Assessment of Biofuels in California and Potential for Future Utilization

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for

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October 2004

"Funding for the this project has been made available by the Governor's Buy California Initiative, the California Department of Food and Agriculture ("CDFA") and the U.S. Department of Agriculture ("USDA"). The content of this publication does not necessarily reflect the views or policies of CDFA or USDA, nor does any mention of trade names, commercial products and organizations imply endorsement of them by CDFA or USDA."

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Alternative Fuels from California Agriculture

Executive Summary

This study analyzed the potential energy resources contained in the biomass residues from the leading crops and livestock in California. As compared with an earlier similar study by Knutson and Miller (1982), where a total of 24 million tons of biomass was reported having an energy value of 336,000 billion Btu's, this current study showed a total of over 18 million tons (excluding 7.2 million tons of lumber mill and forest slash residues), which translates to almost 13 million tons of dry matter. The energy value of this biomass is 189,000 billion Btu's, about 56 % of the 1982 value. The reasons for this difference include less acreage of field crops which yield more residues than tree and vegetable crops, as well as utilization of some of these residues for alternative purposes. Further, the more conservative total energy figure is based on realistic estimates of the moisture contents of the various crop animal residues.

The crop residues were divided into "wet residues" including cattle and poultry manure, lettuce, tomato and vegetable residues totaling 4,961,787 tons of equivalent dry matter; and the other "dry residues" including wheat, rice, cotton, corn and all tree crop residues totaling 7,881,256 tons of dry matter. If a dry biomass steam boiler and electric generator system presently being used at a major walnut processor in California is used as the model for converting all the dry residues to electricity and steam, then the dry residues could be converted to over 6 billion whirs worth over $660 million. The steam byproduct would be worth an additional $70 million. Thus for all the dry residues, the total electricity and steam benefits would amount to $730 million annually.

As for the wet residues, these materials could be anaerobically digested to produce methane, which could be used to produce electricity and steam as is presently being done at a large dairy farm and cheese plant in the Central Valley of California. If this dairy manure digester is used as the model for estimating the total energy benefits of all the wet residues in California, the electricity possible is almost 3 billion kwhrs worth almost $328 million annually, and the steam byproduct would be worth $118 million, whose total is also $446,000,000 per year. The total of the wet and dry residue benefit would be $1,176,000,000 at present energy prices; in other words over a $1-billion per year business. This represents a substantial economic opportunity for the agricultural community on California.

Background Information

Biomass is any organic matter, wood, crops, seaweed, and animal wastes that may be converted into energy. There exist five sectors of biomass material: agricultural wastes, animal waste, municipal waste, wood waste, and pulp and paper. These wastes can be converted into alternative fuels such as hydrogen, methane, biodiesel, ethanol and methanol (Brown, 2003). Relatively recent analysis of agricultural waste handling in California continues to refer to open burning as the default treatment of such biomass.

In agriculture sources of crop residue/waste can come from pruning, field waste or unharvested plant residue, and from defective product and small size cull fruit. Thompson (2004) suggests cull product can be 10-15% of the fresh fruit or vegetable product delivered to the packinghouse. The cull fruit delivered may be scarred, split pits, deformed, have mechanical injury, sunscald-sunburn, mold, bacteria, overripe, immature, or insect damaged. This can ultimately result in huge quantities of material to be either disposed of or utilized in some other way. A traditional large user of such cull product (Joseph Gallo Farms, 2004) reported that up to 80% of the feed ration for replacement heifers is a combination of waste broccoli and lettuce and rice straw.

A high rate of biomass spoilage as feed can occur when the material has high water content, but that is less of an issue for some forms of biofuel (methane digestion) production. Other problems include relatively high cost of transport of such wastes, low value products, and the potential for water pollution related to BOD levels. This study pertains to agricultural wastes such as those produced by California specialty crops.[1] A significant portion of these specialty crops and their respective residues are listed in Table 1, Fruit and Vegetable Crops in California.

The conversion of wastes into fuels has several benefits such as: energy security, sustainability, a lessening of dependence for energy upon other nations, rural economic growth, environmental conservation, and the creation of thousands of new jobs.

The methods of biomass-biofuel energy generation are: gasification, direct fire, modular system, microbiological breakdown, pyrolysis, anaerobic digestion, and fermentation (Brown, 2004). Currently the biofuels spoken of most frequently are ethanol and biodiesel. Ethanol is a biofuel derived from converting the carbohydrate portion of biomass into a sugar suitable for combustion. Biodiesel is generated by extracting oils from oilseed crops, such as soybean or garbanzos (a California crop), and combining it with an alcohol (ethanol or methanol). Such fuels

[1] Specialty crops are defined here as being any crop not supported by federal subsidy programs, a definition that coincides with the grantor agency, the California Institute for the Study of Specialty Crops located at Cal Poly.

have been assessed as having positive long run implications for the USA as reflected by the national Biomass Technical Advisory Committee in *The Vision*, see Figure 1.

The federal government has shown interest in developing alternative energy from biomass by creating the Office of the Biomass Program, a part of the United States Department of Energy. Their goal is to "significantly increase America's use of biofuels, biopower and bio-products on a sustainable basis (USDOE)." Listed below are projected numbers for usage of biopower, biofuels and other bio-products in the United States.

The biomass and renewable energy sector of the California economy has a huge potential. The cumulative production of California agriculture producers yield every year has an immense energy conversion potential. With gas prices steadily climbing, a public outcry for alternatives is imminent.

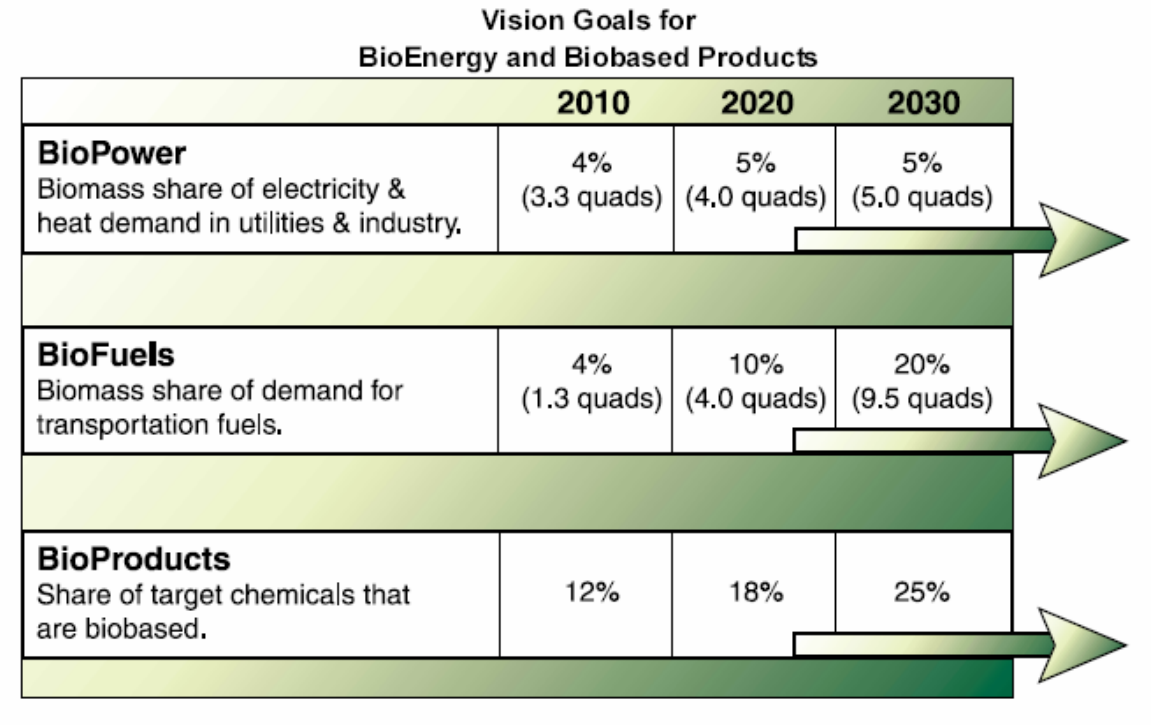

Figure 1. Goals for Bioenergy and Biofuels.
Source: Biomass Technical Advisory Committee, *The Vision for Bioenergy and Biobased Products in the United States*.

Table 1. CALIFORNIA Fruit and Vegetable Crop Acreage, Yield, Production, Prices, and Residue-Waste Volume for 2002, with Greater than 1000 Acres Harvested.

Vegetable Production	Harv acres	Yield (cwt/acre)	Prod m tons (1,000 tons)	Price/cwt a/	Residue/Waste
Artichokes	8,200	115	943	$70.80	111,930
Asparagus	34,000	30	1,020	114.00	146,200
Beans, snap	6,500	80	520	62.30	60,450
Bell peppers	21,000	330	6,930	28.60	61,650
Broccoli	115,000	140	16,100	30.30	697,659
Cabbage, fresh 11.5dm	12,500	380	4,750	14.00	75,000
Carrots, fresh market	77,000	290	22,330	20.30	238,546
Carrots, for processing	2,100	574	1,205	5.43	6,505
Cauliflower	37,000	150	5,550	30.20	32,769
Celery	25,500	710	17,750	12.80	54,649
Corn, fresh market sweet	24,000	170	4,080	24.00	118,797
Cucumbers, fresh market	4,300	240	1,032	28.60	113,520
Garlic	27,000	175	4,725	29.20	12,555
Lettuce, hd-leaf-rom	220,000	295	71,300	21.00	1,758,059
Melons, Cantaloupe	54,900	245	13,451	16.60	1,479,610
Melons, Honeydew	20,400	185	3,774	16.80	415,140
Melons, Watermelon	11,800	510	6,018	12.70	661,980
Onions	43,800	423	18,548	9.17	89,746
Peppers, Chili	2,800	230	644	27.80	8,260
Pumpkins	6,000	250	1,500	10.90	165,000
Spinach	20,000	160	3,200	35.20	16,290
Squash	8,300	190	1,577	21.00	173,470
Tomatoes, fresh market	38,500	300	557	25.40	199,815
Tomatoes, processing	291,000	37.99	11056	57.20	615,837
Potatoes (excl sweet) 21.9	449,000	884.8	875,250	11.60	1,032,254
Potatoes, sweet	10400	122.2	122,200	29.60	15,704
Berries (boysen,rasp,straw)	31160	265.7	17266	93.37	1,900
Apples	26,000	9.04	235,000	408	35,904
Apricots	17,000	5	85,000	306	22,100
Avocados	58,000	3.45	200,000	1,790	22,000
Cherries, sweet	26,000	2.13	55,500	1,740	6,105
Dates	4,500	5.38	24,200	1,550	2,662
Figs	12,900	4.22	54,400	331	5,984
Grapes, all	820,000	8.2	6,721	384	803,503
Kiwi fruit	4,500	5.8	26,100	783	2,871
Nectarines	36,500	8.19	299,000	383	51,744
Olives	36,000	2.86	103,000	590	11,330
Peaches, all	70,000	13.71	960,000	354	99,400
Pears, all	17,300	15.1	262,000	261	33,734
Plums and Prunes	110,000	3.95	372,000	598	106,624
Totals	2,841,383		3,917,480		9,586,236**

Source: California Dept of Finance, *California Statistical Abstract*, Dec. 2003, and NASS- USDA.
Notes: * Excludes Citrus and Nuts; ** based on county leading county crop statistics.

Utilization of Agricultural Wastes

Currently, there are several potential crops whose waste could be converted into biofuels for energy consumption. Broccoli, tomatoes, grapes, carrots, lettuce, and onions are all viable specialty crop possibilities for energy production. Other wastes may be less "viable" as they already have alternative recycled uses, animal manure is a good example as many dairies have developed systems to recycle water and treat waste on site in order to be in compliance with non-point source pollution requirements. Current use of shell fragments in the nut processing industry (see Figure 2 below) in cogeneration of energy is another use that reduces or converts heretofore externalities of agricultural residue wastes viable resources. To best understand the energy potential content of these crops their biomass and agricultural wastes volumes resulting from their production, information was collected on their *residue factors* and relative locations in California, see Tables 2-4. For a complete listing of all crops in all counties, see Appendix Table 1. Appendix Table 2 lists the residue factors used in calculating the residue data in Appendix Table 2.

Figure 2. Biomass Boiler and Cogeneration System at Walnut Processor.

Photo: D. Williams, August 2004

These wastes may be converted in a number of ways. The cheapest and easiest is direct combustion. This method would consist of directly combusting dry biomass wastes in a steam boiler with subsequent conversion to electricity in a steam turbine generator. Another method is digestion into methane gas using an anaerobic digester. Current technology has proved that anaerobic digestion can be an efficient option for wet biomass wastes such as manure. Other conversion methods include gasification, where the biomass is heated in an oxygen-starved environment, generates a low calorific gas, which can be used to spin a turbine. Pyrolysis is the process of heating biomass at extremely high temperatures in an oxygen-free environment to yield solids (char), liquids (oxygenated oils), and gases (methane) (see Brown, Ch. 6).

Table 2. California Program and Non-Program Non-Fruit and Vegetable Crops Acreage (1000s), Production (1000's), Yield, and Residue/Waste (Tons) in 2002.

Non FFV Production	Units	AcresHarv	Production	Yield/acre	Residue/Waste
Wheat* 60	Bu m	390	31500	80.8	1,417,500
Rice* 45	Bu m	521	2127	8300	2,846,115
Corn* 56	Bu m	545	26,600	170	1,117,200
Oats* 32	Bu m	27	2160	80	48,384
Barley* 48	Bu m	75	5100	68	183,600
Milo* 56	Bu m	11	1045	95	47,025
Cotton* 500	Bales m	477	1430	2.98	536,250
Cottonseed 32	Bu m		720		11,520
Sugar beets*	T m	49.0	1862	38.0	74,610
Alfalfa Hay	T	1140	8094	7.10	0
Grass/Meadow Hay	T	500.0	1500	3.00	0
Dry Edible Beans 60	T	89	8.8	0.99	264
Cattle & Calves	M hd	5200	1,144	1293	4,004,761
Hogs& Pigs	M	135hd	17,550		1,717
Sheep & Lambs	M	435hd	23055		11,528
Forestry	m ac	44.14.3	**24.3		124,046
Laying Chickens	m	22542	67626		50,720
Broilers	m	26323	92130		33,562
Turkeys	mhd	18700	225.3		137,913
Total*	M ac	*3868	15,1790,041	<= tons =>	*6,282,404

Sources: Agricultural Statistics 2003, NASS-USDA, Washington, 2003; California County, Agriculture Commissioners Reports, 2002-3. Notes: * indicates federal program crops; ** National Forest lands.

The total waste/residue from agriculture in California (see Table 3) may be nearing 20 million tons across all crops and all counties' agricultural products, which include timber product residue, but not forest waste or slash.[2] This was based on the residue by commodity by county from

[2] R.P. Thompson, registered forester-Cal Poly, suggests that the forest slash and waste is utilized as recyclable material, soil nutrients, and erosion control, and thus is fully utilized.

Table 3. California's Leading and Total Biomass Waste-Residue Crops Acreage or Head (in 1000s) and Residue/Waste (Tons), 2002.

Crop	AcresHarv/Head	Residue/Waste Wet
Cattle m hd	5290	3,936,581
Rice*	500.9	2,989,230
Wheat*	455.1	1,841,521
Lettuce hd & leaf	309.7	1,450,756
Almonds	530.6	1,379,776
Cotton*	514.5	1,188,197
Corn*	545.0	967,401
Grapes all	819.8	828,097
Tomatoes fr/proc	329.7	831,808
Vegetables, other	197.3	864,055
Tree/Vine Replacement	(27.0)**	809,169
Poultry-Chicken m birds	10,128	710,543
Walnuts	194.6	251,062
Peach-Plums-Nectarine	174.6	235,135
From All Crops	**4508.5 acres**	18,283,331

Notes: * Identifies federal subsidy crops; **follows Knutson and Miller.

Table 3, cont. California's Leading Biomass Waste-Residue Crops DryMatter/Waste (Tons), 2002 and Energy Equivalent, million Btu's.

Crop Residue/Manure	Residue/Waste Dry Matter Tons***	Energy Equivalent, Millions of Btu****
Cattle Manure	3,936,581	56,000,000
Rice Straw	2,570,738	36,000,000
Wheat Straw	1,583,708	23,000,000
Lettuce Residue	145,076	2,200,000
Almond Prunings	689,888	11,000,000
Cotton Stalks	1,021,849	14,000,000
Corn Residue	831,965	14,000,000
Grape Prunings/Waste	414,049	7,000,000
Tomato Residue/Waste.	83,181	1,200,000
Vegetables Residue/Waste	86,406	1,300,000
Tree/Vine Replacement	525,960	8,900,000
Poultry-Chicken Manure	710,543	10,000,000
Walnut Prunings/Waste	125,531	2,000,000
Peach-Plums-Nectarine Prunings/Waste	117,568	2,000,000
Total Leading Residues	12,843,043	**188,600,000**

Notes: ***Cattle and poultry manure reported in dry matter tons; Rice straw, corn residue, wheat straw, cotton stalks: 86 % Solids; Lettuce, tomato and vegetable residues and wastes: 10 % Solids; Almond, grape, walnut, peach-plum-nectarine (prunings 75%, waste fruit 10%: average: 50% Solids); Tree/vine replacements: 65% Solids.

**** Manure 7110 Btu/dry pound; Rice Straw 6931 Btu/dry pound; Wheat Straw 7365 Btu/ dry pound; Corn Stalks 7300 Btu/ dry pound; Almond Waste 8300 Btu/dry pound; Cotton 6800 Btu/pound; Tomato, lettuce and vegetable: 7500 Btu/dry pound; Walnut waste 8100 Btu/dry pound; Peach-Plums-Nectarine, Grapes, Tree/Vine Replacement: 8500 Btu/dry pound. This follows Knutson and Miller (1982).

the California county Agriculture Commissioners' Annual Reports for the most recent years available (mostly 2002 and 2003) for the leading crops, but not all crops in every county. These wastes are available in many different forms from waste slurry (manure) to cull fruit or product to tree pruning wastes at field side. Following Knutson and Miller (1982) we assumed a 2.1% tree loss removal from death or species/variety substitution of 30 tons per acre for all tree crops in California. From over 1.28 million acres of California orchard crops that would be 26,972 acres of trees removed. This was not added to acreage numbers, but was included in the Residue/Waste total as a separate item. These crops included many with no other waste/residue contribution as suggested by county extension crop specialists and includes: almonds, apples, avocadoes, cherries, citrus, lemons, oranges, other citrus, peaches, plums, nectarines, pistachios, prunes, and walnuts.

Table 4. California's 10 Leading Biomass Waste-Residue Counties from all Crop Sources (Tons), 2002*.

County	Residue/Waste Tons
Fresno	2,446,075
Kern	2,066,044
Tulare	1,277,590
Imperial	1,142,294
San Joaquin	1,013,752
Monterey	938,087
Colusa	981,800
Kings	886,715
Butte	824,550
Glenn	687,673

Source: *2002 or most recent year available County Annual Crop Reports.

A barrier to the utilization to these technologies, especially pyrolysis and gasification, is the amount of energy necessary to generate energy (USDOE). There exist other methods of energy conversion in recent development, which may prove more practical and efficient in the future utilization of biomass. The biomass wastes can be roughly divided into two groups: wet biomass with moisture contents over 50% and dry biomass with moisture contents under 50 %. The dry biomass categories include all tree prunings and the grain crop straw and cotton stalk residues, along with nutshells and hulls collected at the processor. These dry residues are best-converted using combustion and gasification technologies, such as the one pictured in Figure 2 at a large walnut processor in Stockton, California. This biomass boiler utilizes 34,000 tons per year of walnut shells to produce 4.5 megawatts of electricity and low-pressure steam for the processor process heat

needs. The annual electrical production is 26 million kilowatt-hours, worth almost $2 million, and steam worth $300,000 per year, for a total of almost $2.3 million annually.

For wet biomass, such as manure, which is produced at almost 90% moisture, the most appropriate conversion technique is anaerobic digestion. This process uses special bacteria that convert the manure solids into methane gas, which is an excellent fuel for electrical generation in spark ignition engines. This process is being employed on large dairy farms in California, and Figure 3 shows an installation on a 5000-cow dairy near Atwater, California.

Figure 3. Covered lagoon methane digester and 300-KW engine-generator for 5000 –cow Dairy

Photo: D. Williams, August 2004.

The system is a covered lagoon that captures the methane from the manure and water mixture washed from the dairy's feeding pens, and a 300-KW engine generator that also provides steam for the adjacent cheese plant. Moran (2004) reported that at the open house for this digester,

the methane production could support an additional 300 KW generator, for a total of 600 KW. This would save $550,000 per year in electrical costs at the adjacent cheese plant. The value of the steam from these generators would be worth an additional $200,000 per year, for total savings of $750,000 per year.

Energy Crops

Several crops were assessed for possible introduction as specific California energy crops. The criteria is the crop must need little water to produce, it must be adaptable to the arid weather of California, and a perennial that has a high starch content as well as high oil content for biodiesel production is preferred; economic, environmental and policy-oriented issues apply as well but were not looked at in-depth.

Some possible crop are: mustard seed, garbanzo beans, buffalo gord, milkweed, and switchblade grass. These are potential crops that currently are not utilized for energy.

Garbanzo beans, or chickpeas, are grown predominantly in California (nearly half of garbanzo production takes place in California) due to favorable weather conditions. The production acres of this bean crop have risen over the past six years by nearly 35%. The economic profitability for its production is proven by farmers' increased production; it is time to look further into alternative uses of this commodity.

Mustard seed was also looked at for biodiesel production. Blue Sun Biodiesel is already utilizing this idea in Colorado. With funding from the United States Department of Energy, Blue Sun is setting up cooperatives to help producers make mustard production energy crop (Blue Sun Biodiesel, 2004). Research has shown that mustard seed actually contains a higher percentage oil content (40%) than a popular soybean derivative for biodiesel at 18% oil. Safflower is another oilseed already produced in several (11) California Counties with a total of 127,000 tons in the most recent reporting period found, but has declined in production over the years.

Buffalo gourd is a novel crop, whose biological characteristics give it immense potential in biofuel production due to its high oil and starch content. CDFA funded research in the past on this crop, which is indigenous to the arid southwest for biofuel production. Several other possibilities for energy crops are currently being evaluated,[i] including milkweed, safflower, and canola (Biomass Technical Advisory Committee).

Ethanol Possibilities

Daniel Webb and Steve Shaffer-CDFA present a sense of urgency to establish a fuel ethanol industry in California. Industry experts suggest that California already produces a significant amount of the ethanol. Biotechnology offers the promise that anything containing cellulose, from Midwest-produced corn, to California-produced garbanzo beans, can be utilized in ethanol production. This is because biotechnology companies like Novozyme, and Genecore have been given government grants to find cost-effective ways to convert cellulose to sugar, which can be converted into ethanol. The technology is on the brink of making this conversion economical; especially with the spike in gas prices currently, the usage of cellulose-based ethanol is becoming more and more realistic (Novozymes Biotech, 2004).

The US Department of Energy has granted $14.8 million dollars to Novozyme Biotech, Inc. for a three year study to make cellulose conversion economical with efficient methods of generating ethanol. In 2003, US production of ethanol increased by 30%, amongst other things due to loss of the MTBE additive from gasoline. In the US gasoline already contains an average of 6% ethanol mixture.

This would seem to dispel the myth that ethanol only comes from Midwest corn. The California specialty crop industry needs to become a more active part of an actively growing marketplace.

Policies Involved

With the passing of the 2004 energy bill -- S. 2095, new incentives have been erected to develop clean, renewable energies and establishing the infrastructure necessary. These revisions to the Energy Policy Act of 2003 give way for a $200 million grant program for projects on topics such as alternative-fueled vehicles, and ultra-low sulfur diesel vehicles (biodiesel). Currently, 3.1 billion gallons of renewable fuels add to the US gasoline supply; by 2012, this number must jump to 5 billion by means of "…fuel produced from grain, starch, oilseeds, and other biomass, including plants, grasses, and agricultural residue…(US Senate, 2004)."

The Conservation Reserve Program acreage, a federally run program, which takes millions of acres a year out of agricultural production, have selectively been deemed eligible for energy crop production. The correspondence between the CRP program and program energy crops could be a mutually beneficial alliance.

The federal support exists for large-scale biofuel production. With this federal, and state level support, along with the new technology available, the specialty crop industry in California and just about every other agricultural-commodity producing industry in the United States will stand to be effected.

Analysis of Crop Residues by Location

Fruit and Nut (F&N) Crop Residues

Knutson and Miller (1982) present 1978 geographical distribution (crop density maps) of crop residues for California agriculture on their county mapping of residues, see their pages 11-15. The fruit and nut crop residues are important as they are routinely collected and moved to field edge and a high proportion were traditionally burned at field side as they were not easily soil incorporated (Knutson and Miller, p. 18), all of which makes them viable candidates as biomass fuel sources as the collection process has already begun as part of normal operational practices. Wine grape residues are increasing from many counties as the crop continues to increase acreage devoted to it. Virtually all San Joaquin Valley (SJV) counties showed substantial increases in fruit and nut crop residues. Central Coast and South Coast areas had minimal changes reflected in county data (sources-County Agricultural Commissioner's Annual Crop Reports-see also Appendix Table 1). North Coast counties showed decreases in fruit and nut, but Sacramento Valley counties mostly increased in these crop areas. While the SJV leading counties in F&N all increased their F&N activity, Bay Area and proximal counties all displayed decreases. In the south, Ventura, San Bernardino, and Riverside Counties all decreased F&N intensity.

Field Crop Residues

Substantial decreases have occurred state wide in field crop production in the 24 years since Knutson and Miller's work. The only counties with increased field crop production and thus

residues are Yuba, Colusa, Sutter, and Glenn in the Sacramento Valley. In many counties marginal land that was in grains may have been placed into the Federal Conservation Reserve Program.

Vegetable Crop Residues

Most areas with vegetable crops in 1978 increased their production substantially, yet the total volumes of residue are not high, and these may be limited as that waste has not traditionally been considered something to be gathered. Equipment for gathering would seemingly be readily modified for that purpose. Some crop residues have been managed to reduce plant pathogen loads or buildup, so removal for biomass fuel would improve the situation. It appears that acreage lost to field crops may often be converted to higher value F&N or vegetable crops, which can sustain higher production costs.

Livestock-Manure Wastes

Important shifts in animal populations from Southern California dairies to Southern SJV have taken place, while Imperial Valley cattle feeders being the exception have returned to previous levels of confined feeding of cattle. Major county recipients are Kern, Tulare, Kings, Merced, Stanislaus, and San Joaquin, while the losers are Los Angeles, Ventura, San Diego, Riverside, and San Bernardino Counties. The environmental effects of such intensive fed animal facilities may be reduced with methane digestion facilities (as illustrated in Figure 3) to capture energy, but also likely reduce olfactory problems and insect populations.

Summary and Conclusions

Two general conclusions were drawn from this study, first, compared with the Knutson and Miller (1982) study where a total of 24 million tons of biomass was reported having an energy value of 336,000 billion Btu's, this current study showed a total of over 18 million tons (excluding 7.2 million tons of lumber mill and forest slash residues), which translates to almost 13 million tons of dry matter. The energy value of this biomass is 189,000 billion Btu's, about 56 % of the 1982 value. The reasons for this difference were mentioned earlier, and include less acreage of field crops which yield more residues than tree and vegetable crops, as well as utilization of some of these residues for alternative purposes. Further, the more conservative total energy figure is based on realistic estimates of the moisture contents of the various crop animal residues.

Secondly, based on the estimates from Table 3, the crop residues can be divided into "wet residues" including cattle and poultry manure, lettuce, tomato and vegetable residues totaling 4,961,787 tons of equivalent dry matter; and the other "dry residues" including wheat, rice, cotton, corn and all tree crop residues totaling 7,881,256 tons of dry matter. If the biomass burner shown in Figure 2 is used as the model for converting all the dry residues to electricity and steam, then the dry residues could be converted to over 6 billion kwhrs worth over $660 million. The steam byproduct would be worth an additional $70 million. Thus for all the dry residues, the total electricity and steam benefits would amount to $730 million annually.

As for the wet residues, these materials could be anaerobically digested to produce methane, which could be used to produce electricity and steam as shown in Figure 3. If this dairy manure digester is used as the model for estimating the total energy benefits of all the wet residues in California, the electricity possible is almost 3 billion kwhrs worth almost $328 million annually, and the steam byproduct would be worth $118 million, whose total is also $446,000,000 per year. The total of the wet and dry residue benefit would be $1,176,000,000 at present energy prices; in other words over a $1-billion per year business. This represents a substantial economic opportunity for the agricultural community on California.

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Appendix Table 1. Agricultural Acreage, Value, Production, and Waste Volumes by County and Crop, 2002.

County	Year	Crop	Acres*	$MM Value	Tons	HarvResTon	Cumulative	Dry Matter
Alameda	2002	Alfalfa	871	0.44	4,442	0		
Colusa	2003	Alfalfa			47,535	0		
Imperial	2001	Alfalfa	184,126	144.80	1,109	0		
Inyo	2002	Alfalfa		1.80		0		
Kings	2002	Alfalfa	73,564	50.20	266,156	0		
Madera	2000	Alfalfa	40,100		258,420	0		
Mono	2002	Alfalfa		4.40		0		
Modoc	2001	Alfalfa	31,100	15.40	139,950	0		
Merced	2002	Alfalfa	78,189	73.80	601,071	0		
Plumas Co.	2002	Alfalfa	4,756	1.90	19,024	0		
Riverside	2002	Alfalfa	58,379	47.13		0		
Solano	2001	Alfalfa	31,969	22.10	202,364	0		
Sierra	2002	Alfalfa	875	0.28	2,800	0		
Shasta*	2002	Alfalfa	6,300	3.80	32,130	0		
Siskiyou*	1998	Alfalfa	50,532	25.20	265,293	0		
Tehama	2002	Alfalfa	4,000	2.20	23,080	0		
Tulare	2002	Alfalfa	107,916	90.90	877,000	0		
Yolo	2001	Alfalfa	45,885	31.80	295,958	0		
Kern*	2003	Alfalfa	150,000	115.70	1,293,000	0		
LosAngeles	2002	Alfalfa Hay	5,200		43,680	0		
Glenn	1998	Almon Hulls			10,151	10,151		
Butte	2002	Almond Hulls		2.76	39,350	39,350		
Colusa	2003	Almond hulls			30,750	30,750		
Merced	2002	Almond Hulls			149,669	149,669		
Merced	2002	Almond Shells			49,224	49,224		279,144
Butte	2002	Almonds	36,605	65.76	31,480	57,653		
Colusa	2003	Almonds	23,240	73.21	24,402	58,356		
Fresno	2003	Almonds	65,018	201.60	69,600	228,278		
Glenn	1998	Almonds	21,339	24.30	8,322	16,911		
Kern*	2003	Almonds	89,936	280.50	102,300	166,661		
Solano	2001	Almonds	1,688		1,506	2,818		
Stanislaus*	2002	Almonds	90,100	215.70	102,700	316,341		
Sutter	2001	Almonds	4,849	4.64	3,006	10,554		
Tehama	2002	Almonds	7,205	9.50		25,297		
Tulare	2002	Almonds	15,595	32.52	16,100	56,527		
Madera	2000	Almonds	47,600	72.70	33,320	72,590		
Merced	2002	Almonds	83,535	177.40	79,189	293,291		
San Joaquin	2002	Almonds	43,900	89.80	40,800	74,500	1,379,776	

Fresno	2003	Apples	2,259	13.03	26,470	3,583	
Butte	2002	Apples	222		1,776	417	
El Dorado	2002	Apple	835	6.70	11,774	1,424	
Calaveras	2002	Apples			600	30	
Kings	2002	Apples	374		2,593	504	
Mariposa	2002	Apples	700	0.14	404	720	
Mendocino	2002	Apples	200		2,391	320	
San Benito	2002	Apples	490		7,948	887	
San Joaquin	2002	Apples	5,832		54,002	8,532	
SLO	2003	Apples	1,483		11,739	1,781	
Santa Cruz	2002	Apples	2,756	9.20	41,044	4,808	
Sonoma	2003	Apples	3,008	71.00	47,258	5,371	
Kern	2002	Apples	3,107		52,900	5,752	34,128
San Benito	2002	Apricots	1,345		4,681	1,579	1,579
San Joaquin	2002	Asparagus	19,000		24,100	44,451	
Fresno	2003	Asparagus	3,200	11.95	7,590	7,875	52,326
Monterey	2002	Avocadoes	135		204	22	
Orange	2003	Avocadoes	1,739	19.50	5,394	593	
Riverside	2002	Avocadoes	7,199	36.43	21,597	2,376	
San Diego	2003	Avocadoes	25,729	152.30	75,515	8,307	
SLO	2003	Avocadoes	4,354		6,947	764	
SantaBarbara	2002	Avocadoes	8,620		24,136	2,655	
Ventura	2002	Avocadoes	18,588	99.30	60,894	6,698	21,416
Fresno	2002	Barley	8,600		22,900	34,350	
Modoc	2001	Barley	14,628	1.20		23,697	
Monterey	2002	Barley	995		757	1,493	
Merced	2002	Barley	2,666		7,908	4,319	
SanBernardino	2001	Barley	285		4,275	6,413	
SLO	2003	Barley	17,000	1.92	17,000	25,500	
Siskiyou*	1998	Barley	15,913	2.97	35,805	23,870	
Solano	2001	Barley	5,626		10,359	15,539	
Stanislaus	2002	Barley	1,400		3,880	5,820	
Kern	2002	Barley	9,100		16,400	24,600	165,599
Fresno	2002	Beans Dry	12,500		15,000	4,650	
Orange	2003	Beans dry	1,300		611	189	
Solano	2001	Beans	2,911		2,212	243	
Solano	2001	Bean Seed	478		373	560	
Stanislaus	2002	Beans Dry	18,450		26,190	39,285	
Tehama	2002	Beans Seed	1,168	0.82	1,117	1,676	

Stanislaus	2002	Beans Frsh	6,120		10,600	10,346		
SantaBarbara	2002	Beans Lima	4,430		2,303	253		
San Joaquin	2002	Beans, dry	10,600		11,400	3,534	60,736	
Modoc	2001	Beef			9,000			
Humboldt	2003	Beef Cattle	29,300	14.50	8,057	47,466		
SanBernardino	2001	Beef Cattle		22.30	8,270	24,359		
Siskiyou*	1998	beef-hd	31,000	15.30	1,007	0	71,825	
Kern*	2003	Biomass			521,000	521,000		521,000
		-						not counted
Fresno	2003	Broccoli	6,700	8.00	52,100	87,770		
		Broccoli	7,764		50,466	101,708		
Monterey	2002	Broccoli	55,125	265.80	384,690	722,138		
SanLuisObispo	2003	Broccoli	10,906	47.77	86,956	142,869		
SantaBarbara	2002	Broccoli	25,163	99.60	176,000	329,635		
Santa Clara	2002	Brassicas	798		6,045	10,454		
Stanislaus	2002	Broccoli	4,120		15,800	53,972		
Tulare	2002	Broccoli	1,628	3.98	9,260	2,130		
San Mateo	2002	Brussel Sprt	611	3.60	6,183	680		
Imperial	2001	Cabbage	880		14,058	3,233		
San Benito	2002	Cabbage	914		16,726	1,840		
Orange	2003	Cabbage	103		2,470	844	1,457,273	
Imperial	2001	Carrots	15,112	47.20	363,874	40,026		
Inyo	2002	Carrots	80	0.60	2,400	264		
Kern*	2003	Carrots	37,777	269.10	1,122,000	123,420		
Mono	2002	Carrots	670	4.76	19,800	2,178		
Monterey	2002	Carrots	3,821		67,180	7,390		
Riverside	2002	Carrots	2,763		66,700	7,337		
Siskiyou*	1998	carrots			2,400	264	181,723	
Del Norte	2003	Calves	2,375	26.00	1,069	0		
Napa	2003	CalvesFdr	3,200	1.54	160	0		
Shasta*	2002	CalvesFeeder	16,830	8.70	5,602	13,632		
Alameda	2002	Cattle	14,751	5.09	4,388	23,897		
Amador	2002	Cattle	13,000	6.54	3,737	21,060		
Butte	2002	Cattle	12,900	5.23	3,837	20,898		
Calaveras	2002	Cattle	14000	6.19	4550	22,680		
Colusa	2003	Cattle	26,100	11.63	7,177	42,282		
Del Norte	2003	Cattle	8,375	6.20	5,025	13,568		
El Dorado	2002	Cattle	4,450	3.10	1,860	7,209		
Inyo	2002	Cattle		6.10		0		
Mariposa	2002	Cattle	32,900	10.20	8,650	0		

Mendocino	2002	Cattle	16,153	7.90	6,761	26,168	
Nevada Co.	2001	Cattle	1,600	0.68	880	0	
Plumas Co.	2002	Cattle	14,600	9.28	393	23,652	
	2002	Cattle	31,500	12.15	90,000	51,030	
San Diego	2003	Cattle			11,625	34,241	
San Mateo	2002	Cattle		1.10		0	
SantaBarbara	2002	Cattle			13,073	38,506	
Solano	2001	Cattle	31,415	16.80	12,173	50,892	
Yuba	2003	Cattle	21,000	15.00		34,020	
Yolo	2001	Cattle	16,695	9.50	6,446	27,046	
Imperial	2001	Fed Cattle	325,122	182.30	154,442	526,698	
Tehama	2002	Fed Cattle	25,000	3.15	2,250	3,645	
Marin	2003	Cattle	12,050	8.30	5,459	19,401	
Madera	2000	Cattle			18,960	55,846	
Mono	2002	Cattle		8.80		0	
Sacramento	2002	Cattle		11.80	20,960	61,737	
Stanislaus*	2002	Cattle	182,000	62.90	61,250	294,840	
Sierra	2002	Cattle	4,637	2.73	115	7,512	
Santa Clara	2002	Cattle	13,500	5.60	15,371	21,870	
Tulare	2002	Cattle	562,000	388.30		910,440	
Glenn	1998	Cattle - hd	25,224	11.30	9,268	40,863	
Tehama	2002	Cattle Dairy	2,000	3.00	4,683	3,240	
Sonoma	2003	Cattle -hd	14,000	12.40	8,998	22,680	
Kern*	2003	cattle/Milk hd	258,000	230.30	1,005,850	417,960	
ContraCosta	2002	Cattle-hd	8,466	15.10		13,715	
Fresno	2003	FedCattle	297,000	138.20	876500	240,570	
Kern*	2003	Cattle-hd	258,000		50,250	479,880	
Kings	2002	Cattle-hd	158,832	66.50	45,685	257,308	
Lake	2002	Cattle-hd	5,691	2.70		9,219	
SanLuisObispo	2003	Cattle-hd	85,000	44.75	27,625	81,368	
Tehama	2002	Feeders	13,200	7.40	4,875	0	
Trinity	2000	Feeders	1,800	0.97	600	0	
Madera	2000	Repl Hiefers	21,000	31.30		17,010	
SanBernardino	2001	Repl Hiefers		44.10			3,936,581
			2,554,366				
Fresno	2003	Hogs hd	51,200	5.19	5,200	4,403	
Tehama	2002	Hogs	1,000	0.06	88	86	
Stanislaus*	2002	Hogs hd	20,200			1,737	6,226
Monterey	2002	Cauliflower	17,983		125,320	13,785	
San Mateo	2002	Cauliflower	244	1.09	1,972	3,196	
Stanislaus	2002	Cauliflower	2,015		10,700	26,397	
SantaBarbara	2002	Cauliflower	9,427	45.20	75,900	8,349	51,727

Orange	2003	Celery	57		1,671	184	
San Benito	2002	Celery	541		18,302	2,013	
San Mateo	2002	Celery	541	4.47	18,302	2,013	
SanLuisObispo	2003	Celery	1,110	8.60	38,062	4,187	
SantaBarbara	2002	Celery	4,083		150,000	16,500	
Santa Clara	2002	Celery	215		8,482	933	
Ventura	2002	Celery	10,622	114.70	404,583	44,504	70,334
San Benito	2002	Cherries	615		2,208	725	
San Joaquin	2002	Cherries	14,500	69.40	32,200	3,220	3,945
Fresno	2003	Citrus Other	2,257	16.62	34,390	3,783	
Imperial	2001	Citrus	5,399		33,203	3,652	
Kern*	2003	Citrus all	42,555	331.70	693,700	76,307	
Monterey	2002	Citrus	1,267		19,859	2,184	
Placer	2002	Citrus	127	1.82	635	70	
San Diego	2003	Citrus	15,309	42.70	203,921	22,431	108,428
Fresno	2003	Corn grain	1,790	0.85	7,590	11,385	
Amador	2002	Corn grain	286		1,630	2,445	
Tehama	2002	Corn	1,500	0.00	8,250	12,375	
Colusa	2002	Corn grain	1,700		7,650	11,475	
Glenn	1998	Corn grain	19,522	7.20	87,849	131,774	
Madera	2000	Corn grain	2,900		12,093	18,140	
Merced	2002	Corn grain	3,658		17,272	25,908	
Sacramento	2002	Corn grain	23,430	11.02	114,810	172,215	
San Joaquin	2002	Corn grain	47,600		247,600	371,400	
Solano	2001	Corn grain	13,677		67,975	101,963	
Sutter	2001	Corn grain	5,931	2.11	23,665	35,498	
Yolo	2001	Corn grain	9,195	4628.00	48,550	72,825	967,401
Fresno	2003	Cotton	237,590	341.70	167,750	620,110	
Imperial	2001	Cotton	16,528		23,387	43,138	
Kern*	2003	Cotton	132,110	176.70	211,075	190,238	
Kings	2002	Cotton	82,200	205.40	281,000	214,542	
Riverside	2002	Cotton	9,091		7,363	23,728	
Yolo	2001	Cotton	4,052	2920.00	2,246	10,576	
Madera	2000	Cotton&Seed	32,899		52,638	85,866	1,188,197
Monterey	2002	Dry Beans	1,582		1,957	2,936	2936
Fresno	2002	Eggs dozM	11,789	16.35	1,132	1,132	
Riverside	2002	Egg		60.54	6,336	608	
Orange	2003	Eggs m	1		17,847	2	

SanBernardino	2001	Egg m doz	64,730	26.10	61	6	
San Diego	2003	Egg m doz		40.20	90	9	1,756
Sonoma	2003	Fisheries	3.5 m lbs	4.40			
		-					
LosAngeles	2002	Grain Hay			7,200	0	
Merced	2002	Grain Hay			115,929	0	
San Benito	2002	Grain Hay			23,820	0	
SanLuisObispo	2003	Grain Hay	11,000	2.37	29,700	0	
Sierra	2002	Grain Hay			669	0	
Siskiyou*	1998	Grain Seed	2,025	0.76	4,500	3,038	3,038
Mariposa	2002	Grape Wine	83		98	31	
Mendocino	2002	Grape Wine	15,202	81.30	59,128	9,713	
Nevada Co.	2001	Grape Wine	348	1.24	1,043	191	
Napa	2003	Grapes Wine Rd	29,144	314.50	128,814	20,167	
Sacramento	2002	Grape Wine	26,597	73.90	164,901	23,139	
Napa	2003	Grapes WineWhite	9,962	70.10		2,491	
SanLuisObispo	2003	Grapes Wine	29,626	123.54	115,188	18,925	
ContraCosta	2002	Grapes	1,735	6.60	4,806	1,348	
Fresno	2003	Grapes	218,357	400.80	1,126,000	221,779	
Kern*	2003	Grapes	82,427	402.80	654,440	106,658	
Kings	2002	Grapes	48,704		41,300	28,482	
Madera	2000	Grapes	96,210	233.60	689,800	117,085	
Monterey	2002	Grapes	37,325	147.06	143,947	14,395	
San Joaquin	2002	Grapes	84,100	213.20	515,000	93,550	
Tulare	2002	Grapes	73,110	399.80	600,000	96,555	
Alameda	2002	Grapes Wine	2,255	5.40	4,793	1,043	
Amador	2002	Grapes Wine	3,241	11.12	10,724	1,883	
Calaveras	2002	Grapes Wine	470	1.32	1,360	254	
El Dorado	2002	Grapes Wine	1,464	4.70	4,060	772	
Lake	2002	Grapes Wine	7,400	28.70		3,700	
San Benito	2002	Grapes Wine	3,079	15.62	9,853	1,755	
SanBernardino	2001	Grapes Wine	884		6,183	839	
SantaBarbara	2002	Grapes Wine	16,667	72.40	48,834	9,050	
Sonoma	2003	Grapes Wine	52,176	313.10	160,768	29,121	
Solano	2001	Grapes Wine	4,072	14.00	16,279	2,646	
Santa Clara	2002	Grapes Wine	1,839	8.00	6,068	1,067	
Trinity	2000	Grapes Wn	152	0.20		38	
Yolo	2001	Grapes Wn	10,242	33.20	55,614	8,122	
Riverside	2002	GrapesTable	12,559	51.11	70,200	13,300	828,097
Alameda	2002	Hay	3,800	0.58	8,360	0	
Amador	2002	Hay	1,473	0.67	8,633	0	
Del Norte	2003	Hay			3,160	0	

SanBernardino	2001	Hay	17,532	19.40	141,757	0		
SantaBarbara	2002	Hay	3,012		12,800	0		
Santa Clara	2002	Hay			10,080	0		
Siskiyou*	1998	Hay	16,500	3.70	49,500	0		
San Joaquin	2002	Hay All	87,600	63.60	563,800	0		
Sierra	2002	Hay Mead	1,400	0.29	2,450	0		
Modoc	2001	Hay Mead.	30,000	2.10	16,622			
San Diego	2003	Herbs	487	22.60	8,756			
LosAngeles	2002	Honey			145	0		
Mariposa	2002	Honey	126m Lbs	0.17	52			
Butte	2002	Kiwis	1,164		5,122	1,420	1,420	
Riverside	2002	Lemons	7,694	31.30	129,200	25,840		
SanBernardino	2001	Lemons	315		1,498	165		
SLO	2002	Lemons	1,643	4.55	20,190	2,763		
SantaBarbara	2002	Lemons	1,904		26,466	1,323		
Ventura	2002	Lemons	23,603	182.80	371,144	2,360	32,451	
Fresno	2003	Lettuce Lf	7,220		113,000	5,650		
San Benito	2002	Lett Baby	4,319	24.52	119,000	27,370		
Monterey	2002	Lett SaladPrdt	20,606		380,250	19,013		
Imperial	2001	Lett SprgMix	1,981		17,873	894		
Monterey	2002	Lett SprMix	18,152	119.30	70,430	3,522		
SanLuisObispo	2003	Lettuce	9,297	46.30	125,157	62,579		
Monterey	2002	Lettuce	119,624	738.40	1,358,825	679,413		
Riverside	2002	Lettuce	1,178		85,022	19,555		
Santa Cruz	2002	Lettuce	3,637	29.70	75,177	38189		
SantaBarbara	2002	Lettuce	14,575	62.10	252,000	153,038		
Santa Clara	2002	Lettuce	2,552	9.20	14,933	26,796		
Fresno	2003	Lettuce Hd	20,880	118.80	363,400	181,700		
Imperial	2001	Lettuce hd	12,507	68.90	220,354	110,177		
San Benito	2002	Lettuce Head	3,574	13.91	60,758	3,485		
San Mateo	2002	Lettuce hd	3,574	13.91	69,680	37527		
Imperial	2001	Lettuce Lf	7,627	54.20	158,034	7,902		
Monterey	2002	Lettuce Lf	58,376		1,400,000	70,000		
San Benito	2002	LettuceLeaf	4,051	19.63		3,950	1,450,756	
Lake	2002	Lvstk		0.70				
Kings	2002	Manure	na	na	437,036	437,036		
Merced	2002	Manure			984,453	984,453		
Kern*	2003	Manure			437,000	437,000		1,858,489
								Not counted
Fresno	2003	Melons	35,400	156.50	509,000	55,990		
Imperial	2001	Melons	12,993		123,498	13,585		

Riverside	2002	Melons	4,300		70,413	7,745	
San Joaquin	2002	Melons	3,550		74,500	8,195	
Santa Clara	2002	Cucurbits	734		7,763	854	
Solano	2001	CurcurbitSeed	457		66	99	
Stanislaus	2002	Cucurbits	4,040		56,200	6,182	
Yolo	2001	Melons	3,613	6098.00	29,237	3,216	39,876
Butte	2002	Milk - hd	875		6,918	1,418	
Del Norte	2003	Milk		8.80	37,082		
Glenn	1998	Milk		46.00	155,545		
Humboldt	2003	Milk	22,000	43.20	141,677	3,273	
Kings	2002	Milk		303.50	1,089,942		
Marin	2003	Milk	10,200	25.10	105,500	above	
Madera	2000	Milk		96.10	422,116	9,751	
Merced	2002	Milk	225,620	515.80	2,364,506	365,504	
Monterey	2002	Dairy Cows	1,300		321,564	2,106	
Riverside	2002	Milk		227.83	876,269	20,242	
Sacramento	2002	Milk		38.00	170,689	3,943	
SanBernardino	2001	Milk		444.10	1,578,500	36,463	
San Joaquin	2002	Milk		237.40	1,079,000	24,925	
SantaBarbara	2002	Milk	2,128		26,609	3,447	
Sonoma	2003	Milk	32,000	79.30	322,971	7,461	
Stanislaus*	2002	Milk		390.00	1,750,235	40,430	
Santa Clara	2002	Milk			4,865	112	
Siskiyou*	1998	Milk		2.40	7,965	184	
Solano	2001	Milk hd	1,800			2,916	
Tehama	2002	Milk		11.20		0	
Tulare	2002	Milk		959.70	4,450,450		
Yuba	2003	Milk		8.60			
Mendocino	2002	Milk hd	1,500	3.80	15,504		
Fresno	2003	Milk- hd	13,800	221.20	967,100	22,356	544,531
San Mateo	2002	Mushrooms	17	23.00	2,533	279	
Santa Clara	2002	Mushrooms	127	46.10	18,923	2,082	2,360
Sacramento	2002	Nurs. Stk		26.40			
Alameda	2002	Nursery	466ft^2	13.60			
Del Norte	2003	Nursery	442	14.70			
El Dorado	2002	Nursery	50	1.90			
Humboldt	2003	Nursery		35.80			
SantaBarbara	2002	Nursery	2,564	144.50			
Solano	2001	Nursery	1,108	37.70			
Stanislaus*	2002	Nursery	625	60.20			
Sutter	2001	Nursery	349	10.10			
Madera	2000	Nursery	740 ac	37.50			

Mendocino	2002	Nursery	300m ft^2	3.30			
Monterey	2002	Nursery	1,900	218.70			
Napa	2003	Nursery		4.54			
Orange	2003	Nursery		232.10			
	2002	Nursery		15.08			
San Benito	2002	Nursery	674	28.97			
SanBernardino	2001	Nursery	934	34.60			
San Diego	2003	Nursery	8,934	879.10			
Santa Cruz	2002	Nursery	1,230	61.00			
San Mateo	2002	Nursery In	582	104.30			
San Mateo	2002	Nursery Out	986	39.70			
Kern*	2003	Nursery Plt	7,280	100.70			
Sonoma	2003	Nursery Plt		27.00			
Santa Clara	2002	Nursery Plt	1,089	113.60			
Ventura	2002	Nursery Plt	7,525	167.30			
SanLuisObispo	2003	Nursery Prdts	1,234	63.20			
Calaveras	2002	NurseryPlants		0.35	417		
Inyo	2002	Turf		3.80			
LosAngeles	2002	Orn Tr&Shrub	1,480	118.20			
Riverside	2002	Ornament	3,103	133.09			
LosAngeles	2002	Beddig Plts	144	35.40			
ContraCosta	2002	Bedding Plants	7,400	26.10			
LosAngeles	2002	Indoor Plts	1	7.20			
Ventura	2002	Cut Flwrs	1,194	40.30			0
Napa	2003	Oat Hay	520	0.15	1,820	0	
Sonoma	2003	Oats	1,702		1,668	2,502	
Solano	2001	Oats	1,122		2,805	4,208	
Siskiyou*	1998	Oats	3,400	0.90	6,800	4,760	11,470
Butte	2002	Olives	2,300		4,922	541	
Tehama	2002	Olives	5,351	11.14	18,318	2,015	
Riverside	2002	Dates	5,940	37.50	14,242	1,567	
Napa	2003	Olives	131	0.03	134	15	4,138
Siskiyou*	1998	Onion	450	2.90	28,620	3,148	
Santa Clara	2002	Onions	462		7,577	833	
Fresno	2003	Onions	22,300	164.80	591,000	65,010	
Imperial	2001	Onions	9,934	27.80	198,387	2,831	
LosAngeles	2002	Onions	1,720	12.80	44,108	490	
Modoc	2001	Onions	559	12.00	22,281	159	
Riverside	2002	Onions	553		14,419	1,586	
San Benito	2002	Onions dry	1,502		36,192	3,981	78,040

Madera	2000	Orange	3,710		47,377	408	
Riverside	2002	Orange	12,400		54,375	5,981	
SanBernardino	2001	Orange	4,732	21.80	58,351	6,419	
Fresno	2003	Oranges	34,392	215.30	591,000	65,010	
Tulare	2002	Oranges	97,200	448.70	865,000	0	
Riverside	2002	Other Cit	10,000		86,700	9,537	
SLO	2003	Misc Fruit	3,003		3,003	3,333	90,688
Inyo	2002	Pasture		0.88			
Mono	2002	Pasture		1.60		0	
Solano	2001	Milo	5,943		11,886	8,915	8,915
Fresno	2003	Nectarines	15,150	109.57	138,000	22,050	
Kings	2002	Nectarines	1,500		15,460	2,273	
Butte	2002	Peaches	2,436	7.18	33,130	4,093	
Fresno	2003	Peaches	20,933	158.40	213,000	31,583	
Kings	2002	Peaches	4,200		42,000	6,300	
LosAngeles	2002	Peaches	841	11.60	12,601	1,471	
San Joaquin	2002	Peaches	5,500		55,800	8,290	
Sutter	2001	Peaches	9,387	35.90	151,453	16,960	
Tulare	2002	Peaches	24,300	90.90	138,500	31,225	
Yuba	2003	Peaches	5,960	21.30	90,592	10,490	
Madera	2000	Peach/plums	1,960		38,650	3,893	
Orange	2003	Fruit Decid	373	3.33	8,212	784	
Placer	2002	Peaches	104	0.62	208	114	
Placer	2002	Plums	151	0.53	453	174	
		Mixed Fruit	1,785		4,192	2,246	
Solano	2001	Peach/Plums	2,519		5,410	2,790	
Solano	2001	Mixed Fruit	640		486	693	
Stanislaus	2002	Decid Fruit	8,030		81,330	16,976	
Stanislaus	2002	Peaches	7,900		135,800	14,690	
Tulare	2002	Plums/Nect	31,633	154.62	208,100	42,038	
Kings	2002	Plums	1,721		8,777	2,160	
Kern	2002	Peach/plum/nect	5,271		45,720	7,557	
Tulare	2002	plums dry	5,787		10,000	6,287	235,135
Lake	2002	Pear Other		2.00		478	
Mendocino	2002	Pears	2,094	12.00	38,826	4,035	
Sacramento	2002	Pears	6,015	27.30	114,285	11,729	
Solano	2001	Pears	968		9,509	1,443	
Sutter	2001	Pears	384		5,841	676	
Lake	2002	Pears Bart	3,064	15.50		6,894	25,256

Fresno	2003	PeppersBell	1,500		34,000	12,360	
Orange	2003	Peppers	412	7.50	8,104	891	
Riverside	2002	Peppers	2,402		45,000	4,950	
San Benito	2002	Peppers	1,799	15.32	41,183	4,530	
Solano	2001	Peppers Bell	354		4,248	467	
Santa Clara	2002	Peppers	2,015	13.90	63,468	6,981	30,180
Fresno	2003	Pistachios	7,824	28.78	11,700	3,707	
Kings	2002	Pistachios	8,600	32.20	8,675	3,029	
Madera	2000	Pistachios	19,270	62.80	30,639	9,587	
Tulare	2002	Pistachios	10,345	40.15	16,800	5,235	
Kern	2002	Pistachios	33,590	143.59	64,740	19,544	41,101
Kern*	2003	Potato Cull			61,300	61,300	
Merced	2002	Potato Sweet	9,145	67.07	125,543	13,810	
Imperial	2001	Potatoes	2,935		41,090	62,136	
Kern*	2003	Potatoes	26,459	83.24	528,520	68,841	
Modoc	2001	Potatoes	1,522	3.60	33,484	3,683	
Riverside	2002	Potatoes	982		14,632	1,610	
San Diego	2003	Potatoes			18,236	2,006	
Stanislaus*	2002	Sw Potato	1,000		15,400	1,694	
San Joaquin	2002	Potatoes	3,150		62,000	6,820	
Siskiyou*	1998	Potatoes	12,135	19.10	213,362	23,470	245,370
SanBernardino	2001	Poul Chicken	4,883,429	7.30	8,546	10,548	
Stanislaus*	2002	Poul Chk m bd	83,940	139.20	146,900	181,310	
Calaveras	2002	Poultry		1.93		0	
Fresno	2003	Poultry		246.50	51,000	29,143	
Mariposa	2002	Poultry		1.03			
Monterey	2002	Poultry brlr m	464			1,002	
Monterey	2003	Eggs m birds	1		32,000	3	
Sacramento	2002	Poultry		11.10		0	
Sonoma	2003	Poultry	921,000	40.90		1,989	
Marin	2003	Poultry birds	121,000	3.60		1,989	
	2002	Poultry-1000	3	6.51	4,050	6	
Kings	2002	Turkeys-hd	2,216,000	33.40	30,410	89,970	
Stanislaus*	2002	Turkeys hd	9,718,000		28,230	394,551	
Merced	2002	Chickens	1.9m	196.90	218,821	31	710,543
Fresno	2003	Plums	18,927	119.76	136,100	25,732	
Butte	2002	Prune Plums	10,831		23,872	12,025	
Sutter	2001	Prune Plums	24,632	22.00	29,805	26,122	
Butte	2002	Prunes	10,851	18.29	23,872	12,045	
Glenn	1998	Prunes	7,516	6.50	8,850	7,959	

Tehama	2002	Prunes	10,100	22.30	29,088	11,554	
Yuba	2003	Prunes	12,000	19.60	27,600	13,380	108,816
Sacramento	2004	Pumpkins	556		9,952	1,095	
San Mateo	2002	Pumpkins	244		3,101	341	
San Joaquin	2002	Pumpkins	3,450		51,800	5,698	7,134
		-					
Fresno	2003	Rice	5,790	3.18	17,900	26,850	
Butte	2002	Rice	94,700	101.19	427,210	640,815	
Colusa	2003	Rice	127,350	160.97	503,033	754,550	
Glenn	1998	Rice	81,820	69.90	286,370	429,555	
Merced	2002	Rice			16,836	25,254	
30	2002	Rice	15,500	15.38	61,535	92,303	
Sacramento	2002	Rice	8,831	9.87	38,860	58,290	
San Joaquin	2002	Rice	6,900		29,000	43,500	
Stanislaus	2002	Rice	2,210		8,750	13,125	
Sutter	2001	Rice	81,857	85.50	338,069	507,104	
Tehama	2002	Rice	900	0.68	1,710	1,350	
Yuba	2003	Rice	35,580	43.60	138,762	208,143	
Yolo	2001	Rice	28,717	28.30	115,719	173,579	
Colusa	2003	Rice seed	6,670	9.48	26,347	10,005	
Shasta*	2002	Rice Wild	4,100	2.60	3,206	4,809	2,989,230
		-					
Fresno	2003	Safflower	5,160	2.12	8,410	12,615	
Glenn	1998	Safflower	1,500		900	1,500	
Colusa	2002	Safflower	12,400		13,640	12,400	
Siskiyou*	1998	Rye	2,200	0.19	2,760	3,300	
Sacramento	2002	Safflower	6,319	1.80	7,580	6,319	
Solano	2001	Safflower	6,018		5,657	3,009	
Sutter	2001	Safflower	15,596	3.19	14,504	15,596	
Yolo	2001	Safflower	20,765	6697.00	26,995	20,765	75,504
Solano	2001	Lambs	113,856	7.70	5,692	20,494	
	2002	Sheep	7,000	0.64	400	1,260	
Mono	2002	Sheep		0.99			
Kern*	2003	Sheep/Lambs	120,000		6,400	0	
Mariposa	2002	Sheep-hd	2,756		130	496	22,250
		-					
Stanislaus*	2002	Silage	96,200	44.80	2,090,000	0	
Nevada Co.	2001	Slau Cows	5,360	1.97		0	
Monterey	2002	Spinach	16,206	129.40	122,030	13,423	
Stanislaus	2002	Spinach	3,430		29,800	3,278	
Fresno	2003	Seed	12,960	61.00	15,600	21,780	38,481

SanLuisObispo	2003	Strawberries	1,186	45,190	44,428	4,887	
Orange	2003	Strawberry	1,757	58.50	48,107	5,292	
Ventura	2002	Strawberry	8,582	297.90	242,613	15,770	
LosAngeles	2002	Strawberry	122		2,800	182	
Monterey	2002	Strawberry	6,900	226.80	212,260	13,797	
SanBernardino	2001	Strawberry	267	4.80	7,153	787	
San Diego	2003	Strawberry	698	27.80	24,081	2,649	
Santa Cruz	2002	Strawberry	3,586	107.40	91,802	10,098	
SantaBarbara	2002	Strawberry	3,725	115.80	121,893	4,630	
SantaBarbara	2003	StrawberProc			42,683	2,774	
Orange	2003	Sub Trop	333	3.30	8,212	903	
Monterey	2002	Raspberries	577		7,595	835	
Santa Cruz	2002	Raspberry	1,514	37.00	9,690	1,066	
Santa Clara	2002	Berries			1,157	127	63,798
Glenn	1998	Sugar Beets	950		20,181	1,822	
Fresno	2002	Sugar Beets	11,900		442000	22,824	
Madera	2000	Sugar Beets	460		18,389	882	
Imperial	2001	Sugar Beets	26,300	37.70	1,066,410	50,443	
Merced	2002	Sugar Beets	5,395		161,850	10,348	
Kings	2002	SugarBeets	2,100		84,117	4,028	90,347
Fresno	2003	SwCorn	8,100	23.43	101,000	23,260	
Riverside	2002	Sw Corn	2,004		14,654	1,612	
San Benito	2002	Sw Corn	652		4,610	7,422	
San Joaquin	2002	Sw Corn	3,370		25,600	42,624	
ContraCosta	2002	Sweet Corn	3,211	9.60	10,596	17,643	92,561
Amador	2002	Timber	28,310	6.67		5,325	
Butte	2002	Timber	63,421	18.06		11,929	
Del Norte	2003	Timber	24	9.10		4	
El Dorado	2002	Timber	145,250	21.70		27,320	
Humboldt	2003	Timber	384	148.00		72	
Modoc	2001	Timber	27	6.90	27	5	
Nevada Co.	2001	Timber	40	11.78	1,340	7	
Plumas Co.	2002	Timber	79,802	17.51		15,010	
	2002	Timber	50	9.72		9	
Sierra	2002	Timber	33,342	6.59		6,271	
Shasta*	2002	Timber	152	39.30	152	29	
Tehama	2002	Timber	65	17.30		12	
Trinity	2000	Timber	72,755	24.80		13,684	
Tuolumme	n/a	Timber	54	15.30	n/a	10	
Yuba	2003	Timber	24	8.10		4	

San Mateo	2002	Timber FProd	3	1.20		1	
Mariposa	2002	TimberForestPrdt	3	0.84		1	
Calaveras	2002	Timber-mbf	48500	13.1		9,122	
Santa Clara	2002	Timber mbf	399			75	
Mendocino	2002	Timber-mbf	98	53.90		18	
Siskiyou*	1998	Timber-mbf	187,215	40.40		35,213	
El Dorado	2002	Xmas Trees	84,130	3.10		0	124,121
Sacramento	2002	Tom fresh	824	1.77	16,810	6,230	
Fresno	2003	Tomatoes	119,000	384.30	4,774,000	254,905	
Imperial	2001	Tomatoes	863		19,936	4,432	
Kings	2002	Tomatoes	16,108		520,772	32,309	
Monterey	2002	Tomatoes	1,805		35110	3,214	
Sacramento	2003	Tomatoes	5,717	5.92	199,523	11,724	
Ventura	2002	Tomatoes	209		27,929	8,680	
Colusa	2003	Tom-proc	16,900	32.32	648,960	35,693	
San Benito	2002	Toms	1,174		66,625	2,856	
San Joaquin	2002	Toms	31,500	105.80	1,149,000	65,468	
Santa Clara	2002	Toms	1,037		35,972	2,123	
Solano	2001	Toms	13,801	23.70	483,035	28,327	
Stanislaus*	2002	Toms	16,600	49.30	609,200	34,565	
Yolo	2001	Toms	40,374	68.70	1,429,643	83,157	
San Mateo	2002	Toms proc	1,174	3.46	66,625	2,856	
San Mateo	2002	Toms frsh	298	1.67	2,849	1,284	
ContraCosta	2002	Toms-fresh	119		1,300	561	
Fresno	2003	Toms-fresh	6,830		154,000	56,035	
Kings	2002	Toms-fresh	784		24,547	8,493	
Merced	2002	Toms-fresh	9,856		10,978	17,486	
Orange	2003	toms-fresh	22		374	144	
Riverside	2002	Toms-fresh	281		4,097	1,634	
San Benito	2002	Toms-fresh	299		2,849	1,285	
San Joaquin	2002	Toms-fresh	10,580		116,000	50,035	
Stanislaus*	2002	Toms-fresh	1,920		43,000	15,665	
San Diego	2003	Toms-frsh	2,356	31.10	55,890	20,160	
Tulare	2002	Toms-frsh	89	0.44	840	380	
ContraCosta	2002	Toms-proc	1,180	3.30	49,200	2,560	
Kern*	2003	Toms-proc	13,600		391,000	26,427	
Merced	2002	Toms-proc	16,621	89.11	572,113	33,946	
Sutter	2001	Toms-Proc	9,500	15.30	313,975	19,175	831,808
Fresno	2003	VegMixed	2,165		34,390	12,482	
Del Norte	2003	Veg. Frt.		1.20	45,700	5,027	
LosAngeles	2002	Veget Root	9,964	44.10		0	
SanLuisObispo	2003	VegetTranspl	61	28.25		0	
Alameda	2002	Vegetables	189	0.86		0	

Mariposa	2002	Misc FV	79	0.40		0	
Santa Cruz	2002	Misc Veg	2,973	14.90		0	
Orange	2003	Green Beans	888	4.60	4,440	488	
Marin	2003	Fr. Veg.	183	1.50		0	
Nevada Co.	2001	Frt&Veg		1.70		0	
Fresno	2003	Garlic fr	25,400	151.90	272,600	11,811	
Santa Clara	2002	Chin Veget	703		14,974	1,647	31,456
	2002	Walnut	837	1.84	1,674	1,113	
San Joaquin	2002	Walnut	45,000	75.60	67,500	56,250	
ContraCosta	2002	Walnut s	885	1.10	1,040	812	
Calaveras	2002	Walnuts	650	0.65	700	565	
Colusa	2003	Walnuts	4,550	6.47	6,598	4,801	
Fresno	2003	Walnuts	3,432	9.19	8,510	5,971	
Glenn	1998	Walnuts	6,231	6.30	5,989	5,051	
Kern*	2003	Walnuts	1,480		2,520	2,000	
Kings	2002	Walnuts	6,719		10,079	8,399	
Madera	2000	Walnuts	1,030		1,576	1,303	
Monterey	2002	Walnuts	450		302	376	
Merced	2002	Walnuts	5,726		6,940	6,333	
San Benito	2002	Walnuts	1,915		1,628	1,772	
SanLuisObispo	2003	Walnuts	2,727	366.00	764	1,746	
Santa Clara	2002	Walnuts	290		203	247	
Stanislaus*	2002	Walnuts	25,900	50.80	38,900	32,400	
Shasta*	2002	Walnuts	675	1.08	1,080	709	
Solano	2001	Walnuts	5,302		4,908	5,105	
Sonoma	2003	Walnuts	86		149	118	
Sutter	2001	Walnuts	15,549	28.20	26,433	18,348	
Tehama	2002	Walnuts	13,413	25.10	24,143	16,498	
Tulare	2002	Walnuts	31,466	31.78	31,780	31,623	
Yuba	2003	Walnuts	9,750	18.70	17,648	12,042	
Yolo	2001	Walnuts	7,962	12.60	11,704	9,833	
Butte	2002	Walnuts	20,113	45.06	38,214	25,744	
Lake	2002	Walnuts	4,704	1.70		1,552	
Amador	2002	Walnuts	427	0.43	427	354	251,062
Butte	2002	Wheat	4,000		7,840	13,328	
Fresno	2002	Wheat	61,000		196000	294,000	
Imperial	2001	Wheat	46,620		153,846	261,538	
Kern	2002	Wheat	74,000		234,000	351,000	
Kings	2002	Wheat	65,500		135,585	230,495	
Lassen	2002	Wheat	1900	0.546	3,200	5,440	
Madera	2000	Wheat	4,500		24,375	41,438	
Merced	2002	Wheat	14,419		32,820	55,794	
Riverside	2002	Wheat	5,727		17,181	29,208	

Sacramento	2002	Wheat	9,730	2.48	24,330	41,361	
San Joaquin	2002	Wheat	45,000		82,200	139,740	
Colusa	2002	Wheat	21,400	4.67	49,220	83,674	
Glenn	1998	Wheat	20,486		30,729	52,239	
Shasta	2002	Wheat	635		635	1,080	
Siskiyou*	1998	Wheat	10,550	2.99	25,320	17,935	
Solano	2001	Wheat seed	1,217		3,243	2,069	
Solano	2001	Wheat	29,350		84,190	49,895	
Stanislaus	2002	Wheat	4,000		10,760	18,292	
Tehama	2002	Wheat	2,000	0.34	4,000	6,800	
Yolo	2001	Wheat	33,076	8537.00	85,998	146,197	1,841,521
					Grand Total =		20,693,117 *Tons*

Appendix Table 2. California Crop Residue Factors and References

Cattle: Brown 1.62 tons manure/hd CAFO

Wine Grapes: 10% tonnage waste, 1/4 ton cane pruning waste per acre

*Timber: Knutson and Miller adapted: 4/3 BDtons/mbf*16.6%mill residue*15%tech reduc 1976 to present*

Almonds: SacVal vs SJV: Tony Piva & Pops Gilliam - 1 ton/ac prunings "Years of Discovery" Almond Board

Walnuts: 50% nut wt inshell, 1/3 ton prunings/ac NorCal

Wheat: Brown - production X 1.7 winter wheat

Rice: Brown

Prune Plums: 5% fruit and 1ton/acre prunings @10.175 ton/ac

Peaches: 10.175 over-estimated peach acreage

Almonds: 3.511 tons waste~ton nut meats hulls1.25:1, prunings0.5/ac, shells

*Tomatoes: Tons*1.75%waste proc + 2880lbs/ac biomass (RC Gill and Mitchell, et al.)*

Almond hulls: Nut Harvest

Tomatoes: Fresh 30% waste fruit +2880 lb/ac biomass PH

*Table Grapes: Tons*10%+Acre*1/2ton*

Milk: Assumed pastured dairy cows

Asparagus: Knutson and Miller - 2.2t/ac

Broccoli: Ruiz, River Ranch based on weight reduction examination

Pistachios: New crop since K&M '78

Seed: Assume 1.5t/a +15%cull

Vegetables Mixed: Assumed 1T/ac+30%culls

Almonds: ~1 ton hulls, 0.5 ton prunings/ac, shell waste heavy producing counties assumed 2X prunings-T.Piva

*Onions: (570lb/ac/2000)*Acreage - Mitchell, et al.*

Peaches: 10.175ton/ac production

*Garlic: Mitchell, et al. = Acreage*930#/ac/2000#/ton*

*Onions: (570lb/ac/2000)*Acreage - Mitchell, et al.*

Carrots: Extrapolation from Kern Co.

Citrus: 11% culls

Carrotts: culls 11% assumes no other waste

Potatoes: Cull Tons/TonsPrdn (Kern Co) + field residue 570#/ac Mitchell, et al.

Cattle: 1.62 tons/hd 490,000 manure tons~Brown's ratios, p71,tons manure/AUM

Turkeys: adapted fromBrown, manure only 40.6 tons/1000 birds

Sugar beets: assume 40 tons/acre

Bartlett Pears: Knutson and Miller,

Pears other, CASS, Summary 2002 CAC

Wheat Lassen 18% of Siskiyou Co.

Timber: 12 bf/cuft, 30lb/cuft, 40.6%residue biomass from forest harvest, NE Calif study.

*mbf *0.166*1.333*0.85*

Cauliflower: acres(6546#/2000ton) from Mitchell, et al.*

Lettuce leaf: acres(1950#/2000/ton) - Mitchell, et al.*

Walnuts: North 50% nut wt inshell waste, 0.33 ton/ac prune waste-T.Piva, Orland

Fresh Toms: 30%Wt harv is waste + 2880#/acre biomass

Asparagus: 20%vol=field waste + 11% culls assumed

Strawberry: Assume split frsh/proc 6.5% culls

Safflower: Assumed 2/3 of most grains

Pistachios: Assume 10% hull waste & culls and 1/2 walnut prunings