated from both production and processing and residuals remaining from forestry growth.

Data available from the California Integrated Waste Management Board (1999) included plastic volumes in that waste stream. Therefore in this report, the MSW component was calculated differently than using solely the Biomass Collaborative estimates. Manure produced in San Benito County was predominantly range fed beef, so the manure would be difficult to collect. Adjusted municipal solid waste (MSW) estimates were added back in later, but the manure was not included. The last column on the right of Table E.2 shows the County Technical Biomass, but has total MSW and manure biomass excluded (shaded) from the total MMBTU at the bottom. This smaller San Benito County, Biomass Collaborative production estimate totals 907,765 MMBTUs based on tons of technically available, bone dry biomass.

¹³⁷ The California Biomass Collaborative, "An Assessment of Biomass Resources in California, Dec. 2006. http://biomass.ucdavis.edu/materials/reports%20and%20publications/2006/2006_Biomass_Resource_Assessment.pdf.

Table E.2 Biomass Available in San Benito County (2007, California Biomass Collaborative).

	2007 Gross Bone-dry tons/y	2007 Technical Bone-dry tons/y	Higher heating Value (BTU/lb)	Total MMBTU	Selected MMBTU
Biosolids Generation	2,300	1,800	6,620	23,832	23,832
MSW Paper/Cardboard Landfilled	11,200	5,600	7,642	85,590	85,590
MSW C&D Lumber Landfilled	5,000	2,500	8,304	41,520	41,520
MSW Leaves Grass Landfilled	1,000	500	6,448	6,448	6,448
MSW Prunings & Trimmings	820	410	6,448	5,287	5,287
MSW Branches & Stumps	110	55	6,448	709	709
MSW Other Landfilled	2,500	1,250	3,806	9,515	9,515
MSW Food Waste Landfilled	2,600	1,300	6,018	15,647	15,647
Beef Cow Manure	23,600	5,900	7,416	87,509	87,509
Milk Cow Manure	1,500	800	7,310	11,696	11,696
Other Cattle Manure	21,900	5,500	6,220	68,420	68,420
Swine	200	100	6,839	1,368	1,368
Apples	560	390	8,597	6,706	6,706
Apricots	1,280	900	8,597	15,475	15,475
Cherries	160	110	8,597	1,891	1,891
Grapes	4,920	3,440	8,168	56,196	56,196
Walnuts	1,240	870	8,597	14,959	14,959
Fruit and Nut Unspecified	210	150	8,597	2,579	2,579
Wheat	820	410	7,527	6,172	6,172
Barley	560	280	7,441	4,167	4,167
Unspecified Field & Seed	1,210	610	7,738	9,440	9,440
Combined Seed	240	10	7,738	155	155
Artichokes	390	20	7,738	310	310
Broccoli	490	20	7,738	310	310
Cabbage	610	30	7,738	464	464
Celery	540	30	7,738	464	464
Lettuce and Romaine	11,310	570	7,738	8,821	8,821
Dry Onions	1,500	80	7,738	1,238	1,238
Sweet Peppers	1,460	70	7,738	1,083	1,083
Spinach	3,350	170	7,738	2,631	2,631
Tomatoes & Eggplant	1,610	80	7,738	1,238	1,238
Combined Unspecified Vegetables	7,530	380	7,738	5,881	5,881
Walnut Shell (processing)	2,270	1,820	8,675	31,577	31,577
Forest Thinnings	2,600	900	9,027	16,249	16,249
Forest Slash	43,500	23,800	8,597	409,217	409,217
Shrub	33,000	16,200	8,000	259,200	259,200
Mill Residue	3,000	1,600	8,597	27,510	27,510
Total				1,241,474	907,765

E.3 Modified California Integrated Waste Management Board (CIWMB)

Using the CIWMB data for 1999 presented in Table A.4, Appendix A, a more representative estimate of potential energy from MSW can be generated. This can be accomplished by doing two things: adding a population increase factor, and combining the CIWMB data with California Biomass Collaborative coefficients.

As discussed in Appendix B, the population of San Benito County is increasing and the biomass vegetative cover is decreasing in the county. It makes some sense to increase the annual MSW component even though the other biomass components are not increasing. MSW is directly tied to population growth. San Benito County grew at tremendous rate of 5.6 percent a year between 1980 and 2000. Since 2000, the population has been growing about 1 percent per year.

Increasing the 1999 MSW estimates by 10 percent will likely approximate current levels of MSW production in San Benito County. Increasing the MSW estimates by 20 percent over the initial 1999 values will likely approximate MSW production around the year 2020.

Table E.3 begins with four of the categories presented in Table A.4 and multiplies them by a coefficient of 0.685 to transform the total tons presented in the CIWMB data to an approximate of the bone-dry tons presented by the California Biomass Collaborative.¹³⁸ Only 'Plastic' did not change from the original tonnage presented in Table A.4. In the top half of Table E.3, the original available tonnage was multiplied by 10 percent to represent a 10 percent population growth nearing current levels. Likewise, the lower half of the table is multiplied by 20 percent to represent a 20 percent population grown in 10 years (around 2020).

Table E.3 MSW energy potential based on CIWMB data

	1999 Tons	10% Increase Tons	BTU/lb	10% material recovery	MMBTU	50% material recovery	MMBTU	80% material recovery	MMBTU
Paper	9,226	10,149	7640	1,015	15,507	5,074	77,536	8,119	124,058
Other Organic	12,593	13,853	4935	1,385	13,673	6,926	68,363	11,082	109,381
Plastic	4,344	4,778	12340	478	11,793	2,389	58,965	3,823	94,345
C & D Lumber	1,745	1,920	8310	192	3,190	960	15,951	1,536	25,522
					44,163		220,816		353,305
	1999 Tons	20% Increase Tons	BTU/lb	10% material recovery	MMBTU	50% material recovery	MMBTU	80% material recovery	MMBTU
Paper	9,226	11,071	7640	1,107	16,917	5,536	84,585	8,857	135,336
Other Organic	12,593	15,112	4935	1,511	14,916	7,556	74,578	12,090	119,325
Plastic	4,344	5,213	12340	521	12,865	2,606	64,326	4,170	102,922
C & D Lumber	1,607	1,928	8310	193	3,204	964	16,021	1,542	25,633
					47,902		239,509		383,215

The Higher Heating Values (HHV) are estimated based on the same reference from the California Biomass Collaborative, to establish available energy content of the MSW materials. MSW is all mixed up and not easy to separate. Three categories are calculated: 10% material recovery, 50% material recover, 80% material recovery. The MSW industry developed the concept of source separation. By developing systems that separate solid waste materials at the source, the costs of separating them after collection can be lowered. Source separation can be difficult and costly. Currently the better estimate would be 10 percent (top half) of Table E.3. In 2020, it may be

¹³⁸ Biofuels from Municipal Wastes-Background Discussion Paper. Robert B. Williams. Table 1, page 3. California Biomass Collaborative. March 28, 2007.
http://biomass.ucdavis.edu/materials/reports%20and%20publications/2007/2007_Annual_Forum_Background_Paper.pdf

possible to access up to 50 percent of the biomass in the MSW waste stream (lower half the table). Therefore by 2020, it may be reasonable to utilize 239,500 million BTUs from the MSW waste stream.

E.4 Energy from New Crops

Based on the discussion from Chapter 3 on new crops, the following new energy crops were estimated for potential production in San Benito County: camelina, jatropha, and algae. Camelina and jatropha are oil crops that can grow with limited water. The reported temperature and rainfall historical values indicate that these two crops should grow in San Benito without irrigation. If irrigation is available, the yields will be higher.

The third crop discussed is an aquatic plant, algae. The opportunities for algae production in San Benito County may be limited. If the new wastewater treatment plant is able to resell their treated effluent for irrigation, that may be the highest best use of that water. Alternatively it could be used to grow any number of aquatic plants that can be used for energy production. Algae would be one possibility. At this point possible algae production is purely hypothetical. Some conservative general assumptions were assigned to develop a reference value for that opportunity.

The coefficients for estimating the MMBTU per acre of vegetable oil that would be possible are presented in Table E.4. These are based on fairly common estimates for yield, density, and energy value of the vegetable oil.

Table E.4 Coefficients of new crop energy production

	Camelina¹³⁹	Jatropha¹⁴⁰	algae
Yield per acre	1,200 lbs/acre		
Oil content of seed	40.0% oil content		
Density of vegetable oil ¹⁴¹	7.5 lbs/gallon		
Oil production per acre	64 gallons/acre	200 gal/acre	4,000 gal/acre
Energy content of oil	120,000 btu/gal	120,000 btu/gal	120,000 btu/gal
MMBTU per acre	7.68 MMBTU/acre	24 MMBTU/acre	480 MMBTU/acre

¹³⁹ Camelina Production in Montana. K. A. McVay and P. F. Lamb Montana State University Extension. Montana State University, Bozeman, MT. Revised 3/08.

<http://msuextension.org/publications/AgandNaturalResources/MT200701AG.pdf>

¹⁴⁰ Centre For Jatropha Promotion. Rajasthan, India. www.jatropha-world.org

¹⁴¹ Biodiesel Fuel Vern Hofman, Extension Agricultural Engineer. AE-1240. North Dakota State University. February 2003. <http://www.ag.ndsu.edu/pubs/ageng/machine/ae1240w.htm>

Once an energy value per acres was generated in Table E.4, the number of acres available was estimated. There are four dry land categories that could produce camelina or jatropha. Camelina in particular can be grown as a cover crop between vineyard and orchard crops. Either crop can be grown in areas that may be underutilized currently, such as the airport, road right-of-ways or underdeveloped ground. The other two categories were assigned by slope: flat ground to 15 percent slope and ground with an average slope between 16 and 30 percent. This latter category may fair better with jatropha than with camelina.

The estimated energy production by crop is presented in Table E.5. For the vineyard/orchard crops it was assumed that 50 percent of the acreage could be grown to under-story cover crops. For the other three land categories, it was assumed that by 2020 at least 10 percent of these areas would be grown to one or the other crop. These same three land areas, 276,302 acres, were used for each crop and then the maximum MMBTU values for camelina and jatropha were averaged. The 10 percent of category values were used for the maximum MMBTU values. Since jatropha is 3 times more productive than camelina, the average was 500,072 MMBTU.

Table E.5 Energy value estimates for new crops

Table 2-10 Energy Value Estimates for New Crops										
Camelina		Percent of Current Acres				MMBTU	MMBTU	MMBTU	MMBTU	Maximum
New Crops	Acres	1%	5%	10%	50%	1%	5%	10%	50%	MMBTU
Vineyard/Orchard intercrop	7,880				3,940				30,259	30,259
Flat cropland	101,002	1,010	5,050	10,100		7,757	38,785	77,570		77,570
Flat to 15% slope	76311	763	3,816	7,631		5,861	29,303	58,607		58,607
16% to 30% slope	98,989	990	4,949	9,899		7,602	38,012	76,024		76,024
										242,459
Jatropha						MMBTU	MMBTU	MMBTU	MMBTU	Maximum
New Crops	Acres	1%	5%	10%	50%	1%	5%	10%	50%	MMBTU
Grape/Orchard intercrop	7,880				3,940				94,560	94,560
Flat cropland	101,002	1,010	5,050	10,100		24,240	121,202	242,405		242,405
Flat to 15% slope	76311	763	3,816	7,631		18,315	91,573	183,146		183,146
16% to 30% slope	98,989	990	4,949	9,899		23,757	118,787	237,574		237,574
										757,685
Average of two crops										500,072
Algae										
WWTP, percolation ponds	Acres					Gallon/Acre	BTU/gal	MMBTU		
	90					4,000	120,000	43,200	43,200	
										543,272

As mentioned, the treated water may be quite valuable in conventional agricultural production.

For the energy production value for algae, the acreage listed in the Long-Term Wastewater Management Program for the DWTP and IWTP were used as possible acres available for growing

algae.¹⁴² The acreage currently in percolation ponds was 90 acres. The conservative yield of 4,000 gallons per acre was used over yield that have been posted that are much higher. In of July 2008, the price of food-grade vegetable oil sold for \$0.63 cents per pound. At a more conservative price of \$0.50 per pound, the gross revenue for 4,000 of oil is \$15,000 per acre. If 50 acres of the wastewater treatment plant could support algae, the gross revenue would be \$750,000. This is just a number. It could be less, but it could actually be more also. There are companies that specialize in using aquatic plants to treat wastewater. A constructed aquatic production wetland using species with varying canopies could be tuned to grow more than algae for markets more diverse than biofuels. For the algae crop, 43,200 MMBTUs of energy production was estimated.

E.5 Energy from Waste Cooking Oil

Waste cooking oil can be used for biofuels. Watsonville, CA is using waste cooking oil for biodiesel as referenced in Appendix B. They are also using waste oils for methane gas production at the wastewater treatment plant.¹⁴³

Table E.6 uses the data on San Benito County restaurants presented in Appendix B and estimates the potential energy value available. The coefficient of 48 gallons per week of used oil from each restaurant is drawn from an inventory of restaurants in New York.¹⁴⁴ This value used the oil rate multiplied by 52 weeks per year would yield 2,496 gallons per year. The average energy content for each gallon of oil is reported at 120,000 MMBTU per gallon. For the 90 listed restaurants in San Benito County, using this coefficient will yield an energy content of 26,957 MMBTU per year.

Table E.6 Energy value of used oil as biofuel

**Gallons/year, based on
48gallons/week MMBTU**

¹⁴² Long-Term Wastewater Management Program for the DWTP and IWTP. HydroScience Engineers, Inc. City of Hollister. December 2005.

http://www.hollister.ca.gov/site/html/gov/office/documents/Section_2.pdf

¹⁴³ Using Treatment Plant Digesters to Process Fats, Oils, and Grease, Greg Kester, Perry Schafer, and Bob Gillette. BioCycle Magazine July 2008. Volume 49. No. 7. page 47. www.jgpress.com

¹⁴⁴ An Assessment of Waste Vegetable Oil Supply in Brooklyn, NY and its Potential as a Biodiesel Feedstock. Christopher Behr, eDesign Dynamics. For Cornell University. New York. 10-14-05. <http://nyc.cce.cornell.edu/emerginginitiatives/Waste%20Oils%20&%20Fats%20Supply%20Final%20Report.pdf>

City	Restaurants	2496	120,000
Hollister, CA	70	174,720	20,966
Tres Pinos, CA	4	9,984	1,198
San Juan Bautista	16	39,936	4,792
			26,957
Watsonville, CA	125	312,000	37,440
Gilroy	124	309,504	37,140
Salinas	283	706,368	84,764
			159,345

The lower portion of Table E.6 gives estimates for the energy value of used oil in the surrounding communities. Watsonville, CA is likely utilizing a significant portion of used oil generated in their community. They may also already be drawing used oil from San Benito County to Watsonville for conversion into biofuels.

E.6 Summary of San Benito Annual Biomass Energy of Available Feedstocks

These available annual estimates are summarized in Table E.7. The available energy in the local biomass is estimated at 1,717,503 MMBTU per year. This is 23.9 percent of the total annual estimated energy consumption for San Benito County.

Table E.7 Summary of San Benito County biomass energy content

Source	MMBTU
Current CA Biomass Collaborative	907,765
MSW	239,509
Future Crops	543,272
Waste Vegetable Oil	26,957
Total Biomass Energy	1,717,503
Total San Benito Energy Use	7,200,000
Percent Energy Offset with Biomass	23.9%

E.6.1 Conversion Efficiencies Converting these raw materials into usable energy requires energy to do so. Conversion of firewood to heat has a 60 percent conversion efficiency.¹⁴⁵ So 40 percent of the input energy is lost in the conversion process. Coal has a 75% conversion efficiency. Wood fuel pellets have an 80 percent heat conversion efficiency. Natural gas has a heat conversion efficiency of 85 percent.

Biodiesel esterification will also consume some energy. Relative to other conversion processes, biodiesel esterification from vegetable oil is not an energy intensive process. Never the less the finished biodiesel will have fewer available BTUs than the feedstock.

¹⁴⁵ Energy Cost Calculator. Dennis Buffington. Pennsylvania State University.
http://energy.cas.psu.edu/ENERGYCOSTS_08.XLS

Electrical generation is less efficient than heat or biodiesel conversion. Biomass to electricity through a more efficient process of integrated gasification/combined cycle (IGCC) is about 35 percent efficient while more conventional systems closer to 25 percent efficient.¹⁴⁶ Electricity is very efficient once it is created. Non-biomass sources of electricity generation may make a valuable contribution.

If all biomass was converted to heat production with a conversion efficiency of 80 percent, the maximum biomass energy produced would be 1,374,003 MMBTU of energy. This represents a maximum of 19 percent of the total energy use (7,200,000 MMBTU).

E.6.2 Conservation of Energy Another component of balancing local energy production with local energy use is conservation. As discussed in Appendix A, California has maintained a constant per capita consumption of electricity while nationally the per capita consumption of electricity has increased. Advances in technology play a role in conserving energy. As discussed in Appendix C, The evolution of green buildings standards with better insulation, more efficient appliances, windows that capture more solar energy and leak less; are all examples of improved technology.

One of the challenges facing San Benito County is that the average citizen drives further to work than the state average (6 minutes each way). As liquid fuel prices have spiked in June of 2008, driving has scaled back. Driving less, car-pooling, bicycling and walking influence energy consumption. San Benito County already has in place a coordinating body in the Council of Governments, <http://sanbenitorideshare.org/about.htm>.

There have been frequent attempts to raise the national fuel efficiency standards for new vehicles. Again, the record crude oil prices have placed a premium on fuel efficient vehicles. SUVs and large luxury vehicle sales have plummeted. The markets are driving the average fuel efficiency up without setting high national standards. Adopting hydrogen and electric vehicles would lower the

¹⁴⁶ California Biomass and Biofuels Production Potential. Robert B. Williams. California Biomass Collaborative. Draft Report. December 2007

liquid fuel use. In cases where the hydrogen and electricity were generated from renewable sources, it would also lower emissions and the carbon footprint.

E.6.3 Non-Biomass Sources of Energy While this document is focused on biomass energy, the non-biomass, solar resources are too significant to leave out. California has tremendous solar resources. Plant production, and therefore biomass production, is dependent on ample solar resources. The California Energy Commission estimated the San Benito County solar energy production potential at 822,419 MW-hours per day.¹⁴⁷ This compares with the total county electrical use reported in Table 2.6 of 302,000 MW-hours per year (302,000,000 kW-hr for both residential and commercial use). The available solar energy is many times greater than the annual energy use.

Solar energy is not necessarily the least cost technology, but is available in San Benito County. Replacing part or all of the annual electrical use in San Benito with solar energy would allow utilization of biomass energy in other media (liquid or gaseous fuels).

E.6.4 Imported energy There are economic benefits to producing biomass energy locally. Transportation and storage of biomass can be cost prohibitive. As long as the environmental and economic benefits outweigh the costs, importing and exporting biomass feedstocks and energy is useful in balancing resources. Food and energy availability in the US would be quite restricted if is relied entirely on locally grown energy. Moving corn in from the Midwest to power an ethanol plant, may have high costs associated with it, but if the environmental benefits are significant they can justify the cost of importing the corn.

Likewise, exporting biomass from San Benito to neighboring counties may also make economic sense. Moving biomass from San Benito to biodiesel projects in Watsonville and Gonzales, CA; MSW and other to the proposed jet biofuels project in Gilroy, CA; or moving San Benito County biomass down the proposed biomass solar power plant in Coalinga, CA; may be excellent uses of San Benito County resources.

¹⁴⁷ California Solar Resources. California Energy Commission. CEC-500-2005.072-D. April 2005.
<http://www.energy.ca.gov/2005publications/CEC-500-2005-072/CEC-500-2005-072-D.PDF>

E.6.5 People vs. Plants In general, biomass is more difficult to produce in the urban areas where population density is high. Highly concentrated populations provide concentrated waste utilization opportunities. Organic residuals and wastes though are leftovers and will always produce only a fraction of the energy available with unused feedstocks.

Biomass grows best in the farmland and open areas out away from the urban centers. Just for discussion purposes, the estimates provided by the California Biomass Collaborative were divided by respective county populations. San Benito has a relatively small population and a relatively small output of biomass at the county level. Table E.8 indicates that there is a relatively high ratio of biomass to humans of 1.15. It is the highest value of the other counties in the Central Coast Recycling Market Development Zone: Santa Cruz, San Luis Obispo, and Monterey. San Benito County has a biomass to human ratio similar to Merced and Fresno Counties that surround San Benito County.

Table E.8 Per capita biomass production of San Benito County and surrounding Counties.

	Total Biomass	Biomass for Thermal Conversion	US Census 2006 Pop.	Per Capita Biomass (tons/person)
San Benito	80,100	64,100	55,842	1.148
Santa Cruz	147,600	137,300	249,705	0.550
San Luis Obispo	252,500	215,900	257,005	0.840
Monterey	288,100	234,200	410,206	0.571
Central Coast RMDZ		651,500	972,758	0.670
Merced	708,500	274,500	245,658	1.117
Santa Clara	467,000	380,000	1,731,281	0.219
Fresno	1,317,800	934,900	891,756	1.048
Counties Surrounding San Benito		2,240,900	3,841,453	0.583