



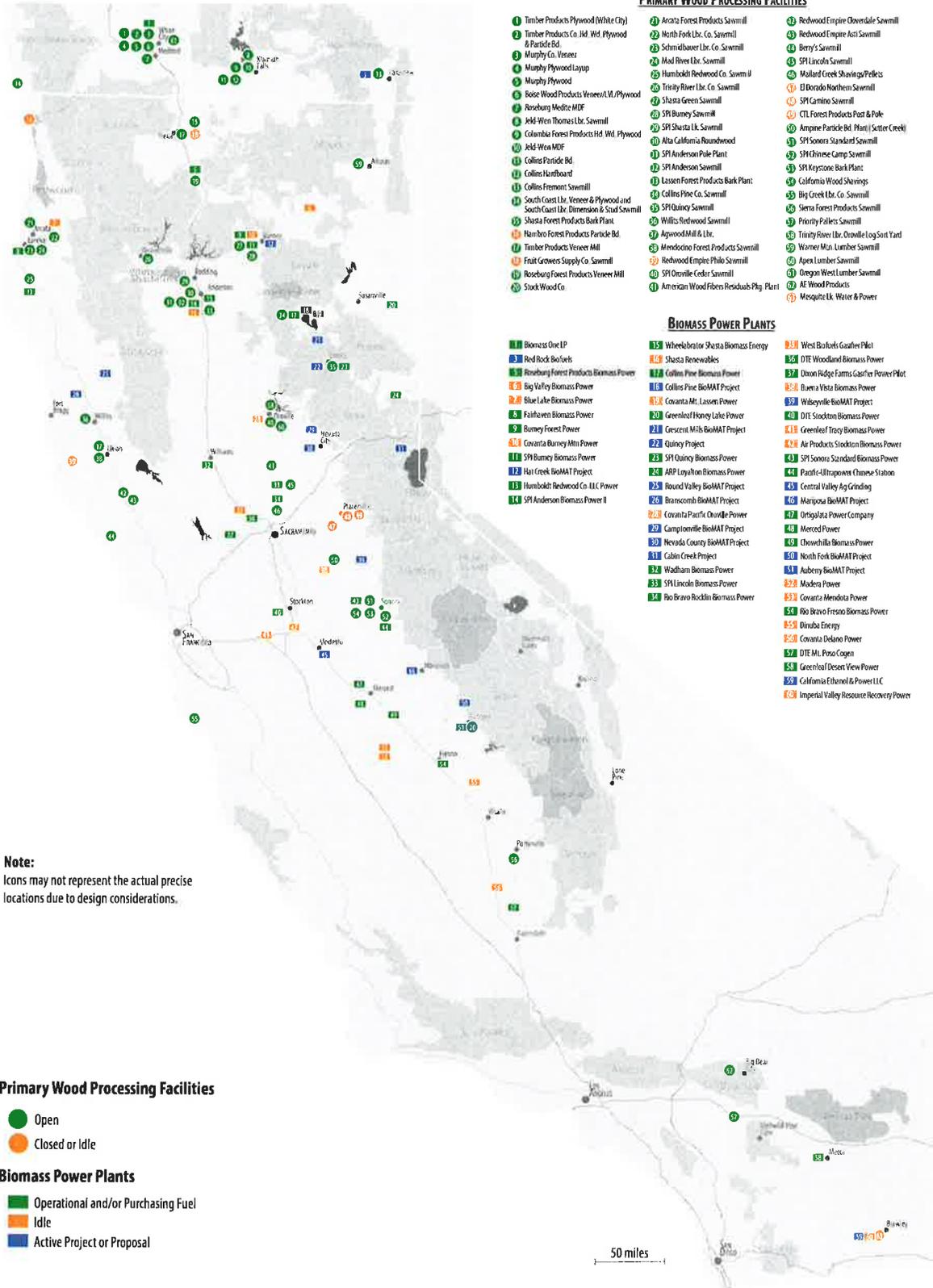
Appendix C
Supporting Research



Appendix C – 1



WOOD PRODUCTS PRIMARY PROCESSING & BIOMASS ENERGY FACILITIES



Note:
Icons may not represent the actual precise locations due to design considerations.

- Primary Wood Processing Facilities**
- Open
 - Closed or Idle
- Biomass Power Plants**
- Operational and/or Purchasing Fuel
 - Idle
 - Active Project or Proposal



Appendix C – 2

LOCAL

Biomass plants make pitch for dead trees to produce electricity

By Marc Benjamin

mbenjamin@fresnobee.com

JULY 15, 2016 02:25 PM , UPDATED JULY 18, 2016 10:34 AM



Biomass facility Rio Bravo of Fresno processes wood into energy for Pacific Gas & Electric Co., but with the plant facing higher costs to produce energy than other methods, has faced the prospects of closure. Proponents believe the facility and ot BY JOHN WALKER



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Trees are dying in the Sierra at modern-day unprecedented rates, posing elevated fire danger and creating health, water and air quality concerns, but a possible solution to rid the forest of dead and dying trees is getting short shrift, officials say.

California's biomass industry is set up regionally to turn agricultural waste into electricity while eliminating open burning. But many local biomass plants have closed or are closing soon because it costs less to produce electricity with solar and wind, which get subsidies that are not available to biomass.

As contracts expired with investor-owned utilities, biomass plants have shut down in Delano, Mendota, Firebaugh, Dinuba and Terra Bella, leaving a handful in the San Joaquin Valley: Malaga, Chowchilla, El Nido in Merced County and Mount Poso north of Bakersfield. There are plans to build smaller biomass plants in the Sierra to address tree mortality, but critics say they won't accommodate dead tree disposal needs.

TOP ARTICLES

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Environmentalists say biomass plants pollute the air and aren't sorry to see them go. But the [San Joaquin Valley Air Pollution Control District](#)'s executive director says biomass plants are preferable to open agricultural burning or a raging forest conflagration that could pump huge amounts of unfiltered smoke and particulates airborne – as did the recent Erskine Fire and the Rough Fire last year.

At its peak, the [Rough Fire](#) was emitting 25 times more particulate matter, 105 times more fine particulate matter, eight times more nitrogen oxides and 16 times more volatile organic compounds than occurs on a normal day in the Valley, said Seyed Sadredin, executive director of the San Joaquin Valley Air Pollution Control District.

Such fires, fueled by dead and dying trees, cost tens of millions of dollars to fight and create a potential for health problems and lost lives and property.

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“The state has made it a big priority to get rid of these dead trees, and one way they wanted to do it is to send them to biomass facilities,” Sadredin said. “But they are not doing what they should to keep biomass facilities afloat.”

Electricity generated by biomass is costlier than other options such as solar and wind, a concern to state and public utilities commission officials who are responsible to ratepayers, said Julee Malinowski Ball, executive director of the [California Biomass Energy Alliance](#).

And diverting organic materials to biomass plants helps the state meet certain air quality and landfill goals.

California requires a 50 percent reduction of landfill waste from cities and counties compared to 1990. The state has set a policy goal of 75 percent reduction by 2020, but it's not mandated.

“It's truly a no-brainer because there are a number of well-located (biomass) facilities that are underutilized,” Malinowski Ball said. “It means millions of tons of organic material diverted from the least favorable environmental outcomes, such as landfilling and burning.”

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Meanwhile, a large supply of organic material looms in the Sierra.

There are an estimated 66 million dead trees in California's forests. The U.S. Forest Service has cut down 87,590 in the Sierra, Sequoia and Stanislaus national forests,

And, despite concerns that Rio Bravo pollutes the air, Spurlock said critics should consider the alternative.

"We are burning 35 tons of wood an hour and you see nothing come off," he said, pointing to a smokestack behind him. "If you lit a stack of wood right here more smoke would come out."

It's unfair to compare the cost of generating electricity by biomass plants to solar- and wind-generated electricity, Spurlock said. Solar and wind energy companies employ fewer people and have fewer expenses, and also benefit from significantly larger tax credits and property tax exemptions.

The California Public Utilities Commission is proposing awarding biomass contracts totaling 50 megawatts to improve forest health.

Spurlock said Rio Bravo might snag utilities contracts through the utilities commission later this year, but the contracts will max out at 20 megawatts for PG&E and Southern California Edison and 10 megawatts for San Diego Gas & Electric. Meanwhile, 190 megawatts of biomass-generated electricity is going offline statewide later this year, officials say.

Larry Osborne, general manager of the idled Dinuba and Firebaugh plants, said there's no way to operate biomass without a subsidy like those provided for solar and wind energy. The Dinuba plant closed last October, and Firebaugh's was shut down in 2012.

"It's not like we're trying to make a lot of extra money; it just costs more money to make power this way," he said.

In Mendota and Delano, two plants owned by Covanta were closed when contracts expired at the end of 2014 and 2015. At one point, Covanta had five California biomass plants producing in excess of 110 megawatts. It has none now.

Opportunities to reopen will rely on subsidies and whether the state utilities commission contracts are lengthy enough to justify reopening, said James Regan, director of communications for New Jersey-based Covanta.

The 50 megawatts in biomass contracts won't be enough incentive for Covanta to restart its plants because there are no guarantees for long-term profit.

"It's about knowing you can operate for five to 10 years that would make it viable for us to reopen," Regan said.

He said biomass should be examined through a different prism than solar or wind. It should be viewed as an alternative to landfills or burn piles that will pollute or allow wood to rot, Regan said. And biomass should be judged as a power source that uses recycled material.

"I think the benefits are being overlooked," he said.

The Rio Bravo plant, built in 1988, underwent a \$10 million renovation eight years ago. Each hour, it turns 35 tons of wood from agricultural waste and the forest into power sufficient for a city nearly the size of Clovis.

Spurlock said the plant filters 98 percent of key pollutants that would have come from open field burning – nitrogen oxides, sulfur dioxides, carbon dioxide and particulates – out of the the air. Sadredin puts the figure between 80 percent and 90 percent. Environmentalists say it's worse than that.

ENVIRONMENTALISTS CONCERNED

Environmentalists say biomass plants are unnecessary and could be hazardous for people living near them.

Delano resident Lupe Martinez, assistant director with the Center on Race, Poverty and the Environment, said the biomass plant at the southern edge of his city left an acrid-smelling fog or cloud late at night or early in the morning some days.

In the 25 years the biomass plant was operating, Martinez said, the health effects weren't clear.

"I ask myself if there would be such a high level of health problems if it wasn't here," he said. "How many more asthma cases and respiratory problems do we have in

the areas that are most severely hit by drought and bark beetle infestation. Thousands more have been felled by Caltrans, electric utilities and other state and local agencies.

Trees are being cut down strategically based on their potential to create a problem, such as being along roadways or in danger of hitting utility lines or falling on homes, said Kim Carr, Cal Fire's assistant deputy director for Climate and Energy, who also sits on the state's [Tree Mortality](#) Task Force.

"There are thousands of acres of dead and dying trees, and there aren't the resources to cut all of them," she said.

It's going to get worse before it gets better, said Len Nielson, Cal Fire's forester in the Madera-Merced-Mariposa Unit.

"It's a curve that is getting steeper and steeper," he said. "At some point we are going to run out of trees and bugs, and the increase will taper off."

In more than 100 years of recordkeeping, California's forests have never had this level of tree mortality, said Sheri Smith, regional entomologist for the U.S. Forest Service.

CONTRACT EXPIRING

Minutes south of Fresno, [Rio Bravo](#) plant officials in Malaga are getting wood chips from the forest, said plant manager Rick Spurlock. The plant sells 24-plus megawatts daily generated from agricultural and forest wood waste, powering an equivalent of 24,000 homes. But the higher rate it's been receiving to produce electricity for Pacific Gas & Electric expires at the end of October.

Rio Bravo's pricing arrangement is one of several ending this year. After that, those plants will not be cost-efficient enough to operate, and so there will be fewer options for disposing of agricultural and wood waste locally. Meanwhile, air pollution control officials are concerned that closing Rio Bravo will lead to more open burning or increased landfill use, and will limit options for disposing of dead and dying trees.

Even though the plant's contract with PG&E doesn't expire until March 2019, prices that allow biomass plants to operate profitably end in October, Spurlock said.

Earlier this year, the plant got a three-month price extension through PG&E and the state Public Utilities Commission. All pricing is confidential, but when the existing rate expires the new one will be less than half, estimates Malinowski Ball.

That price, Spurlock said, "does not cover what it costs us to make the power, so the plant would be forced to curtail operations."

PG&E spokesman Denny Boyles said the utility bought 92 percent of the state's biomass-produced electricity and extended the higher-priced contract for Rio Bravo and a second biomass plant in Tuolumne County to dispose of dead or dying trees.

Boyles said the higher rates "are temporary, interim solutions" to address Gov. Jerry Brown's tree mortality emergency proclamation.

"We are sensitive to local issues and job impacts," Boyles said. "We are also sensitive to price impacts to our customers. Biomass is considerably higher in price than other renewable resources."

The most recent Valley plant to close was in Delano, which was the largest and had a potential to produce 50 megawatts daily. It joined plants in Mendota, Dinuba, Terra Bella and Firebaugh in recent closures because of expired contracts.

Spurlock said Rio Bravo's shutdown will result in the loss of 25 plant jobs and a \$3.5 million annual payroll, as well as annual plant expenditures of \$2 million for maintenance and another \$5.5 million in fuel purchases, wood and agricultural waste. Overall, he said, there are about 100 employees in the plant's supply chain.

Delano because of it?"

Delano has one of the highest unemployment rates in the state and community leaders made attracting jobs a priority. But Martinez questions the cost.

"We all need jobs, but we need to do it in an environmentally friendly way," he said.

Polluting companies are often attracted to less affluent communities, Martinez said.

But despite being critical of the plant, he admits that biomass also has benefits because "I don't want the growers burning."

Others are more critical of biomass and say alternatives are available now. Composting is less polluting, whereas trucking tree waste from the mountains several times a day worsens air quality.

"They do have to clear dead trees off roads, away from power lines and structures, that's a priority, but the rest of the trees should stay in the forest and break down right there," said Tom Frantz, a Shafter farmer and leader of the Association of Irrigated Residents.

A standing dead tree that's bare of needles isn't as hazardous as a recently dead, dying or live tree with all its needles, he said.

"I don't think we increase the fire danger by leaving the dead trees except when they just die off and their needles are extremely flammable," Frantz said.

More efforts should be made to compost and put remnants back into the soil, he said. Chipping dead trees in the forest and leaving the chips on the forest floor is constructive, too, so there's no need to transport chips to produce electricity, Frantz said.

If agricultural burning should return to the Valley, Frantz said, it would only occur when environmental conditions allow it.

But Sadredin, the San Joaquin Valley Air Pollution Control District's executive director, said open burning would cause more air quality problems than emissions from biomass plants.

He said biomass plants were a major factor in the 80 percent reduction in open burning since 2005.

Sadredin endorses more use of biomass plants, even though the air district has identified some as polluters. The air district has fined Valley plant owners about \$475,000 in the past six years. The Malaga plant wasn't fined during that period. The Mendota plant was fined \$2,100 and the Delano plant was fined about \$108,000, according to air district records.

But, Sadredin added, "If we don't have a viable biomass industry or reasonable cost-effective alternatives to open burning, then we have no choice but to roll back our prohibitions against open burning."

Environmentalists, he said, believe cost-effective "non-burning" alternatives exist but aren't being used.

There are pilot programs underway, Sadredin said, that allow fuel production from agricultural waste, but none has proved to be cost-effective on a widespread basis.

One idea is composting in warehouse-size buildings with piping that would "gasify waste with little or no emissions," Sadredin said. But such a plan would take hundreds of Costco-size buildings with specialized piping to divert gases – an expensive proposition, he said.

In addition, Sadredin said, transporting waste to composting sites also produces pollutants.

The ideal scenario, Sadredin said, would be to have enough biomass available to handle both agricultural waste and dead trees from the forest.

"We have all that investment sitting idle," he said. "We need to find a way to bring those back to life rather than starting from scratch."

WOOD MORGUE

Richard Thornton expanded his tree and orchard removal business, Right-A-Way Construction, and calls it The Wood Morgue on Dinkey. But it can't stay open if Rio Bravo closes.

In a 5-acre clearing off Dinkey Creek Road behind signs for "The Fishing Club," Thornton collects bark beetle-infested trees and woody debris from Southern California Edison contractors, mountain residents and their paid contractors in the Shaver Lake area.

The wood is placed in separate piles before it is run through a massive grinder and converted into wood chips. The chips are then shipped to Rio Bravo and turned into electricity.

"If they go away, I don't know what we're going to do," Thornton said. "There's no use in chipping it; you may as well burn it."

Thornton isn't running a high-profit business because the wood has virtually no value, but the volume seems potentially endless. It costs about \$400 to transport a 25-ton load from Shaver Lake to Rio Bravo, he said.

The amount Thornton charges to chip the trees pays himself and three employees, as well as the cost of transportation to Fresno.

He is ready to open a second location near Meadow Lakes, about 25 minutes west, but would need to buy another grinder, which could cost close to \$1 million.

"I'd buy another grinder because I have the work for it, but that's only if I know I have a home for the product," Thornton said, referring to Rio Bravo.

Riley Allen, a seventh-generation logger from Auberry who takes wood to Thornton, said the Sierra needs more businesses like The Wood Morgue.

"Without grinders and what he has and without a place to take it, everyone would be up a creek," Allen said.

Richard Bagley, president of the Highway 168 Firesafe Council, said Thornton and the Rio Bravo plant are providing a valuable service to Fresno County's Sierra residents.

"Everybody benefits from that being available," Bagley said. "Right now, there would be no place for people to take their material without biomass."

HEALTH EFFECTS

Clearing out dead trees from the forests remains a great concern for many officials because of the potential for cataclysmic fires.

The [Erskine Fire](#) in Kern County last month spread quickly, in large part, because of dead dry brush, dead trees and high wind, fire officials say.

The June 23 fire took more than two weeks to contain, destroyed 250 homes and killed two people. It also led to more breathing difficulties for residents.

Making matters worse, Kern Valley Hospital was forced to close.

When the hospital was evacuated it had 69 patients in its skilled nursing facility and 10 in acute care. In addition to low water pressure, phone lines were down and most cell phone service was compromised, said Tim McGlew, chief executive officer for the Kern Valley Healthcare District.

"The fire was literally coming right at us," said McGlew. "We knew we were in trouble when we saw the way the wind was blowing."

The hospital closure left the local ambulance company scrambling and American Red Cross officials as a medical lifeline for residents struggling to breathe. Ambulances arrived from Bakersfield and shuttled patients to hospitals along with county buses.

Nine employees and a half dozen hospital volunteers were among the 250 families that lost their homes, McGlew said.

Steve Davis, chief operating officer with Liberty Ambulance in Ridgecrest, said the 911 calls were overwhelming. Many were for respiratory complaints.

A volunteer fire chief in Inyo County, Davis said he had never seen a fire like Erskine. He said it was decades in the making because of overgrowth and dead trees.

"I thought I was driving through Armageddon," he said recalling his first trip into the fire zone. "It was dark and there were 3- to 6-foot flames on either side of me."

Residents reported problems that included asthma, COPD, allergies and other breathing issues, said Jessica Piffero, regional communication director for the American Red Cross.

"Since Day One it was a problem," she said. "We got inhalers, nebulizers, anything to help the residents; it's been the old, the young, everyone has had problems because of the air quality."

As firefighters gained the upper hand on the fire, the number of breathing problems subsided. Some residents, Piffero said, left Kern Valley with plans to return when it's safe.

But even after the fire, breathing issues could persist as residents sift through debris.

"We are doing what we can to provide appropriate masks and gloves for them," Piffero said.

WATER WORRIES

Smoke and flames aren't the only hazard that massive forest fires can generate.

Steve Haugen, the Kings River watermaster, has been observing runoff from last year's massive Rough Fire in eastern Fresno County.

It could take three to five years before it's known whether water, debris and sediment running off in the area of the Rough Fire have caused problems.

He estimates that up to a quarter of the 150,000 acres scarred in the Rough Fire is a severe burn area, where the ground was basically cooked, he said, which means it will take longer for grasses and shrubs to re-grow. That means more sediment and debris will be in waterways.

"After a burn you have changed the character of the watershed and it takes quite a bit of time to heal," Haugen said.

The first winter passed without significant storms, which reduced the amount of debris going into waterways and eventually to Pine Flat Lake, where water is moved into the Kings River channel and is then diverted for drinking water and agriculture.

But if large storms come, it could drive more debris into waterways, he said.

A floating debris barrier is in place at Pine Flat Lake that limits areas for recreation. The barrier catches large chunks of debris, such as logs and limbs, before they can get to the main portion of the reservoir.

Debris can take up space that would normally be filled with water. In some cases, nearly 1 percent of reservoirs have been filled by fire debris, space that would otherwise be filled with water. At Pine Flat, that's about 8,000 acre-feet.

Fine sediment creates turbid water that also takes its toll.

It can affect water filters at treatment plants as well as in-home water filters. On farms, turbid water doesn't go into the ground as quickly, potentially affecting crop growth and water recharge, and micro-sprayers also are less effective.

"It's little things, those kinds of things you really can't put your finger on," Haugen said. "It's small, incremental change, but every one of them has a cost."

BILLS AND HEARINGS

The crisis has the attention of lawmakers. Rep. Jim Costa, D-Fresno, held a hearing in Clovis in June to discuss tree mortality and followed up with a trip to the Sierra.

He said he plans congressional hearings in September to further explore tree mortality issues and to develop a federal disaster declaration for the Sierra, which could bring aid to residents.

Biomass, he said, can help clear the forests.

"I'm suggesting that on a short-term basis this could involve a subsidy and utilize this resource to get dead trees out of the forest," Costa said. "In the meantime we need to keep our fingers crossed that we don't have a repeat of the Rim or the Rough fires."

Rep. Tom McClintock, R-Elk Grove, said he will introduce legislation in coming weeks to propose a "categorical exclusion" exempting contractors from federal environmental rules that forbid cutting of dead trees in the most severely affected areas.

"We have environmental laws that stopped cutting with the express promise it would improve forest ecology," McClintock said.

It didn't, he said.

Historically, the forest maintained 20 to 100 trees per acre, but the California average in national forests is 266, said McClintock, whose district extends south along the spine of the Sierra into Mariposa, Madera and Fresno counties.

Those dead trees should be put to productive use, he said.

"We have more than 60 million trees available," McClintock said. "It's ludicrous that we have forests filled with dead trees and policies that keep us from removing them."

In a report issued last October, the U.S. Forest Service said that fighting wildfires comprised more than 50 percent of the agency's budget in 2014 compared with 16 percent in 1995. The forest service study expected wildfire expenses will continue growing.

Assemblyman Brian Dahle, R-Bieber, proposed spending \$70 million to keep existing biomass plants open. The benefits would be decreased potential for larger fires, fewer health effects and less money spent on fighting fires. Battling the Rough Fire last year cost more than \$100 million.

He's invited fellow legislators from across California to his Lassen County-based district to see the forest devastation and reminds them that much of their water comes from Northern California, water that can be tainted by large fires.

Dahle's bill passed but was not funded. The idea, he said, was to offset costs of keeping biomass plants open by using the state's Greenhouse Gas Reduction Funds.

"We need to come in and fill that gap, but they didn't fund it," Dahle said. "I was asking for money to keep the plants running" near areas with the most tree mortality.

The state, he said, has spent \$3 billion on fire suppression since 2008, an average of about \$400 million per year.

Assemblyman Devon Mathis, R-Visalia, said incorporating biomass into the electricity grid is common-sense policy.

"A fire is going to burn, so take the material and put it to good use in a biomass plant and generate electricity," he said.

FUTURE UNCERTAIN

Although larger biomass plants in the Valley are closing, plans are underway to build small plants in communities close to high-danger zones with California Energy Commission funds. But those plants can't accommodate the number of trees cut down or dead in the forests. The energy commission has \$15 million available for forest biomass projects.

Locally, a [2-megawatt plant is proposed in North Fork](#) and a 1-megawatt plant is proposed in Mariposa.

In the meantime, seven plants supplying 190 megawatts of electricity to the grid will go offline by the end of October because of lowered rates, said Carr, Cal Fire's assistant deputy director for Climate and Energy, who sits on the state's Tree Mortality Task Force.

Madera County Supervisor Tom Wheeler, who also is a member of the 11-county task force, said those new biomass plants will be too small to make a dent in the dead wood load. He said 100 times more wood waste is ready for biomass than the plants in North Fork or Mariposa will be able to handle when they open in 2018.

That's where the closed plants in Delano, Dinuba and Firebaugh could play a role, he said.

Wheeler points out that utility ratepayers also are taxpayers who will pay hundreds of millions of dollars to fight more dangerous fires and pay higher insurance rates because of fire destruction.

"You have no control over a fire or its costs," he said. Meanwhile, Wheeler said, "there are all these incentives for wind and solar but they cut them all out for biomass; it doesn't make sense."

The Public Utilities Commission's proposed award of biomass contracts totaling 50 megawatts isn't near enough, critics say.

Covanta's plants once produced more than 100 megawatts of electricity, 75 coming from plants in Delano and Mendota and another 38 from three plants in Northern California.

In the months before shutting down, company spokesman Regan said, the plants were getting more wood waste from farms due to the drought.

"We were seeing 50 percent more clearings just because there wasn't water," he said. "Citrus trees were being brought in like crazy. Are you going to just burn it?"

Meanwhile, dead trees are stacked on private property or left along roadsides throughout the Sierra because there's no place for them. Handmade signs that announce wood dumping is prohibited are ignored at turnouts along Highway 168 near Shaver Lake.

If all [66 million trees](#) were cut down and sent to the Dinuba plant, said Osborne, general manager of the Dinuba and Firebaugh plants, it could operate for 1,674 years.

Osborne said he is working on bid packages for the state Public Utilities Commission to produce some of the megawatt contracts at the Dinuba plant, which he said could open in two to four weeks once contracts are approved.

Said Osborne, "I'm getting a lot of calls from people who will give us the fuel because they have nowhere else to go, but I don't want to end up with wood that I can't use."

Marc Benjamin: 559-441-6166, [@bebenjamin](#)





Appendix C – 3

Biomass plant scrapped to make way for commercial development

By Bob Brownne
Oct 11, 2019



An excavator dismantles what's left of the Tracy Biomass Plant on Wednesday as Millie and Severson General Contractors clears the site at 14800 W. Schulte Road.
Bob Brownne/Tracy Press

The last remnants of the Tracy Biomass Plant are coming down this month to make way for a new commercial development along Schulte Road.

Crews from Millie and Severson General Contractors of Pleasanton have been working since the third week of August, according to site superintendent Kevin Holben, and he expects it will take two more weeks to remove the last parts of the plant and other debris from the 38-acre site.

GWF Power Systems opened the plant in 1990. The plant burned up to 160,000 tons each year of old orchard trees, nut shells, fruit pits, and urban wood waste diverted from landfills. The facility's steam turbine was capable of producing 20 megawatts of electricity, enough to power 20,000 typical homes.

The last company to operate the biomass plant, formally known as the Thermal Energy Development Partnership facility, was Greenleaf Power LLC of Sacramento. Greenleaf bought the plant in 2013 and closed it in 2015.

Back in 2017, when Greenleaf was seeking federal assistance to reopen the plant, company officials told the Tracy Press that PG&E had turned to other green power sources that were less expensive than biomass, effectively reducing the plant's share of the energy market.

Records from the San Joaquin County Assessor's office show that the property at 14800 W. Schulte Road was sold in April of this year. County public information officer Jolena Voorhis confirmed Wednesday that LBA Logistics of Irvine submitted plans to



+8

Power plant looking for spark to reopen

the county this week to build a 510,990-square-foot distribution warehouse and a 16,584-square-foot truck sales and rental facility.

Voorhis added that the site is zoned for commercial development and the new project doesn't require planning commission review. The county will do an environmental review of the site, known as an "initial study," before the project can be approved.

LBA Logistics also owns a new 490,000-square-foot warehouse just west of the former biomass site, and the company is advertising that building on its website.

Contact Bob Brownne at brownne@tracypress.com or 830-4227.



Appendix C – 4

NEWS

Oroville co-generation plant that spent about \$11 million a year in Butte County is closing

By MARY WESTON |

PUBLISHED: October 18, 2012 at 12:00 a.m. | UPDATED: April 21, 2018 at 10:37 a.m.

OROVILLE — Pacific Oroville Power, Inc. is closing and taking \$11 million a year out of the local economy.

The co-generation plant has been burning wood waste to produce electricity on South Fifth Avenue since 1984. Covanta Energy, Inc. bought the plant in 1997.

Now the plant burns primarily agricultural and forest waste, said plant manager Wayne Amer.

The plant is closing for a number of economic reasons that make electric production unprofitable, he said. Amer said state regulations contribute, but the closure cannot be pinned on one thing.

“All of the costs are too high for electric production right now,” Amer said.

The plant, with about 22 employees, has an indefinite closing date, he said.

Employees can opt to transfer to other plants that have job openings, he said. Some employees have already done that.

Amer said the plant closing will have a trickle-down effect on the economy, as POPI spent about \$11 million a year in the county.

In addition, the closure creates a problem for farmers who brought ag waste to the plant.

“You can’t burn anything in the industry,” he said.

The Butte County District Attorney’s Office has been investigating possible environmental violations at the plant for the last three years. Although the investigation is ongoing, nothing has come out of it yet.

When asked if the closure had anything to do with the District Attorney’s investigation, Amer replied that contributed, but it’s really not one thing, but many things including market-driven electricity costs.

He said no citations have been issued.

However, Butte County Supervisor Steve Lambert thinks state regulations have contributed greatly to this and other plant closures.

“If we are going to regulate these companies out of business, we need to have a solution,” Lambert said.

The area needs jobs to fuel the economy and keep more small businesses from closing, he said.

District Attorney Mike Ramsey confirmed that POPI had not been cited for anything. Ramsey said he could not elaborate at this time.

Phone calls to Covanta were not returned by deadline on Wednesday.

The plant will close when all the fuels on the site are burned, which could take until December.

Amer said Covanta will keep the property in case it wants to reopen the plant at a later time.

If reopened, the plant would have to have all new co-generation and burning equipment, he said.

The Oroville plant processes more than 500 tons of biomass wood waste materials each day, according to the Covanta website. Materials are diverted from landfills and used as a fuel.

The plant also receives about 70,000 dry tons per year of agricultural green waste that helps the facility produce enough clean, renewable energy on a daily basis to generate approximately 16.5 MW of electricity, which is enough to power 16,500 homes, according to the website.

PG&E agreed to pay more for the plant's electricity in exchange for higher operating standards.

Staff writer Mary Weston can be reached at 533-4415 or mweston@orovillemr.com.



Mary Weston



Appendix C – 5



Sep 30, 2018
by Sonal Patel

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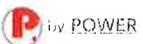
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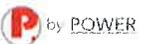
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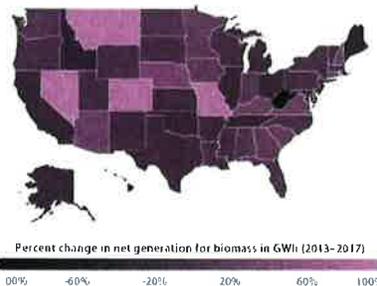
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U.S. Biomass Power, Dampened by Market Forces, Fights to Stay Ablaze

Though experts say biomass should continue to play a key role in the U.S. renewable power portfolio for its baseload properties, contributions to forest management, and other reasons, a swathe of uneconomic biomass power plants across the U.S.—especially in the West—have been recently idled or shut down.

While the larger conversation about plant economics and mass retirements in the U.S. has been focused on coal and nuclear power plants, the nation's much smaller biomass power industry is grappling with similar issues in markets where cheap natural gas, wind, and solar generation resources are proliferating.

According to the Energy Information Administration (EIA), the number of biomass (or biopower) plants producing electricity from combustion, co-firing, gasification, anaerobic digestion, and pyrolysis, nearly doubled between 2003 and 2016 (from 485 to 760). Yet, biomass power accounted for only 1.6% of net U.S. electricity generation in 2017, producing 64,057 GWh. Production has fluctuated slightly—and varied widely by region (Figure 1)—since 2013, when the industry produced 60,858 GWh.



1. *Going dark* The 10 states that produced the most net biomass generation in 2017 were: California (5,911 GWh); Florida (4,941 GWh); Georgia (4,917 GWh); Virginia (4,035 GWh); Alabama (3,377 GWh); Maine (2,930 GWh); Louisiana (2,796 GWh); South Carolina (2,687 GWh); North Carolina (2,633 GWh); and Michigan (2,578 GWh). Over the past five years, Virginia's net biomass generation surged 39%; Georgia's, 29%; South Carolina's, 21%; Alabama's, 17%; and Florida's, 11%. But California's net biomass generation shrank 11%; Maine's, 24%; and Michigan's, 5%. Fourteen other states saw decreases, including Idaho (29%); Illinois (19%); and Texas (10%). Source: EIA/POWER

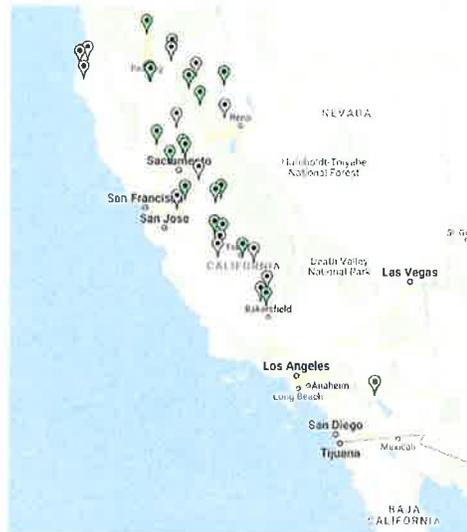
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WIND

The predicament is most apparent in California, where, despite a flurry of measures to prop up biopower, net biomass generation has shrunk by 11% since 2013. While nearly 530 MW is online in the state, about 200 MW remains idled. These include sizable projects like the 48-MW Covanta Delano plant and the 25-MW Covanta Mendota plant. About 100 MW is ready to come online as needed within 30 to 90 days, Julee Malinowski-Ball, executive director of the California Biomass Energy Alliance (CBEA), told *POWER* in September.



According to the California Biomass Energy Alliance (CBEA), half the nation's biomass industry calls California home. But of 34 operating solid fuel biomass power plants located in the state's 19 counties, nearly 530 MW is online and about 200 MW remains idled. Source: <http://www.calbiomass.org/facilities-map/>

The situation facing biomass projects in California—a state that just pledged to produce 100% of its power from renewables by 2045—was mostly price-related, she noted. “[O]ur Renewable Portfolio Standard [RPS] is designed generally, for the most part, to be technology neutral under the guise of ‘least-cost, best-fit,’ but no utilities are procuring renewables based on that combined assessment,” she said. “They’re just buying the cheapest renewable out there and that isn’t your baseload renewable resources like biomass and geothermal.”

No specific resource is available to pinpoint just how many biomass facilities have been idled or are financially flailing, but recent announcements are telling. Among facilities showing distress in the face of cheap gas is the 2013-opened 102.5-MW Gainesville Renewable Energy Center in Florida, whose merchant energy owners in November 2017 sold the facility to Gainesville Regional Utilities (GRU), which had a power purchase agreement (PPA) with the facility, in a \$754 million deal. In Virginia, where Dominion Energy converted a handful of coal-fired power plants to biomass over the past five years, three 51-MW units—Altavista, Hopewell, and Southhampton—“make economic sense to run because with cheaper fuel, tax credits, and renewable energy credits, these are very competitive,” and are actually bid into the PJM market as baseload units, a spokesperson told *POWER* in May.

Dominion, however, in August placed its 1994-completed 83-MW Pittsylvania Power Station into cold operation because it no longer receives tax credits and is not as competitive. The project could be retired in 2021, the company said. After the Minnesota

55-MW Benson power plant in Minnesota (Figure 2), whose power it was obligated to buy under a PPA. The company also moved to terminate PPAs for 35 MW of biomass in Hibbing and Virginia, Minnesota.



2. Wasted energy. The 55-MW Benson Power biomass facility in Benson, Minnesota, opened in 2007, burning a mix of poultry litter and wood to produce electricity. Xcel Energy recently bought the plant to shutter it, effectively terminating a power purchase agreement that ensured Benson's operation through September 2028. Xcel said biomass power at the power is about seven times more expensive than wind energy. *Courtesy: Xcel Energy*

According to consulting firm Innovative Natural Resource Solutions, biomass plants in the Northeast have also been particularly hard-hit because prices for natural gas and heating oil are at recent lows—"and there is no reason to think this will change in any meaningful way."

Roiled by Policy Conflicts

Some states have implemented measures to stem the financial bleed, the firm noted. Maine's legislature, for example, in 2016 passed a bill to provide nearly \$14 million in above-market payments to sustain biomass operations at its six standalone plants, and the state's Public Utilities Commission (PUC) in April 2018 also voted to approve a portion of a subsidy meant to keep two stranded wood-to-energy power plants owned by Stored Solar LLC alive.

In New Hampshire, the Legislature on September 13, 2018, narrowly voted to override Gov. Chris Sununu's June 2018 veto of Senate Bill 365, which requires electric utilities to buy power from six of the state's independent but loss-making biomass power plants for three years. The projects consume more than 40% of all low-grade timber harvested in the state each year, and the veto prompted at least three biomass power companies to stop buying wood chips from local suppliers and switch their plants to reserve status.

In Connecticut, the future looks murkier for Greenleaf Power's 37.5-MW Plainfield Renewable Energy facility, which was completed in 2013 as a result of a state-sponsored procurement for baseload Class I renewable energy through the Project 150 program, after the state in March released its Comprehensive Energy Strategy, which plainly supports development of "zero-carbon" resources and aims to phase out biomass and landfill gas renewable energy credits (RECs). Meanwhile, ReEnergy in

act to renew its eligibility to sell RECs.



Map of U.S. biomass power facilities (March 2017). The facilities indicated on this map use wood and other byproducts to generate power for sale on electric grids. Source: Biomass Power Association (www.usabiomass.org)

An Environmental Pushback

Making matters worse, the biomass power industry is also fighting to thwart an environmental group campaign that contests the carbon neutrality of wood-burning plants. Activist opposition kicked up following the release of a widely cited and highly controversial Manomet study in 2010—which found burning forest trees for power can release more carbon dioxide into the atmosphere per unit of energy than oil, coal, or natural gas—and Massachusetts in 2012 issued rules limiting RECs to only biomass plants that adhere to climate standards and consider forest impacts.

However, this April, the U.S. Environmental Protection Agency (EPA) stepped into the debate, declaring it would treat biomass from managed forests as carbon neutral when used for energy production stationary sources. Meanwhile, the apparent demise of the EPA's Clean Power Plan—which prompted biomass co-firing (with coal) or standalone plants in "wood-basket" states like Arizona, Oregon, Washington, Minnesota, and others—may not turn out so badly for the industry. While the proposed Affordable Clean Energy rule does not prescribe biomass fuels as a best system of emission reduction—"because too few individual sources will be able to employ that measure in a cost-reasonable manner"—the EPA solicited comments on use of both forest and non-forest biomass as a compliance option.

Another consideration with implications for biomass economics is that some plants, especially if used for combustion or co-firing, must also abide by federal and state pollution rules, which sometimes require expensive upgrades. As Malinowski-Ball noted, California industry has already installed multimillion-dollar pollution equipment or "is open" to upgrading emissions control equipment—but only if long-term contracts are an option. "If a facility just gets a three-year contract, no bank is going to say, 'here's all this extra money to put in an electrostatic precipitator,'" she said. The industry is addressing that with policymakers, touting biomass' bigger environmental benefits, such as for forest management.

Managing Feedstock Availability

Another issue forcing plants to pare down power production—and even idle, or shut down—is a volatility in feedstock availability and pricing. As Eric Kingsley, a partner at Innovative Natural Resource Solutions, noted, wood fuel isn't like other energy commodities, which means it doesn't have the benefit of a transparent, real-time price discovery system. Suppliers range in size and credit-worthiness. But though prices often fluctuate,

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However, as with other fuels, biomass availability can be impacted by weather and seasonality, he noted. Biomass is also a low-value forest product, which means that because it generates little revenue for landowners: "Nobody is trying to grow biomass, and nobody wants a biomass-only harvest," he said. Kingsley also pointed out that the industry must deal with transportation costs, including current constraints in trucking capacity. Yet, securing a stable supply isn't impossible "with thoughtful planning and simple risk mitigation," he said.

A New Purpose: Wildfire Mitigation

In California, at least, the biomass industry is taking a novel approach to address its threatened viability. "We're never going to be 'least-cost,' and utilities never actually take a look at 'best-fit.' And when we look at the RPS, we know under this scenario no utility is ever going to procure more biomass," she said. "But we know biomass has benefits far beyond the renewable electrons." Biomass power, for example, has a tremendous potential to help manage forests, she said, noting that California, along with several Western states, is battling more frequent and increasingly devastating wildfires, and the state is pushing hard to address the issue proactively.

Gov. Jerry Brown issued a "Tree Mortality" proclamation in 2015, and in 2016, he signed SB 859. The measures direct the state's three investor-owned utilities to enter into five-year contracts (under the BioRAM program) to get a total of 146 MW from biomass facilities that source fuel from forest materials removed from specific high-fire-hazard zones. As of 2017, the utilities exceeded the required procurement: Pacific Gas and Electric held 63 MW; Southern California Edison, 66 MW; and San Diego Gas and Electric, 24 MW. And this August, state lawmakers passed SB 901, a bill that allows utilities to use customer payments to help underwrite the cost of wildfire liability as well as to extend BioRAM contracts by five years.

However, that measure, too, has critics. California Public Utilities Commission President Michael Picker in an [August opinion penned for CAL matters](#) said that many biomass plants "are not well-suited to use fuel from high-risk fire areas since it is difficult to deliver sufficient fuel without incurring prohibitive costs, even if electric customers pay a premium for energy." Increasing biomass would also necessitate building new lines to transmit power to customers, which could be costly. Meanwhile, public agencies have become the major supplier of wood as the California timber industry has shrunk, and most have limited budgets to log and remove dead trees, he noted.

'Disruptors' on the Horizon

For now, the biomass (and biogas) power industry is also counting on the proliferation of distributed generation. "There's a large opportunity for biomass to contribute to a 100% renewable future, and it lends itself extremely well to distributed power generation at industrial/agricultural sites, especially on a microgrid basis combined with other renewables. I expect this approach to be a significant path forward in California. Concentric Power is actively working on several such projects now," Brian Curtis, CEO and founder of Concentric Power, told POWER in September.



renewable electricity in the Renewable Fuel Standard (RFS). Congress created the standard in 2005 and expanded it in 2007 to approve participation of electricity produced by certain types of biomass, biogas, and the biogenic portion of municipal solid waste. But, as 111 biomass and biogas entities pointed out in a strongly worded letter sent to the agency on September 6, 2018, the EPA has been dragging its feet for four years on processing applications from power producers seeking renewable identification numbers, which are credits used for compliance and are the “currency” of the RFS program. If permitted to participate in the program, the baseload power-delivering entities, which lamented they have been “left behind by federal policies favoring other technologies at our expense,” would be classified in the cellulosic fuel (D3) category, where the EPA has fallen short of targets.

“Some of us generate power using methane from landfills, digesters and waste treatment plants; others utilize forest residues and other biogenic fuels, including the biogenic portion of municipal solid waste (MSW), that are combusted to make renewable electricity,” the letter says. “By whatever mechanism biomass and biogas electricity is produced, when our energy is used as transportation fuel, it qualifies as an RFS fuel, and we are entitled, by law, to participate in the RFS program.” ■

—*Sonal Patel* is a *POWER* associate editor.

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Experts ponder future of biomass industry

One diagnosis of the state of the U.S. biomass power industry would be: schizophrenic disorder marked by disorganized thinking and lack of motivation. Another might call the patient deeply affected by external issues such as social reform, environmental protection, and regulations on electricity generation.

Whatever your preference, our biomass industry report begins in California, where biomass power generation rocketed to prominence in the 1980s, reached a peak of 7,362 GWh in 1992, and then fell and flatlined at around 6,000 GWh annually for the next decade. The final chapter of the story differs considerably from region to region.

Before resuming the tale in California, let's be clear about our definitions. The biomass plants discussed in this article generate electricity by burning wood wastes (see "What is biomass?") from various sources in a boiler. The steam generated drives a conventional steam turbine and generator (see "Biomass technology is familiar").

To narrow our focus, we'll consider only that segment of the biomass industry that generates electricity and sells it to municipal or investor-owned utilities (IOUs), which then put the

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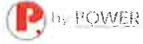
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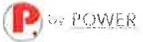
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SOLO WHOLESALE

What is biomass?

Biomass is essentially wood waste, in its various forms. The three main categories of biomass are agricultural waste materials, forestry waste materials, and urban wood waste.

Agricultural waste materials include pits, shells, hulls, stalks, orchard and grape prunings, and orchard removals. Forestry waste materials include bark, sawdust, log yard cleanup materials, sander dust, slash piles, and forest thinning material. Urban wood waste includes pallets, dunnage, manufacturing scraps, construction waste, green waste, and waste paper that can't be recycled.

All of these sources are considered "open-loop" biomass fuels. There is also a category of "closed-loop" biomass, comprising material grown specifically for combustion in a biomass facility. Among these materials are hybrid poplar, eucalyptus, and switchgrass.

Biomass technology is familiar

The boilers used to convert the latent heat of biomass to steam are either stoker-grate units (with rotating, traveling, or shaker grates) or bubbling or circulating fluidized-bed units. The boilers typically feed a conventional steam turbine-generator, with controlled extractions for process steam and/or feedwater heating. The average biomass plant has a capacity of about 20 MW, and its size is constrained by fuel-gathering issues. A few plants are substantially larger.

Because biomass is a high-moisture, low-Btu fuel, plant efficiency is limited. Popular steam cycles (with low flame temperatures) run at about 900 psig and 900F. No plant in the U.S. operates at higher than 1,500 psig. NO_x emissions are typically limited by a selective noncatalytic reduction system, with either an electrostatic precipitator or baghouse reducing particulate emissions. Some fluidized-bed plants use limestone injection to control their SO₂ emissions.

Sliding into the Pacific?

There are about 80 biomass power plants of significant size in the U.S., and they have a combined capacity of about 1,700 MW. Most run in baseload mode. As of March of this year, California was home to 28 of these plants, with a cumulative rating of around 550 MW. The remainder are scattered across 15 other states. Maine, Michigan, and Florida together have about 30% of the industry's total installed capacity.



1. Two-decade track record. The 49.5-MW Wheelabrator Shasta Energy Co. power plant has been in commercial service for almost 20 years. It burns about 750,000 tons/year of mill waste and forest residues from Shasta County and surrounding areas. The plant uses three Zurn traveling-grate stoker boilers, three Elliott condensing turbines, and one small GE back-pressure turbine. Its entire output is bought by Pacific Gas and Electric Co. Courtesy: Wheelabrator Technologies Inc.

That's the good news. The bad news is that California seems to be lagging other states in building new biomass plants and keeping existing ones in business. Some industry pundits even think that biomass in the Golden State is in danger of falling off the generation radar screen over the next decade. The last two biomass plants commissioned in California were a 4-MW facility (in 2001) and a 3-MW unit (in 1999). About 90% of the biomass plants in California were built in the 1980s. This situation is completely unexpected for a state that considers itself a pioneer in carbon controls, the use of renewable fuels, and penalizing coal-fired generation.

How did California go from being the front-runner to an almost has-been in the biomass power race? Are there lessons learned for developers and regulators? The answer begins with a short history lesson.

Green power is born

In 1978, Congress passed the Public Utility Regulatory Policies Act (Purpa) in an effort to diversify and strengthen domestic energy production. Soon afterward, California instituted policies to aggressively implement Purpa and stimulate development of renewable energy sources.

Recall that the late 1970s were marked by such high inflation and energy scarcity that experts were projecting a rise in the price of crude oil to \$100 a barrel or more by the mid-1980s. In response to that environment, California required its three regulated IOUs to offer long-term power-purchase agreements (PPAs) to qualified facilities at very attractive prices for both demand and energy. Some of the PPAs had terms as long as 30 years and an initial 10-year period during which the energy prices were fixed. These lucrative contracts were instrumental in kick-starting California's biomass power industry.

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2. Waste? Not. Using urban wood waste as power plant fuel decreases the amount of waste that must be landfilled. Should developers be given economic credit for processing these waste streams? Courtesy: Colmac Energy Inc.

Biomass power emerges

The first small biomass plants in California began producing electricity in 1982. By the end of the decade, the state's wood-fired generation infrastructure had grown considerably.

Most of California's early biomass plants burned sawmill residues exclusively. But as more plants were constructed and the number of operating sawmills declined during the 1980s, biomass facilities learned the value of fuel diversity. Forest thinnings, agricultural by-products and residues, orchard removals, and urban wood waste began ending up in boilers. So did urban and construction waste, discarded "raw" furniture, waste from wood product manufacturing, broken pallets and trusses, landscape and right-of-way trimmings, and dunnage. Only demolition wood waste was ruled out because of the perceived hazards of burning painted or treated wood.

By the late 1980s, California's biomass industry was consuming over 7 million tons of organic waste annually—about 25% of the volume being sent to the state's landfills. Turning biomass into electricity became an integral part of the state's management of forest, agricultural, and other wastes. By the early 1990s, 49 biomass plants were supplying over 800 MW of reliable baseload generation to the state's grid. In California, biomass power was in its heyday.

The climate changes

Over the next 15 years, three events conspired to slowly undermine the foundation of California's biomass power industry. The grim oil price projections that followed the Arab oil embargo and energy crisis of 1973 proved very wrong. And energy payments to the early biomass plants dried up as their PPAs' initial fixed-price period expired.

The size of the payments was based on exaggerated projections of utilities' avoided costs, which in turn assumed rapidly increasing energy costs. But the utilities' actual avoided costs turned out to be significantly lower. In many cases, the revised energy payments were too small to support the continued operation of a biomass plant. Yet by the end of the 1990s, there were still 38 biomass plants on-line in California.

The third event that further eroded the state's biomass industry was the California electricity crisis of 2000–2001. In their quest for lower-priced supplies, the state's utilities bought out one-fourth of existing biomass-fueled electricity production contracts.

Spiking wholesale prices opened the door of opportunity for a short while, as did a short-lived \$10/ton state subsidy for

100 MW of capacity were restarted, but between 2000 and 2005, ten more California biomass plants shut down for good, leaving the 28 plants and 550 MW of capacity mentioned at the top.



3. Grating wood. The boiler at Hampton Affiliates' 7-MW biomass plant in Darrington, Wash., is equipped with a Wellons stoker-fired rotating grate system and produces 140,000 lb/hr of steam. The plant entered operation in 2006. Courtesy: Wellons Inc.

Biomass improved air-quality in California

In the Central and Southern Valleys (the Sacramento, San Joaquin, Coachella, and Imperial Valleys) of California, the traditional way to dispose of agricultural (ag) residues is to burn them in open fields. Among the residues burned in this way are orchard prunings and removals, vineyard prunings, and rice crop wastes. As more biomass plants were built in California, there was less open burning of ag waste in rural agricultural areas. This was good for the environment, because the plants that began burning the waste did so in highly controlled boilers equipped with pollution controls. In some areas, air pollution emissions fell by over 95%.

Just as California biomass plants were shutting down in the late 1990s for economic reasons, the state Legislature recognized the positive impact of the biomass plants on air quality. It put in place a \$10/ton subsidy that was paid to plants that collected and used as fuel ag wastes that otherwise would have been burned out in the open.

Many of the plants used the subsidy to purchase collection and chipping equipment, or to hire third-party suppliers to collect additional wastes. The result was a significant upswing in ag residues in late 2000 and early 2001. Hundreds of thousands of tons of additional ag waste were collected and used for plant fuel, with attendant reduction in air pollution from open burns.

But in mid-2001, the Legislature pulled the plug on the subsidy. That left many of the biomass plants with equipment that had to be paid off, or with contracts that had to be honored or bought out.

The net effect of the ag fuel subsidy was the shuttering of a substantial number of California biomass plants. Subsequently, widespread open burning resumed.

Another subsidy, another dead end

lobbying by the state industry's trade association—the California Biomass Energy Alliance (CBEA)—the legislature and regulators in Sacramento slowly came to recognize that biomass power plants benefit the agriculture, forestry, and solid waste sectors, too.

Between 2002 and 2006, customers of California IOUs paid a small fee on their electric bills called the "Public Goods Charge." The California Energy Commission (CEC) was charged with distributing the funds to promote and support various aspects of the state's renewable energy industry. Some of these funds were given to owners of biomass power plants as a subsidy of up to 1.5¢/kWh for power produced during the first five years of the program.

The CEC realized that during "off-peak" hours, the biomass plants would probably shut down or curtail their output because the subsidy wasn't sufficient to cover their marginal production costs. But it also recognized the benefits of having the biomass plants running full-time. By consuming as much waste wood as possible, less would be injected into the state's conventional waste processing and disposal streams. This was a laudable objective, and it was achieved to some extent.

However, the California PTC expired on December 31, 2006, and the CEC has not determined if, or at what level, it will be reinstated. Yet collection of the Public Goods Charge from ratepayers will continue to the end of 2011. This uncertainty is of great concern to the California biomass power industry, and clouds its future outlook substantially.

Race to the bottom

Yet another state regulatory mandate hasn't benefited the biomass power industry nearly as much as the PTC or the agricultural waste subsidy. On January 1, 2003, California's Renewable Portfolio Standard (RPS) law went into effect. It requires the state's regulated IOUs to get 20% of their retail supplies from renewable sources by 2017. In 2006, the deadline for meeting this requirement was advanced to 2010.

Unfortunately for biomass, the RPS does not distinguish renewable fuel-fired capacity by technology or deliverability. But in the free-market competition among renewables, low price will always win. So against wind farms, whose fuel is free and which are subsidized by a large federal PTC of 1.8¢/kWh, biomass plants don't fare well.

Although more than a dozen new contracts have so far been signed with biomass plants during the RPS era, only one new project has broken ground, and it was not due to the RPS. What's more, no idled plants have been restarted.



circulating fluidized-bed boilers drive a single ABB turbine-generator. The boilers are fueled largely by urban wood waste collected from various sites across southern California's Inland Empire. Some agricultural waste is used as well. The plant entered commercial service in February 1992. Courtesy: Colmac Energy Inc.

The jury is still out on the effectiveness of California's RPS process, which many consider the most complex in the nation. Most in the biomass industry believe that of the recent contracts signed as a result of winning RPS bids, most do not have terms that are attractive enough to warrant building a new plant or restarting an existing one. As mentioned, biomass projects also are disadvantaged in head-to-head competition against projects fueled by other renewable energy technologies that enjoy larger tax credits and subsidies.

A policy, but not a mandate

The latest chapter in the history of California biomass power began in late 2005, when Governor Schwarzenegger assembled a state Interagency Biomass Working Group composed of virtually every regulatory agency in his administration, including the California Public Utilities Commission (CPUC). He charged the group with identifying how to improve the state's biomass-to-energy situation. The CBEA considers this action a definite acknowledgement of the industry's societal and environmental benefits.

In April 2006, the governor issued an executive order that calls for biomass-fueled electricity production to constitute 20% of California's RPS. Because the overall RPS targets 20% of all electricity supplies, biomass would now seem set to contribute 4% of California's future electricity supply, which will require a doubling of existing capacity. In July 2006, the Working Group issued the "Bioenergy Action Plan for California" to support the executive order.

Challenges to full implementation of the executive order remain, however. An executive order issued by the governor may represent state policy, but it is not a law, regulation, or mandate. At press time, the CPUC was still trying to figure out how (and if) to implement this policy. Many oppose a biomass set-aside within the RPS. Sadly, what seemed like a watershed event for returning the California biomass industry to respectability has only made its future less certain.

Better news nationally

The experience of the biomass-to-power experience elsewhere in the U.S. during the 1990s and the first half of this decade parallels its history in California. Closures and curtailments have been the norm. But with passage by the U.S Congress of the JOBS Bill in late 2004, the climate for biomass projects seems likely to improve.

The final bill offers a PTC of 1.9¢/kWh for wind energy and geothermal energy, and 1.0¢/kWh for other resources such as solar, biomass, small irrigation power, and municipal solid waste. Companies needed to qualify or begin production by the end of 2007 and would then receive the tax credit for 10 years, except existing biomass plants, which have the credit for five years.

The bill offers a 1.0¢/kWh PTC to solar, small irrigation power, municipal solid waste, and "open-loop" biomass projects (plants

patchwork of new state incentive programs (ranging from RPS mandates to enhanced state tax credits) has revived interest in biomass-fueled power production. New projects have been proposed nationwide, from Arizona to Washington and Connecticut to Florida. Because the next generation of biomass plants will likely be more geographically diverse, the California situation—too many plants competing for the same waste fuel sources—will be less likely to repeat itself.

Two broad categories of plants are being proposed by developers, and their business models are substantially different. One model is to find an idle biomass (or coal) plant, buy it for a fraction of its original cost, retrofit it to meet state RPS requirements (low emissions and/or advanced combustion technology), and fire it back up to collect the substantial "green tag" revenues available in that locale. These projects rely on the existence of an RPS-driven green tag market, can come on-line quickly, and anticipate a quick return of capital from the market (which, it must be said, has been notoriously volatile). A variation on this theme applies to new projects in Connecticut, whose state clean energy fund subsidy stretches and levelizes the green tag value over an extended period, making conventional financing a possibility.

The second model is that of a more conventional combined heat and power (CHP) plant, typically installed on the grounds of a forest products facility. Such a plant, typically of a smaller size, would use internally generated waste wood materials for at least a portion of its fuel supply and provide turbine extraction steam for the facility's low-/medium-pressure process drying needs—and, of course, electricity to the local utility grid. The plant may or may not supply electricity to the facility, depending on the facility's usage patterns and local industrial electric rates. Such projects typically require a long-term PPA with known rates. The power sold outside the fence may or may not be bundled with green tags.

Inside the proposed IRS "netting rule"

One dark cloud that must be removed from the biomass horizon is a proposed rule by the U.S. Internal Revenue Service (IRS) that would require a biomass plant located at an industrial site and owned by the same entity to "net" the industrial plant load from the biomass plant's output. In other words, the production tax credit could be claimed on only the net amount of power produced, even if the industrial plant's electrical load is not served by the biomass plant.

Implementation of the rule would directly counter the intent of U.S. Environmental Protection Agency and Department of Energy programs to encourage development of combined heat and power facilities, which are among the most efficient and cost-effective users of biomass fuels. The USA Biomass Power Producers Alliance is lobbying both the IRS and the U.S. Congress to modify the proposed rule.

Back to the future

If all biomass projects currently under way are completed, they will add about 270 MW of installed capacity by the end of 2007. The split will be roughly 50/50 between the two business models.

about half of the biomass industry's losses over the past 15 years.

Even better news is in the offing. Late last year, Congress extended the JOBS Bill PTC's "placed in service date" deadline by one year to December 31, 2008. The extension is expected to bring about a further expansion of 100 MW or more by that date, which would increase the industry's total installed capacity by another 5%.

Some clouds remain on biomass power's horizon, however. For one, there are a limited number of idled plants that can be restarted quickly. CHP projects at forest products facilities are a niche market that will be saturated within several years. Another shortcoming of proposed biomass projects is their poor economic competitiveness in state-sanctioned RPS auctions held by utilities for new renewable capacity. To date, such projects haven't done well in these auctions, and many of those that have been winning bidders have been unable to attract financing due to a lack of a guaranteed fuel supply or a poor understanding of their costs. This situation is likely to persist as long as biomass power receives only half the federal PTC available to wind and geothermal producers. Not surprisingly, wind and geothermal facilities have dominated the open RPS solicitations to date across the U.S.

Leveling the playing field

To proliferate nationwide, biomass power plants must find a way to pay for the haulage and processing of waste materials from farms and forestry operations, instead of relying on milling residues or landfill wood diversion for their fuel. Expanding the fuel supply will not only expand the market for biomass power; it will also ratchet up the public environmental benefits of the technology.

For instance, millions of tons of agricultural residue (such as stalks and prunings) are burned openly in the U.S. each year. These could become acceptable fuels for biomass power production—if the economics can be made to work. In addition, federal agencies have identified nearly 200 million acres of federal forest and range land that are in dire need of thinning to restore forest health and reduce wildfire risk. Most of the potential billions of tons of the removed material would have no use, other than as fuel.

A biomass facility that burns fuel sources such as these would require a stronger revenue stream than it is likely to obtain from winning an all-source RPS auction. Making the federal PTC for biomass power production equal to that for wind and geothermal production would bridge much of the gap.

If only Washington were to share states' and utilities' growing recognition of biomass power's environmental benefits. Some states now give biomass supplies double credits toward RPS compliance, and some utilities have held "biomass only" RPS solicitations. The firm capacity that biomass power can provide, which is rare among renewables, is beginning to be valued more highly in some locales. The rapid ratcheting up of many RPS programs (1%/year of total utility load) will expand markets for biomass power plants, which will have additional value when—no longer if—a regional and/or national carbon cap and trade system is put in place (see sidebar "Biomass plants' negative GHG profile").

negative GHG profile

Biomass power plants use waste wood for fuel, burning it under controlled conditions to generate electricity. The use of wood waste as fuel eliminates the need to dispose of it in any of the more traditional ways. Each of the alternate disposal paths generates far greater levels of overall greenhouse gas (GHG) emissions because many of those emissions are of more potent GHGs than the CO₂ that is essentially the only GHG emitted by a biomass power plant.

Urban wood wastes have traditionally been disposed of in landfills, wasting their potential energy and using up valuable landfill space. Furthermore, the natural biodegradation of the woody wastes in landfills generates methane, a GHG that is 20 to 25 times more potent than CO₂ in terms of its contribution to global warming. Use of these wood wastes as biomass plant fuel eliminates the generation of methane and saves landfill volume for other wastes that cannot be recycled or burned.

Open burning of agricultural wastes produces copious quantities of criteria air pollutants, substantial amounts of methane, and some nitrous oxide. Leaving forest wood wastes to rot on the forest floor has the same downside as landfill disposal, and burning them produces negative effects similar to the burning of agricultural residues.

For this reason, biomass power plants have a net negative GHG profile. A study by Future Resources Associates has calculated this benefit as about one ton of net negative GHG emission per megawatt-hour of electricity generated by a biomass power plant. That's in addition to the GHG reductions achieved by the capacity of fossil-fueled generation that the biomass plant displaces.

The California Public Utilities Commission has recognized this fact. The following passage is extracted from its January 2007 decision on biomass plants' GHG emissions that implements California SB 1368, the state's GHG emissions performance standard:

In particular, the record shows that electric generation using biomass (e.g., agricultural and wood waste, landfill gas) that would otherwise be disposed of under a variety of conventional methods (such as open burning, forest accumulation, landfills, composting) results in a substantial net reduction in GHG emissions. This is because the usual disposal options for biomass wastes emit large quantities of methane gas, whereas the energy alternatives either burn the wastes that would become methane or burn the methane itself, generating CO₂. Since methane gas is on the order of twenty to twenty-five times more potent as a GHG than CO₂, and since methane has an atmospheric residence time of twelve years, after which it is converted to atmospheric CO₂, trading off methane for CO₂ emissions from energy recovery operations leads to a net reduction of the greenhouse effect.

Many of the 900 MW of proposed or studied biomass projects that we have identified would utilize these farm and forest fuels. To improve their economics, the industry must continue to educate governments about the myriad benefits of this renewable fuel. Even utilities are entering the biomass market. For example, Public Service of New Hampshire recently spent \$75 million to convert a 50-MW coal-fired power plant to burn wood. It expects to earn \$15 million a year in renewable energy credits

service in January 2007.

It has been nearly 20 years since we have been able to talk about an expanding biomass power industry in the U.S. (and Canada). Although the resurgence has largely bypassed California, in places such as the Pacific Northwest, the Upper Midwest, and New England, a strong comeback is under way, fueled by innovative state programs, the JOBS Bill's PTC, and rising fossil fuel prices. More work still needs to be done in Washington, however (see sidebar "Inside the proposed IRS "netting rule"). Substantial expansion of biomass power production beyond its traditional forest products and urban wood fuel base awaits a full PTC and more-widespread recognition of the technology's societal and environmental benefits.

—*Phil Reese is a partner of Reese-Chambers Systems Consultants Inc., an industrial permitting, air quality, and risk management consulting firm based in Somis, Calif. He also is a principal and director of Colmac Energy Inc. and chairman of the California Biomass Energy Alliance. Reese can be reached at phil@reesechambers.com. Bill Carlson is the principal of Carlson Small Power Consultants, a biomass power consulting firm based in Redding, Calif. He also is chairman of the USA Biomass Power Producers Alliance. Carlson can be reached at cspc@shasta.com.*

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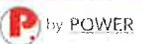
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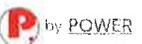
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Is Biomass Dead?

With subsidies running short and emissions regulations still a challenge, the promise of biomass as a sustainable source for utility-scale power generation remains elusive. Yet, there are novel applications keeping the industry alive.

The Covanta Biomass Plant, just south of Delano, California, was once a crown jewel for the prospect of sustainable energy in California. The 50-MW plant once employed 50 people and was all the rage during a time of hope that biomass might be a prosperous sustainable energy source.

Today, its structures are rusting and vegetation grows where it shouldn't. What was once a sprawling industrial facility, with many moving parts and people, is now a ghost town, an abandoned plant, resonating with a message that biomass power is simply not what it was hoped to be.

The plant operated from 1990 until 2015, and burned agricultural waste such as uprooted trees and pruned branches from nearby almond, peach, and nectarine orchards. But along came subsidies for energy sources such as solar, wind, and other sustainable power options, and the plant fell into demise. Other plants have taken the same route. And more will likely shut down in the near future.

Dependence on subsidies, emissions problems, and other issues, have put utility-scale biomass on the decline. The viability of biomass as a fuel is dubious, and it's not competing well with other fuel sources. For specific applications, however, biomass and other waste products, such as biomethane, may be useful.

Biomass and Waste as Fuel: Prevalent but Slowing

"By providing an alternative source of energy from a renewable domestic resource, existing biomass energy facilities diversify the nation's energy portfolio, which can help our utilities weather unexpected changes in the price or availability of other resources," said Mack McGuffey, an environment attorney and partner with Troutman Sanders LLP in Atlanta, Georgia. "However, so long as natural gas remains at historically low levels, the demand for electricity remains flat, and the controversy regarding the 'carbon-neutral' nature of biomass remains unresolved, the interest and investment in new biomass energy facilities is likely to be low."

According to the U.S. Energy Information Administration (EIA), in 2018 there were 178 biomass power generating facilities in the U.S., with a total capacity of 6,374 MW of power. The EIA says, "electricity generation from biomass and waste is a diverse collection of organic feedstocks including wood and wood waste solids, black liquor [a byproduct of making wood pulp], municipal solid waste, and landfill gas. These four feedstocks accounted for

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was very small.

Things are slowing for biomass. In the same report, the EIA says that electricity generated from biomass and waste totaled 70.6 million MWh in 2018, or about 2% of total U.S. electricity generation. "Expansion in electricity generation from biomass and waste has ended in recent years, after growing from 2004 through 2014, and in 2018 was 2% below its peak generation of 71.7 million MWh in 2014."

Behind the Downtrend of Utility-Scale Biomass Power

The expectation of biomass as a fuel source for large-scale power plants started strong about a decade or longer ago, but has struggled to show its full value. The Wall Street Journal said in 2009: "While solar power is taking root in the sunny Southwest and wind power is growing in the blustery band from the Dakotas to Texas, other places are turning to trees and grass as their best bet for producing renewable energy, leading to a new building boom in 'biomass' power plants."

Ten years later, the same newspaper reported: "An industry considered sustainable today can seem nefarious tomorrow—just look at biomass." It cited the expected returns of firms in the biomass power generation business, such as Covanta, Southern Company, Dominion Energy, and Pacific Ethanol, who entered the industry with a prosperous return on investment, but after a decade, such returns are lost. Much has to do with the emissions of biomass combustion.

"Though one can never completely separate the regulatory from the economics in power, the economics by themselves are challenging for biomass," said Penn Cox, who held top leadership posts at Ferrovial and Rollcast Energy, a biomass development company that developed several projects. "Assuming good waste wood procurement, a new plant in the Southeast will have a fuel cost of about \$25 per MWh. That is fuel alone—it doesn't include O&M [operation and maintenance] costs, debt service, return to investors, et cetera. Older plants and plants in the Northeast or Upper Midwest will have higher prices. That compares quite favorably to coal, depending on the source and transportation costs, but is not very competitive with GTCC [gas turbine combined cycle], which would be around \$20 per MWh and has lower O&M and capital costs. Recently, solar developers are bidding into RFPs [requests for proposals] for utility-scale solar with leveled, all-in prices of less than \$30 per MWh, so times are tough for thermal power, especially solid fuel. Biomass is not alone."

Cox illustrated the tough times for biomass by looking at the state of New Hampshire. Its six biomass plants have been around since the 1980s, "but have struggled to remain operational over the last several years," explained Cox. "The legislature passed a bill earlier this year that would require utilities in the state to purchase a certain amount of biomass power to support the plants."

Specifically, New Hampshire House Bill 183 would have created one "Baseload Renewable Generation Credit" for each net MWh of production from eligible facilities. The state's electric distribution companies would have been required to purchase all the credits offered and produced by the plants located in their service territories. "The bill was ultimately vetoed by the governor," said Penn Cox. An attempt to override the veto came up four votes short.



sold its generation under a power purchase agreement (PPA) with Austin Energy. "It opened in 2012 and is the largest biomass facility in the U.S., so it is very efficient and is in a very attractive wood basket," explained Cox. "Unfortunately, because of low gas prices, and cheap wind and solar, the plant rarely dispatched in the ERCOT [Electric Reliability Council of Texas] market. Even though the plant did not dispatch, the terms of the PPA required Austin Energy to make capacity and O&M payments that would essentially keep the owner whole. Austin Energy recently purchased the plant from Southern to avoid continuing to pay out on the PPA."

Biomass and Waste Still Viable and Promising in Some Applications

Slow expansion, however, does not mean it, or other fuel sources like it, are dead and gone. Opportunity exists, not just in biomass, but also as the EIA statistics point out, with waste products.



1. Using innovative technology, Ameresco processes raw biogas generated at the 91st Avenue Wastewater Treatment Plant in Phoenix, Arizona, into renewable natural gas suitable for injection into the nation's high-pressure natural gas pipeline. Courtesy: Ameresco

Ameresco's 91st Avenue Wastewater Treatment Plant (Figure 1) in Phoenix, Arizona, is purifying organic waste materials into biomethane, or renewable natural gas (RNG). The RNG is then used as a fuel source for renewable electric power generation.

RNG is an ultra-clean and ultra-low-carbon natural gas alternative. As organic waste breaks down, it emits methane gas that would otherwise be released into the atmosphere. Now, it may be purified and used as an alternative renewable energy source.

"A significant amount of power is produced by biomethane power generation," explained Michael T. Bakas, executive vice president, Distributed Energy Systems, with Framingham, Massachusetts-based Ameresco. The firm partnered with the City of Phoenix to establish the biomethane plant. "Biomethane that is used at power plants makes up 20% to 25% of the biomethane in North America. The RNG generated at the 91st Avenue Wastewater Treatment Plant was a wasted resource that represented an opportunity for the City of Phoenix to not only make a powerful statement about its commitment to the environment and sustainability, but to also reap significant financial benefits," said Bakas.

In other applications, biomass as an energy source may help solve two challenges: it mitigates environmental problems and can be burned with very low oxygen to produce biochar. Farmers use biochar to enhance and improve soil quality. Furthermore, the biochar captures carbon and is a promising source of carbon sequestration.

wire), supplies nearly half the nation's fresh water, and its full of serene green water hyacinths with pretty lavender-colored blooms. In spite of such beauty, the plants are a menacing vegetation and a dangerous weed.

"It deprives fish and plants of nutrients and poisons the atmosphere with methane," said Olivia Thierley of the German-based Char2Cool, operating in Ethiopia. "It brings hydroelectric plants and the drinking water supply to a halt."



2. Water hyacinth is a big problem at Lake Tana in Ethiopia. However, the invasive vegetation can be harvested and biochar made through pyrolysis, which is the thermal decomposition, in a limited-oxygen environment, of biomass into a carbon-rich solid residue (char), gases, and liquids. Courtesy: Char2Cool

Char2Cool has found a solution. It uses large waterborne machinery to harvest the water hyacinths (Figure 2) and turn the unwanted vegetation into treasure: biochar. By cultivating the biomass, it's producing a CO₂-negative fuel. "Now, it becomes a major opportunity," Thierley said.

Opportunity Remains

If, as baseball legend Yogi Berra said, "It ain't over, 'til it's over," then biomass still remains as a workable fuel source for sustainable power in many ways. It remains as a fuel source and biomass plants still operate. In order for it to regain a second wind, though, it will need to continually overcome challenges.

"From an environmental perspective, biomass energy faces greater challenges than other renewable resources due to the ongoing controversy surrounding the question of whether CO₂ emitted from combusting biomass is—or always is—'carbon neutral,'" said McGuffey. "[The U.S. Environmental Protection Agency] has made several attempts to craft a policy regarding the carbon-neutral nature of biomass without success, but a new proposal is expected in March 2020. Despite these challenges, several companies remain active in biomass energy, and there are many utility-scale biomass energy facilities in operation throughout the U.S."

While the biomass bonanza from plants like Covanta's in California may be dead, byproducts such as biomethane, and other applications such as the utilization of biomass vegetation to create biochar—as in the harvest of water hyacinths from Lake Tana in Ethiopia—do show promise in more selective operations. It is also used for smaller-scale, off-grid applications, such as a farm in Canada that cultivates willow trees and growth around a wetlands area, converting it into a fuel to be used for farm property use.

and tomorrow. As the futurist, Buckminster Fuller, who lived nearly nine decades and saw America expand from an agricultural to an Industrial nation, said, "Pollution is nothing but resources we're not harvesting. We allow them to disperse because we've been ignorant of their value." ■

—Jim Romeo (www.JimRomeo.net) is a technology writer and speaker.

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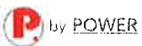
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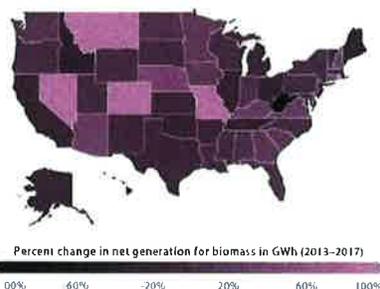
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U.S. Biomass Power, Dampened by Market Forces, Fights to Stay Ablaze

Though experts say biomass should continue to play a key role in the U.S. renewable power portfolio for its baseload properties, contributions to forest management, and other reasons, a swathe of uneconomic biomass power plants across the U.S.—especially in the West—have been recently idled or shut down.

While the larger conversation about plant economics and mass retirements in the U.S. has been focused on coal and nuclear power plants, the nation's much smaller biomass power industry is grappling with similar issues in markets where cheap natural gas, wind, and solar generation resources are proliferating.

According to the Energy Information Administration (EIA), the number of biomass (or biopower) plants producing electricity from combustion, co-firing, gasification, anaerobic digestion, and pyrolysis, nearly doubled between 2003 and 2016 (from 485 to 760). Yet, biomass power accounted for only 1.6% of net U.S. electricity generation in 2017, producing 64,057 GWh. Production has fluctuated slightly—and varied widely by region (Figure 1)—since 2013, when the industry produced 60,858 GWh.



1. *Going dark* The 10 states that produced the most net biomass generation in 2017 were: California (5,911 GWh); Florida (4,941 GWh); Georgia (4,917 GWh); Virginia (4,035 GWh); Alabama (3,377 GWh); Maine (2,930 GWh); Louisiana (2,796 GWh); South Carolina (2,687 GWh); North Carolina (2,633 GWh); and Michigan (2,578 GWh). Over the past five years, Virginia's net biomass generation surged 39%; Georgia's, 29%; South Carolina's, 21%; Alabama's, 17%; and Florida's, 11%. But California's net biomass generation shrank 11%; Maine's, 24%; and Michigan's, 5%. Fourteen other states saw decreases, including Idaho (29%); Illinois (19%); and Texas (10%). Source: EIA/POWER

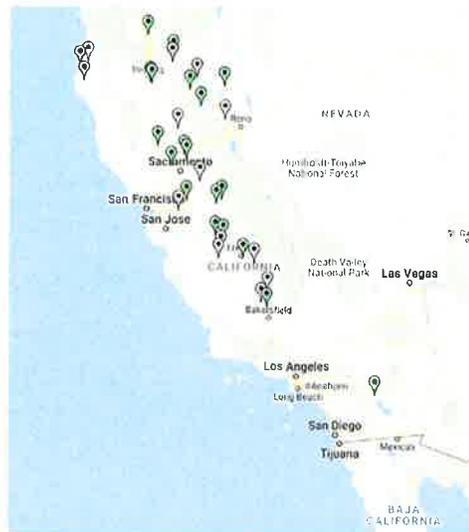
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WIND

The predicament is most apparent in California, where, despite a flurry of measures to prop up biopower, net biomass generation has shrunk by 11% since 2013. While nearly 530 MW is online in the state, about 200 MW remains idled. These include sizable projects like the 48-MW Covanta Delano plant and the 25-MW Covanta Mendota plant. About 100 MW is ready to come online as needed within 30 to 90 days, Julee Malinowski-Ball, executive director of the California Biomass Energy Alliance (CBEA), told *POWER* in September.



According to the California Biomass Energy Alliance (CBEA), half the nation's biomass industry calls California home. But of 34 operating solid fuel biomass power plants located in the state's 19 counties, nearly 530 MW is online and about 200 MW remains idled. Source: <http://www.calbiomass.org/facilities-map/>

The situation facing biomass projects in California—a state that just pledged to produce 100% of its power from renewables by 2045—was mostly price-related, she noted. “[O]ur Renewable Portfolio Standard [RPS] is designed generally, for the most part, to be technology neutral under the guise of ‘least-cost, best-fit,’ but no utilities are procuring renewables based on that combined assessment,” she said. “They’re just buying the cheapest renewable out there and that isn’t your baseload renewable resources like biomass and geothermal.”

No specific resource is available to pinpoint just how many biomass facilities have been idled or are financially flailing, but recent announcements are telling. Among facilities showing distress in the face of cheap gas is the 2013-opened 102.5-MW Gainesville Renewable Energy Center in Florida, whose merchant energy owners in November 2017 sold the facility to Gainesville Regional Utilities (GRU), which had a power purchase agreement (PPA) with the facility, in a \$754 million deal. In Virginia, where Dominion Energy converted a handful of coal-fired power plants to biomass over the past five years, three 51-MW units—Altavista, Hopewell, and Southhampton—“make economic sense to run because with cheaper fuel, tax credits, and renewable energy credits, these are very competitive,” and are actually bid into the PJM market as baseload units, a spokesperson told *POWER* in May.

Dominion, however, in August placed its 1994-completed 83-MW Pittsylvania Power Station into cold operation because it no longer receives tax credits and is not as competitive. The project could be retired in 2021, the company said. After the Minnesota

55-MW Benson power plant in Minnesota (Figure 2), whose power it was obligated to buy under a PPA. The company also moved to terminate PPAs for 35 MW of biomass in Hibbing and Virginia, Minnesota.



2. Wasted energy. The 55-MW Benson Power biomass facility in Benson, Minnesota, opened in 2007, burning a mix of poultry litter and wood to produce electricity. Xcel Energy recently bought the plant to shutter it, effectively terminating a power purchase agreement that ensured Benson's operation through September 2028. Xcel said biomass power at the power is about seven times more expensive than wind energy. *Courtesy: Xcel Energy*

According to consulting firm Innovative Natural Resource Solutions, biomass plants in the Northeast have also been particularly hard-hit because prices for natural gas and heating oil are at recent lows—"and there is no reason to think this will change in any meaningful way."

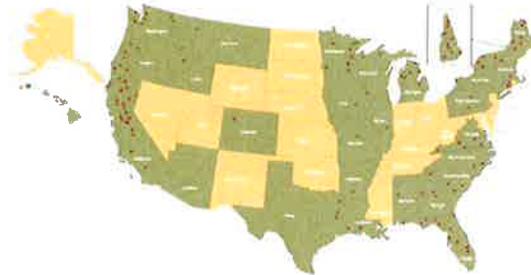
Roiled by Policy Conflicts

Some states have implemented measures to stem the financial bleed, the firm noted. Maine's legislature, for example, in 2016 passed a bill to provide nearly \$14 million in above-market payments to sustain biomass operations at its six standalone plants, and the state's Public Utilities Commission (PUC) in April 2018 also voted to approve a portion of a subsidy meant to keep two stranded wood-to-energy power plants owned by Stored Solar LLC alive.

In New Hampshire, the Legislature on September 13, 2018, narrowly voted to override Gov. Chris Sununu's June 2018 veto of Senate Bill 365, which requires electric utilities to buy power from six of the state's independent but loss-making biomass power plants for three years. The projects consume more than 40% of all low-grade timber harvested in the state each year, and the veto prompted at least three biomass power companies to stop buying wood chips from local suppliers and switch their plants to reserve status.

In Connecticut, the future looks murkier for Greenleaf Power's 37.5-MW Plainfield Renewable Energy facility, which was completed in 2013 as a result of a state-sponsored procurement for baseload Class I renewable energy through the Project 150 program, after the state in March released its Comprehensive Energy Strategy, which plainly supports development of "zero-carbon" resources and aims to phase out biomass and landfill gas renewable energy credits (RECs). Meanwhile, ReEnergy in

all to renew its eligibility to sell RECs.



Map of U.S. biomass power facilities (March 2017). The facilities indicated on this map use wood and other byproducts to generate power for sale on electric grids. Source: Biomass Power Association (www.usabiomass.org)

An Environmental Pushback

Making matters worse, the biomass power industry is also fighting to thwart an environmental group campaign that contests the carbon neutrality of wood-burning plants. Activist opposition kicked up following the release of a widely cited and highly controversial Manomet study in 2010—which found burning forest trees for power can release more carbon dioxide into the atmosphere per unit of energy than oil, coal, or natural gas—and Massachusetts in 2012 issued rules limiting RECs to only biomass plants that adhere to climate standards and consider forest impacts.

However, this April, the U.S. Environmental Protection Agency (EPA) stepped into the debate, declaring it would treat biomass from managed forests as carbon neutral when used for energy production stationary sources. Meanwhile, the apparent demise of the EPA's Clean Power Plan—which prompted biomass co-firing (with coal) or standalone plants in “wood-basket” states like Arizona, Oregon, Washington, Minnesota, and others—may not turn out so badly for the industry. While the proposed Affordable Clean Energy rule does not prescribe biomass fuels as a best system of emission reduction—“because too few individual sources will be able to employ that measure in a cost-reasonable manner”—the EPA solicited comments on use of both forest and non-forest biomass as a compliance option.

Another consideration with implications for biomass economics is that some plants, especially if used for combustion or co-firing, must also abide by federal and state pollution rules, which sometimes require expensive upgrades. As Malinowski-Ball noted, California industry has already installed multimillion-dollar pollution equipment or “is open” to upgrading emissions control equipment—but only if long-term contracts are an option. “If a facility just gets a three-year contract, no bank is going to say, ‘here’s all this extra money to put in an electrostatic precipitator,’” she said. The industry is addressing that with policymakers, touting biomass’ bigger environmental benefits, such as for forest management.

Managing Feedstock Availability

Another issue forcing plants to pare down power production—and even idle, or shut down—is a volatility in feedstock availability and pricing. As Eric Kingsley, a partner at Innovative Natural Resource Solutions, noted, wood fuel isn’t like other energy commodities, which means it doesn’t have the benefit of a transparent, real-time price discovery system. Suppliers range in size and credit-worthiness. But though prices often fluctuate, “they are remarkably stable” over time, panning out to be

[Biomass Magazine](#)

However, as with other fuels, biomass availability can be impacted by weather and seasonality, he noted. Biomass is also a low-value forest product, which means that because it generates little revenue for landowners: "Nobody is trying to grow biomass, and nobody wants a biomass-only harvest," he said. Kingsley also pointed out that the industry must deal with transportation costs, including current constraints in trucking capacity. Yet, securing a stable supply isn't impossible "with thoughtful planning and simple risk mitigation," he said.

A New Purpose: Wildfire Mitigation

In California, at least, the biomass industry is taking a novel approach to address its threatened viability. "We're never going to be 'least-cost,' and utilities never actually take a look at 'best-fit.' And when we look at the RPS, we know under this scenario no utility is ever going to procure more biomass," she said. "But we know biomass has benefits far beyond the renewable electrons." Biomass power, for example, has a tremendous potential to help manage forests, she said, noting that California, along with several Western states, is battling more frequent and increasingly devastating wildfires, and the state is pushing hard to address the issue proactively.

Gov. Jerry Brown issued a "Tree Mortality" proclamation in 2015, and in 2016, he signed SB 859. The measures direct the state's three investor-owned utilities to enter into five-year contracts (under the BioRAM program) to get a total of 146 MW from biomass facilities that source fuel from forest materials removed from specific high-fire-hazard zones. As of 2017, the utilities exceeded the required procurement: Pacific Gas and Electric held 63 MW; Southern California Edison, 66 MW; and San Diego Gas and Electric, 24 MW. And this August, state lawmakers passed SB 901, a bill that allows utilities to use customer payments to help underwrite the cost of wildfire liability as well as to extend BioRAM contracts by five years.

However, that measure, too, has critics. California Public Utilities Commission President Michael Picker in an [August opinion penned for CALmatters](#) said that many biomass plants "are not well-suited to use fuel from high-risk fire areas since it is difficult to deliver sufficient fuel without incurring prohibitive costs, even if electric customers pay a premium for energy." Increasing biomass would also necessitate building new lines to transmit power to customers, which could be costly. Meanwhile, public agencies have become the major supplier of wood as the California timber industry has shrunk, and most have limited budgets to log and remove dead trees, he noted.

'Disruptors' on the Horizon

For now, the biomass (and biogas) power industry is also counting on the proliferation of distributed generation. "There's a large opportunity for biomass to contribute to a 100% renewable future, and it lends itself extremely well to distributed power generation at industrial/agricultural sites, especially on a microgrid basis combined with other renewables. I expect this approach to be a significant path forward in California. Concentric Power is actively working on several such projects now," Brian Curtis, CEO and founder of Concentric Power, told POWER in September.

renewable electricity in the renewable fuel standard (RFS). Congress created the standard in 2005 and expanded it in 2007 to approve participation of electricity produced by certain types of biomass, biogas, and the biogenic portion of municipal solid waste. But, as 111 biomass and biogas entities pointed out in a strongly worded letter sent to the agency on September 6, 2018, the EPA has been dragging its feet for four years on processing applications from power producers seeking renewable identification numbers, which are credits used for compliance and are the “currency” of the RFS program. If permitted to participate in the program, the baseload power-delivering entities, which lamented they have been “left behind by federal policies favoring other technologies at our expense,” would be classified in the cellulosic fuel (D3) category, where the EPA has fallen short of targets.

“Some of us generate power using methane from landfills, digesters and waste treatment plants; others utilize forest residues and other biogenic fuels, including the biogenic portion of municipal solid waste (MSW), that are combusted to make renewable electricity,” the letter says. “By whatever mechanism biomass and biogas electricity is produced, when our energy is used as transportation fuel, it qualifies as an RFS fuel, and we are entitled, by law, to participate in the RFS program.” ■

—*Sonal Patel* is a POWER associate editor.

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Appendix C – 7

PG&E GAS R&D AND INNOVATION

WHITEPAPER

Biomass

9/18/2018



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Summary: Biomass

Definition: Biomass is living or recently living plants, animals or waste and is often referred to as “Biomass” or “feedstock”. Biomass is considered a renewable source of energy due to regrowth and carbon capture of plant matter, continuous production of human or animal waste, and the displacement of fossil fuels. It is by far the oldest source of energy humans have ever used, (starting a fire with wood for example), but modern techniques have made this source of energy scalable to today’s needs. Biomass is generally processed by one or several technologies into fuel or electric power and is generally broken down into the following categories:

1. Woody Biomass
2. Agricultural Residue
3. Municipal Solid Waste
4. Animal Manure
5. Wastewater
6. Landfills
7. Energy Crops

The definitional aspect of Biomass in the value chain is that it is the original source for biogas or syngas and subsequent clean fuels or gases. Generally speaking, Biomass is waste from human activity or is purposely grown and then harvested. Once collected, aggregated, and in some cases pre-processed, Biomass moves to the conversion or processing step in the low-carbon gas/fuel value chain.

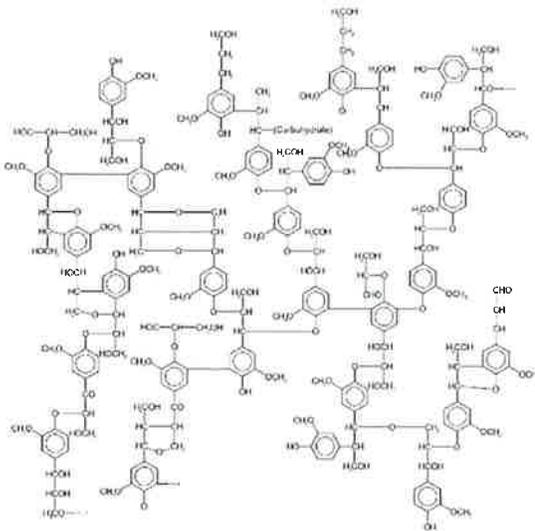


Figure 1 Lignin Polymer (Liquefied Wood, 2011)



Lignocellulosic Biomass: This is a term for Biomass that is plant-based, like trees, bushes, or grass, and also for agricultural waste like corn stover or sugarcane bagasse, forestry residues, or energy crops like switchgrass or sugarcane. It would NOT include wastes like dairy manures or wastewater. Lignocellulose is the scientific term for plant dry matter, composed primarily of Lignin, which is a rigid polymer that is found in wood and bark, and carbohydrate polymers (like cellulose).

Most Biomass can be categorized as lignocellulosic Biomass. This is important because lignocellulosic Biomass has only one effective, commercialized form of conversion into energy in the form of gas – pyrolysis (which is itself a step within gasification). *All non-lignocellulosic Biomass can be effectively converted to energy through biochemical means in an anaerobic digester.

**Note: one of the very earliest and most effective forms of energy conversion for lignocellulosic Biomass is actually fermentation through a multi-step process, involving pre-treatment and hydrolysis of the lignocellulose to release fermentable simple sugars, which produces liquid biofuels like ethanol and biodiesel (Wisconsin Biorefining Development Initiative). However, for PG&E’s purposes as a gas utility, this conversion technology is not applicable.*

More Introductory-level Resources on Biomass:

US Energy Information Administration: [Biomass Explained \(Text\)](#)

US Energy Information Administration: [Biomass and the Environment \(Text\)](#)

California Energy Commission, UC Davis: [Assessment of Biomass Resources in CA \(Report\)](#)

Quantitative Sizing of Biomass Potential

PG&E Internal Analysis (Oldham, 2017):

- **Total:** 89 bcf by 2030, 202 bcf by 2040, 205 bcf by 2050
- Animal Manure
 - Carbon intensity: -50 to -250 gCO₂/MJ (but without credits for avoided methane, 35-55)
 - Supply from dairy farms, primarily.

10 BCF (2030)	19 BCF (2040)	19 BCF (2050)
---------------	---------------	---------------

- Landfill Gas
 - Carbon intensity: 20-50gCO₂/MJ



- Most facilities already producing energy in long-term PPAs, so some of these numbers are higher than when can be added in new potential supply. They're already counted.
- Supply from Waste Management companies, landfill owners, municipalities that own landfills.

42 BCF (2030)	54 BCF (2040)	56 BCF (2050)
---------------	---------------	---------------

- Agricultural Residues:

- Carbon intensity: 20-50gCO₂/MJ

3 BCF (2030)	31 BCF (2040)	24 BCF (2050)
--------------	---------------	---------------

- MSW

- Carbon intensity: 15-35gCO₂/MJ
- Supply from Waste Management companies, municipalities that own facilities.

26 BCF (2030)	51 BCF (2040)	52 BCF (2050)
---------------	---------------	---------------

- Wastewater Treatment

- Carbon intensity: 15-35gCO₂/MJ
- Same Suppliers as Landfills.

4 BCF (2030)	4 BCF (2040)	7 BCF (2050)
--------------	--------------	--------------

- Woody Biomass

- Carbon intensity: 30-40gCO₂/MJ
- Suppliers – timber companies

4 BCF (2030)	43 BCF (2040)	47 BCF (2050)
--------------	---------------	---------------

Assessment of Biomass Resources in California (California Biomass Collaborative, University of California, Davis, 2015):

Summary: Within the resource categories considered here, total or gross estimated Biomass is 78 million bone dry tons (BDT) per year. Technical (recoverable) resource is estimated at 35 million BDT/y (see Table 1 and Figure 2 below).

Roughly 45% of the gross Biomass resource is considered to be technically available for conversion or other uses. The remainder occur in sensitive habitat areas, on steep slopes not suitable for harvesting, are needed to maintain soil tilth and fertility, or are unrecoverable by harvesting and recovery equipment (Kaffka, 2014).



- Total: 78M BDT per year
- Technically recoverable resource 35M BDT/y (roughly 45% gross Biomass resource) (about 600 trillion BTU, or 0.6 Quad)
- Total Biogas potential: 93 bcf methane/year
 - Animal Manure: 3.4MM BDT - 19.7 bcf
 - 66M Agricultural animals in CA – 5.3M cattle
 - Total manure production from animals is 11.7M BDT/y – 10.9M BDT of that is from cattle
 - Landfill Gas: 106 BCF – 53 bcf
 - MSW: 1.2MM BDT – 12.6 bcf
 - Waste Water Treatment: 11.8 BCF – 7.7 bcf
 - Woody Biomass?
 - Main categories are logging slash, mill residues, Biomass from forest thinning and stand improvement operations, chaparral.
 - Gross Forest Biomass: 26.8M BDT
 - Technically available 14.3M BDT

Table 1 Resources and Generation Potentials from Biomass in California, 2013 (California Biomass Collaborative, University of California, Davis, 2015)

Category	Units	Agriculture	Forestry	Municipal Wastes	Total
Gross Resource	Million BDT/y	25	27	26	78
Technical Resource	Million BDT/y	12.1	14.3	9.0	35
Gross Electrical Capacity	MWe	2360	3580	3957	9,897
Technical Electrical Capacity	MWe	990	1910	1749	4,650
Gross Electrical Energy	TWh	15	27	29	71
Technical Electrical Energy	TWh	7.4	14.2	13	35

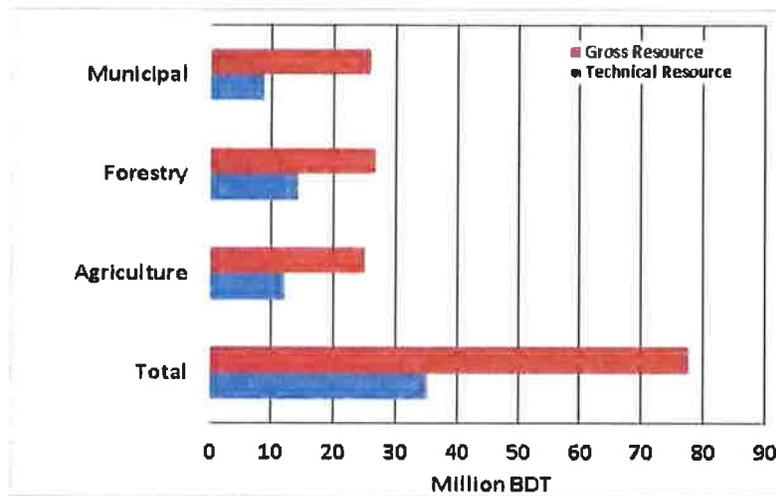


Figure 2 Resources and Generation Potentials from Biomass in California, 2013 (California Biomass Collaborative, University of California, Davis, 2015)

Table 2 Biogas Technical Potential from California Resources (California Biomass Collaborative, University of California, Davis, 2015)

Feedstock	Amount Technically Available	Biomethane Potential (billion cubic feet)
Animal Manure	3.4 MM BDT ^a	19.7 ^a
Landfill Gas	106 BCF ^a	53 ^d
Municipal Solid Waste (food, leaves, grass fraction)	1.2 MM BDT ^b	12.6 ^e
Waste Water Treatment Plants	11.8 BCF (gas) ^c	7.7 ^f
Total		93

Notes and Sources:

MM BDT = million bone dry (short) tons, BCF = billion cubic feet

a. Williams, R. B., B. M. Jenkins and S. Kafka (California Biomass Collaborative). 2015. *An Assessment of Biomass Resources in California, 2013 – DRAFT*. Contractor Report to the California Energy Commission. PIER Contract 500-11-020.

b. Technical potential assumed to be 67% of amount disposed in landfill (2013).

c. From EPA Region 9; Database for Waste Treatment Plants

d. Assumes 50% methane in gas

e. Assumes VS/TS= 0.83 and biomethane potential of 0.29g CH₄/g VS (food waste) & VS/TS = 0.9 w/ BMP= 0.143g CH₄/g VS (leaves, Grass)

f. Assumes 65% methane in gas.



Macro Challenges (High Level):

- ***There isn't enough Biomass to meet our needs*** – With 0.6 Quad of energy before conversion there isn't enough Biomass in the state to make enough biogas to replace PG&E's gas throughput of 822,655 MMSCF (about 0.8 Quad) (PG&E Corporation, 2016). Assuming a conversion efficiency of 70%, California Biomass would potentially displace about 0.4 Quad, i.e. half of Natural Gas delivered by PG&E. In some cases, like sources from the human waste stream, the goal is actually to *reduce* the amount of waste generated. This is a constraint that can be alleviated by the *production* of sources of purpose grown, environmentally-friendly Biomass. This is normally associated with elephant grass, prairie switchgrass or corn for ethanol, but one particularly promising technology is algae (specifically, micro-algae) that can be grown to meet demand for PG&E's green gas customers.
- ***Biomass/Biogas is more expensive than alternatives*** – At the moment, Biomass is generally generating biogas at the price of \$14 - 42/MMBTU (The Oxford Institute for Energy Studies, 2017). Natural Gas is currently at around \$3/MMBTU. Moreover, assuming a conversion rate of 30% for electricity generation, it leads to a cost greater than \$140/MWh). While PG&E doesn't necessarily expect to see comparable pricing (given low-carbon credits and the positive environmental value of biogas), projects that offer significantly lower prices will be more likely to garner investment.
- ***It's challenging and expensive to get feedstock to processing or conversion facilities*** - Currently, it costs a between \$14 – 42 per MMBTU (depending on the feedstock) to source Biomass from where it is produced or grown and centralize it for conversion or processing (The Oxford Institute for Energy Studies, 2017). That cost goes directly to the bottom line because biogas is not yet cost competitive with other sources of energy (electric and gas) sourcing or generation.
- ***Especially within California, diversity of geography, industry, settlement work against us*** – The incredible diversity of land, ecosystems, biomes, and human settlement is usually considered one of California's greatest assets. However, with less standardization comes higher cost. Therefore, solutions California develops for Biomass may be even more effective and affordable when implemented in states with greater homogeneity of economic activity or territory.
- ***Water to grow the Biomass is an issue*** – Especially in California, water is a critical resource. Biomass and biogas feedstock by definition require water for production, and the most efficient forms of biogas conversion (anaerobic digestion) require higher water content for optimal processing. This creates a conflict that outstanding technology solutions will address.



Key Challenges in Leveraging Biomass as a Low-Carbon Fuel Source (Medium Level)

The major categories of problems related to current technically recoverable Biomass sources generally fall within one of four categories:

1. **Dispersed nature of Biomass**
2. **High costs for aggregation**
3. **Low energy density**
4. **Heterogeneity**
5. **Pilot Facilities for new technology are capital intensive upfront**

Generally speaking the sources of Biomass (i.e. trees, animal manure, crop residuals, trash from our houses, etc.) are by nature not all concentrated in one place. This leads to physical and technical barriers to accessing the Biomass to collect it, and higher costs to centralize that Biomass in one place for processing. These costs are exacerbated by the low-energy density of these sources of fuel since much of what trucks bring to processing facilities is air or water, which is not useful for, or detrimental to the conversion to fuel. Finally, the fact that all sources of Biomass are different even within the same category also makes standardization (and therefore cost efficiencies) difficult to obtain (Williams, 2013).

Customization for each form of Biomass, and even customization within the same category to account for seasonality, sourcing, or individuality of the source increases costs dramatically. Some of these problems might be solved by new technology, but its development is heartbreakingly slow due to the enormous upfront capital it takes to build, fund, permit, and begin operations on demonstration processing facilities. *(Discussed more at length in "Processing")*



Dairy Example: One would expect cow manure to be a relatively consistent and concentrated form of Biomass.

However, different consistencies and chemical makeup of manure from cows changes based on what they eat, the season, the temperature, or the health of each cow etc. All of these variables increase the cost to

administer a facility that uses manure as a fuel source...and in some disastrous cases, lack of or improper customization kills the bacteria that are the key element of anaerobic digestion, dooming the entire facility. In addition, only the very largest 43% of dairies have enough concentrated cows (and manure) to provide a consistent stream of Biomass to a nearby anaerobic digester. Smaller dairies, though willing, would have to pay more to transport the manure long distances to aggregate enough Biomass to feed a centralized biogas plant. Most of what they end up transporting is actually water,



which can be up to 90% of the weight of manure, and is why manure is not as energy dense as fossil fuels (California Dairy Statistics Annual , 2017). All of this complicates and intensifies the expense of using dairy manure in biogas development.

SUCCESSFUL TECHNOLOGIES WILL:

1. Reduce capital costs and size of potential facilities to reduce the need for aggregation
2. Increase the energy density, or reduce the amount of land needed for Biomass generation
3. Introduce homogeneity in otherwise diverse forms of Biomass
4. Reduce the water or air content of sources of Biomass before transport
5. Centralize the production/growth of Biomass where a processing facility can be co-located
6. Enable the processing or partial processing of Biomass to travel cheaply to sources of Biomass
7. Drive costs down for the growth of purpose-grown energy crops such as micro-algae

Technical Challenges: Tech with Potential to Reduce Costs and Scale the Use of Biomass in California (Technical Level)

There are 3 major categories of Biomass technology that address the aforementioned challenges associated with using Biomass affordably and at scale. While many of these technologies have implications for conversion and processing later in the supply chain, those will be addressed in a separate paper.

1. Purpose-Grown Crops & (Micro) Algae

Eliminates many constraints on scaling up Biomass resources, the Biomass itself is homogenous, and can offer productive means of consuming waste heat, CO₂, waste water and otherwise problematic outputs from conversion facilities.

Cost reduction technologies to take existing stationary densification methods and making them more efficient.

2. Cheap Mobile Biomass Densification

For some Biomass, the cost of aggregation over long-distances is too high to justify harvesting it (i.e. dead bark beetle trees up in the mountains). In these cases, having a mobile densification technology may increase the number of energy units carried per truckload. Since people pay for energy, this reduces time, money and energy spent in recovering these sources of Biomass.



3. Pre-treatment of Biomass/Quality Improvement

There are a few other means of pre-treating Biomass so that it makes a higher quality energy fuel. In addition, some types of Biomass can be made into significantly more productive fuel sources when pre-processed before conversion. This is especially useful where Biomass is already aggregated (like Rice Straw at Rice processing plants) but the Biomass is unusable or inefficient (Satlewal, 2017).

PURPOSE GROWN CROPS

While not widely practiced in California, growing energy crops that are purposefully produced as a source of biogas feedstock is common in Europe where biogas production is a thriving market, in the US Midwest and in South America where corn and sugar beets are grown for fermentation into bio-fuel ethanol. One major challenge with purpose growing crops of any kind is the inevitable conflict with the use of land. If land can be used to grow food, it's hard to make the case that that land can or should be economically used for energy generation purposes. Secondly, monocultures of energy crops are desirable because of their uniformity and efficiency – but often presents environmental problems and introduces high risks. Finally, energy crops run into the same problem of costly aggregation as many other forms of biogas feedstock or Biomass.

Which energy crops are best?

The suitability of a particular crop for methane production is described by the following equation:

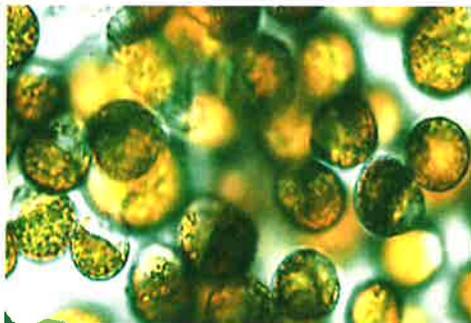
$$\text{Methane Potential} * \text{Crop Yield} = \text{Methane Yield per Hectare}$$

Additionally, qualitative and financial factors contribute to the overall suitability of energy crops for a particular location or conversion method (labor, pesticides, fertilizer, machinery, etc). While corn is globally the most popular energy crop, it is also used for food (University of Illinois at Urbana-Champaign, 2017). Crops that can be used in rotation like rapeseed, sunflower, Biomass sorghum, or hemp (Zegada-Lizarazu & Monti, 2011) that can be used in fallow fields or in soil rotations may actually be best suited for energy generation in an agricultural powerhouse state like California. It is not a huge surprise that this research was conducted in Germany. In 2000, the Renewable Energy Sources Act kicked off a steep increase in the use of energy crops as a feedstock for biogas plants in Germany (primarily for electric generation). The number of biogas plants soared to 5,000 in 2009, with energy crops topping out at 4.4% of arable land in the country (Bioenergy Crops LTD, n.d.). The Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB) did a study evaluating 403 silages of 43 crop species and found that for methane generation, lignin is an important Biomass constituent that

determines specific methane yields. Traditional energy crops valued for their high sugar content (like sugar beets and potatoes) actually had lower methane content than crops like alfalfa clover grass, and miscanthus which can be used in crop rotations in fallow fields. For 30 out of 43 investigated crop species the average methane content laid between 54% and 57% of the produced biogas (Herrmann, 2016). However, one particular energy crop, algae, does offer additional benefits explored below.

ALGAES

Algae have long been considered among the most promising sources of Biomass for future energy needs for many reasons that seem nearly too good to be true. Algae is an incredibly fast-growing source of Biomass, it captures and sequesters CO₂, and can be cultivated in oceans or ponds that don't force a tradeoff between energy crop growth, arable land for food production and potable water. Why then are algae not already in common usage in the global energy system? The short answer is that the amount of energy it takes to mix, harvest, and convert microalgae into biogas is so significant that it nearly negates its own total energy production. As a result of this, the commercialization of algae is unlikely without additional innovation.



(NORD University, 2018)



(Livealgae UK)

Figure 3 Pictures of Various Algae

What are algae?

Macroalgae are better known simply as seaweed. Microalgae are usually uni- or multi-cellular plant organisms that form colonies. Generally speaking algae are considered very efficient, since they can devote more of their energy into

photosynthesis (trapping light and CO₂) because they don't have to spend energy maintaining elaborate support and reproductive structures. Microalgae photosynthetic efficiency is 4.5% of solar energy again less than 1% for other crops. (Bolton, 2017).

Why could they be so good as a feedstock for biomethane?

Algae is tempting because of the complementary nature of its feedstocks and of algae as a feedstock. Algae consumes CO₂ during photosynthesis, and requires heat and water, all inputs that are considered waste for power plants or contaminants from the anaerobic digestion process. The algae itself is then used in an anaerobic digester to generate biomethane. Finally, digestate, the high nutrient waste product from anaerobic digestion, is like a super fertilizer, and can in turn be used to stimulate the growth of algae. In some ways, the perfect complementarity of the system mirrors a self-contained ecosystem, where each step uses the waste of another step to fuel growth. For these reasons:

- Algae production may be very well suited to co-production with wastewater treatment plants. This is open water near gas pipelines that can easily be repurposed to algae use. Algae used in anaerobic digestion don't require purity, so harvesting can be done more cheaply and in conjunction with existing wastewater treatment steps.
- Algae is a massive consumer of CO₂, a notable greenhouse gas, and as this feedstock scales to meet demand, it may provide a carbon market that makes use of sequestered carbon from other industries or from elsewhere in the energy generation system.
- Open cultivation systems clearly make the most sense for investment especially in temperate California, but seasonal changes in light and temperature still offer challenges to algae production on a larger scale.

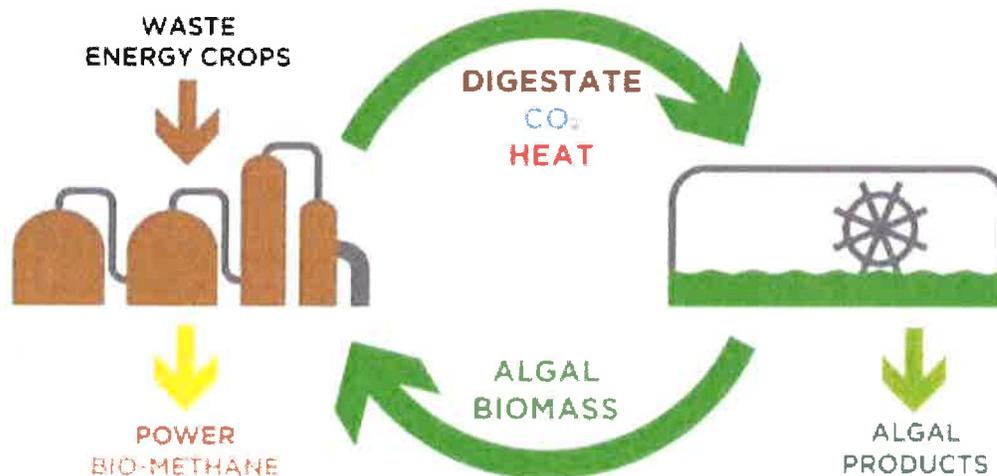


Figure 4 Lifecycle of Algal Product Production (AlgaeBioGas, 2017)



There are three major steps in leveraging microalgae. Cultivation, Harvesting, and Pre-Treatment. (AlgaeBioGas, 2017)

Cultivation: Microalgae cultivation can generally be broken down into indoor and outdoor systems, open and closed cultivation systems, and immobilized and free-floating species. Open systems (usually outdoor) are significantly cheaper, easier to build and manage, and much of their disadvantages (cross-contamination, etc) are not relevant for their application in generating biogas.

Harvesting: The key challenge with harvesting is that microalgae are often dispersed in the water, very small, and only slightly denser than water. Separating the algae entirely from water is difficult and energy intensive. Pure microalgae cultures aren't necessary for biogas processing, so when used as a feedstock for biogas, retaining some of that water is less important, so harvesting can be done more economically. Several forms of harvesting have been developed including chemical, mechanical, electrical, and biological separation.

Pre-Treatment: There are some things that can be done once algae are harvested to make them better suited to anaerobic digestion. Productivity can vary widely based on species and cultivation – with a maximum Biomass yield of 13-15 g m⁻² d⁻¹ (Murphy, 2015). Some technologies such as thermal hydrolysis have been successfully applied to algae to increase that methane yield by up to 24%. However, pre-treatment is something of a double edge sword. If we are using more energy to generate more energy, the net energy benefit would have to be worth the cost and effort of the pre-treatment.

Table 3 Advantages and disadvantages of common cultivation systems (Murphy, 2015)

Cultivation system	Advantages	Disadvantages
<i>Open</i>	<ul style="list-style-type: none">• Cheap• Good gas exchange with the atmosphere (release of O₂ is possible)• Easy to operate• Easy to scale up	<ul style="list-style-type: none">• High risk of contamination (not as significant for biogas systems)• High evaporation losses• Large area required• Light limitation if thick layers are used
<i>Closed</i>	<ul style="list-style-type: none">• Good control of cultivation parameters• Reduced contamination risk• Less CO₂ losses• Reproducible cultivation conditions	<ul style="list-style-type: none">• Expensive• Scale up is difficult



Table 4 Methods and Processes of cultivation systems (Murphy, 2015)

Method	Process	Comments	Dry solids output concentration (%)
<i>Chemical based</i>	Precipitation / flocculation	<ul style="list-style-type: none"> - Addition of electrolytes or synthetic polymers to neutralize negative surface charge - The use of metal salts for coagulation and flocculation is cautioned due to potential inhibition of the specific methanogenic activity of methanogenic and acetogenic microbes 	3 – 8
<i>Mechanical based</i>	Centrifugation	<ul style="list-style-type: none"> - Centrifugal forces are utilized to separate based on density differences - Probably the most rapid and reliable method of recovering suspended algae - Easy to operate - High investment and operating costs 	10 – 22
	Filtration	<ul style="list-style-type: none"> - Often used for filamentous strains - For small, suspended algae tangential flow filtration is considered to be more feasible - high costs and power requirements 	2 – 27
	Sedimentation	<ul style="list-style-type: none"> - Low costs - Low reliability because of fluctuating density of algal cells - Slow 	0.5 – 3
	Dissolved Air flotation	<ul style="list-style-type: none"> - Air is released under high pressure and forms tiny bubbles in the water column, which adhere to the suspended matter causing the suspended matter to float - Has been proven in large scale - The additional use of flocculants might be problematic for further processing of the algae 	n.a.
<i>Electrical based</i>	Separation based on electrophoresis	<ul style="list-style-type: none"> - No chemicals needed - High power requirements and electrode costs 	n.a.
<i>Biological based</i>	Autoflocculation	<ul style="list-style-type: none"> - High pH and the consumption of dissolved CO₂ lead to co-precipitation of algal cells together with calcium phosphate 	n.a.
	Bioflocculation	<ul style="list-style-type: none"> - Flocculation caused by secretion of polymers 	n.a.
	Microbial flocculation	<ul style="list-style-type: none"> - Addition of flocculating microbes 	n.a.



Table 5 Methane and biogas production from different microalgae species measured by BMP tests (Murphy, 2015)

Species	Temp. [°C]	Biogas prod. [L/kg VS]	CH ₄ prod. [L/kg VS]	CH ₄ content [%]	Literature
<i>Arthrospira platensis</i>		481 ± 14	293	61	Mussgnug et al., 2010
<i>Chlamydomonas reinhardtii</i>		587 ± 9	387	66	Mussgnug et al., 2010
<i>Chlorella kessleri</i>		335 ± 8	218	65	Mussgnug et al., 2010
<i>Chlorella vulgaris</i>	28 – 31		310 – 350	68 – 75	Sanchez and Travieso, 1993
<i>Dunaliella salina</i>		505 ± 25	323	64	Mussgnug et al., 2010
<i>Dunaliella</i>	35		420		Chen, 1987
<i>Euglena gracilis</i>		485 ± 3	325	67	Mussgnug et al., 2010
<i>Nanochloropsis</i> spp.	38	388	312	80.5	Schmack, 2008
<i>Scenedesmus obliquus</i>		287 ± 10	178	62	Mussgnug et al., 2010
<i>Spirulina</i>	35		320 – 310		Chen, 1987
	38	556	424	76.3	Schmack, 2008
<i>Spirulina maxima</i>	35		190 – 340		Samson and LeDuy, 1983
Mixed algae sludge (<i>Chlorella-Scenedesmus</i>)	35 – 50		170 – 320	62 – 64	Golueke et al., 1957
	50	500	Not specified		Golueke et al., 1957
	35	405	Not specified		Oswald et al., 1960
	45	611	Not specified		Golueke et al., 1959
	35		100 – 140		Yen et al., 2007
Green algae	38	420	310	73.9	Schmack, 2008

Cultivation of algae can either use solar energy (photoautotrophic) or bio-reactions using other Biomass (heterotrophic). It seems at this point that heterotrophic cultivation has been abandoned and research focuses on photoautotrophic cultivation.

Table 6 Advantages and Disadvantages of Photoautotrophic and Heterotrophic Cultivation (Ferrell & Sarisky-Reed, 2010)



		ADVANTAGES	CHALLENGES
Photoautotrophic Cultivation	Closed Photobioreactors	<ul style="list-style-type: none"> • Less loss of water than open ponds • Superior long-term culture maintenance • Higher surface to volume ratio can support higher volumetric cell densities 	<ul style="list-style-type: none"> • Scalability problems • Require temperature maintenance as they do not have evaporative cooling • May require periodic cleaning due to biofilm formation • Need maximum light exposure
	Open Ponds	<ul style="list-style-type: none"> • Evaporative cooling maintains temperature • Lower capital costs 	<ul style="list-style-type: none"> • Subject to daily and seasonal changes in temperature and humidity • Inherently difficult to maintain monocultures • Need maximum light exposure
Heterotrophic Cultivation		<ul style="list-style-type: none"> • Easier to maintain optimal conditions for production and contamination prevention • Opportunity to utilize inexpensive lignocellulosic sugars for growth • Achieves high biomass concentrations 	<ul style="list-style-type: none"> • Cost and availability of suitable feedstocks such as lignocellulosic sugars • Competes for feedstocks with other biofuel technologies

Algae can be used to produce a broad range of bio-fuel through different thermochemical, biochemical or chemical processes:

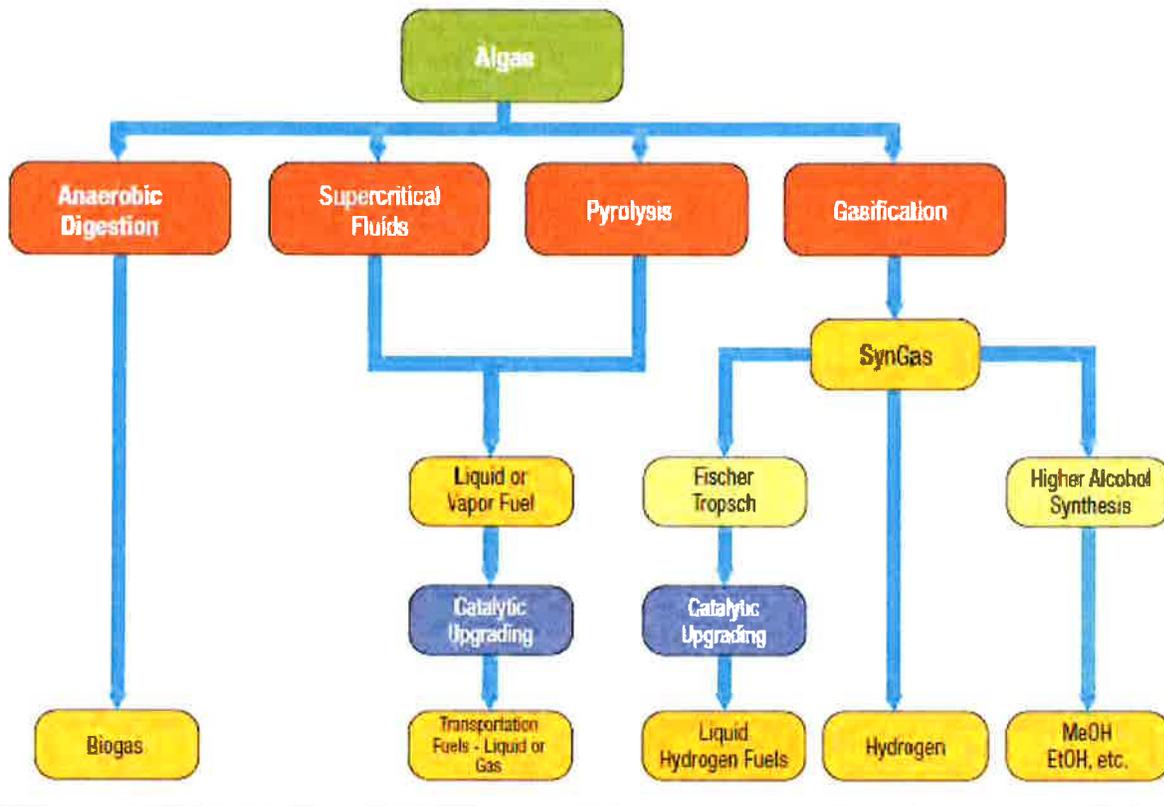


Figure 5 Pathways for Algae Use (Ferrell & Sarisky-Reed, 2010)

CHEAP MOBILE DENSIFICATION

The chief barrier to using more Biomass is densification. Densification offers several advantages to current practice. They include: improving the efficiency of transportation from the source of Biomass to where it will be consumed, molding feedstock into a uniform size and shape, improved energy density, and conformance to the specifications of destination technologies used to convert the feedstock into energy. Densification is most effective with lignocellulosic Biomass (woody Biomass) partially because lignin improves the process, the need for uniform and dry feedstock for gasification technologies, and also due to the distributed nature of much of the woody Biomass resource in California. Making this process cheaper, or more mobile is the next key hurdle.

Densification: The most common forms of densification are the pellet mill, the briquette press, and screw extruder.

As the name implies, the Pellet Mill takes in finely ground ingredients, and turns them into dense pellets. This technology is usually classified either as “ring die” or “flat die” and generally consists of a hard steel die with 1-2 rollers. By heating, softening, and spreading the feedstock over the rotating die and rollers, the Biomass is “forced through the perforations to form densified [material]” which are then cut off into pellets. (Tumuluru, 2011)

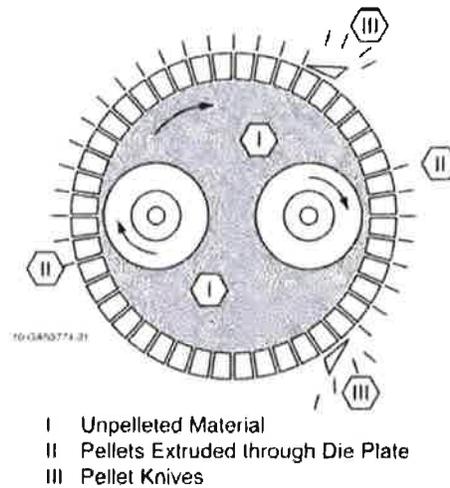


Figure 6 Working processes of a pellet mill die (Tumuluru, 2011)

Briquette Presses can handle larger feedstock particles and higher moisture. They generally work by creating steam under high pressure, hydrolyzing the material, then subjecting that material to high heat and pressure, which binds the particles together. Hydraulic Piston Presses can be used as briquetting machines (production at 50-400kg/hr, with higher moisture content >15%). The other alternative is the Mechanical Piston Press, which is often used for larger scale production as it is energy efficient, has a long operating life (production 200-2500 kg/hr) (Tumuluru, 2011).

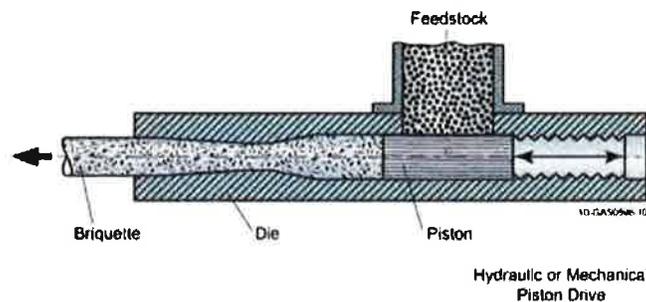


Figure 7 Mechanical or hydraulic piston press (Tumuluru, 2011)

Screw Extruders work in four stages: input Biomass, initial compression, final compression, and discharge. Generally, the Biomass is ground up so it can be fed into the extruder, where it is heated to 200+° C which helps bind the material together. During final compression, the material enters a tapered die at high temperature (again reducing moisture). After cooling small extruded log are produced, more ideally suited for burning or co-firing technologies.

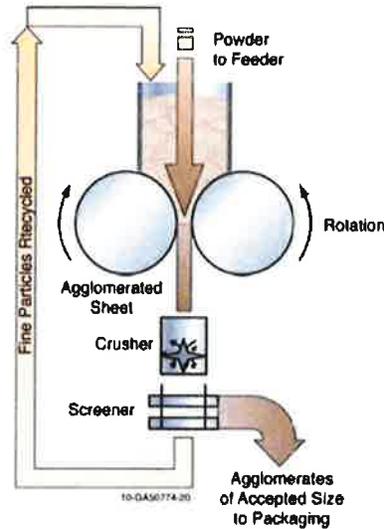


Figure 8 Roller press mill (Tumuluru, 2011)

Efficiency: Since this feedstock is the source of gas and therefore energy generation, how much energy the densification process *consumes* is important in the overall energy efficiency of biogas. That efficiency is affected by temperature and pressure used by the technology. It is also affected by the moisture content, particle size and distribution of feedstock, and biochemical composition like starches, proteins, fats, and other lignocellulosic components. Generally, extrusion requires more energy due to compression and pushing. Pellet mills are usually the most energy efficient.

Some elements of the technology might have more impact when improved than others. Pressure is a key input that determines the quality of the pellets or briquettes. Die geometry can influence desirable outcomes like moisture content, durability and density of the final product. All of these outcomes are dependent on the feedstock, and higher levels of protein and lignin are considered assets (often associated with woody Biomass).

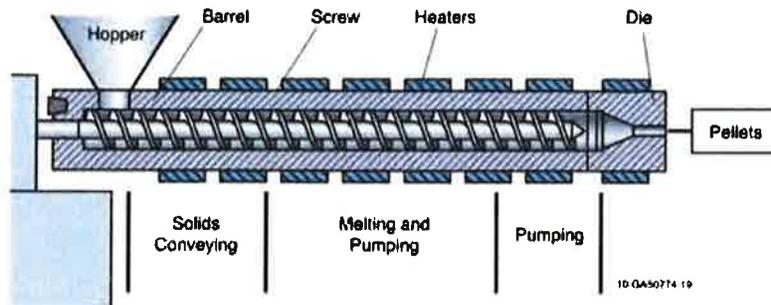


Figure 9 Extruder for Biomass or polymer processing (Tumuluru, 2011)

Cheap and Mobile: The technologies above are well established, but Biomass sourcing remains expensive because of its dispersion – these technologies need to be small enough to be portable while also running continuously and efficiently. Mobile pelleting plants exist today primarily for consumer home use application. However, in order to unlock the constraints around harvesting woody Biomass, this mobile technology must be cheaper to use in the field, accommodate a wide variety of Biomass, and process the Biomass at industrial speeds. Accomplishing this could unlock as-of-now technically and economically un-recoverable Biomass in California.

Real World Example: Pelleting in Europe is quite common and is used primarily for heating (64% of the market) and the remainder for power production (36%) (AEBIOM, 2018). Wood pellets are already being used in the production of renewable biogas through woody Biomass gasification. In Luxembourg, LuxEnergie opened its Kirchberg Power Plant in 2017 after retrofitting the plant to run on Biomass from natural gas (Luxembourg: Wood Gasification Plant Opened, 2017). The facility processes 2.5 tons of wood pellets to serve Kirchberg’s district heating network. Luxembourg likely imports these pellets from Germany or Sweden (AEBIOM, 2018), and is only able to do so economically because of the energy dense nature of the Biomass pellets.

Summary (European Biomass Industry Association, 2018)

- An increased bulk density (from 80-150 kg/m³ for straw or 200 kg/m³ for sawdust to 600-700 kg/m³ after densification), resulting in lower transportation costs, reduced storage volume and easier handling.
- A lower moisture content (humidity <10%), favoring a long conservation and minor losses of product during the storage period.
- An increased energy density and more homogeneous composition, resulting in better combustion control possibilities and thereby higher energy efficiency during combustion.



For more information:

- European Biomass Industry Association (European Biomass Industry Association, 2018)

PRE-TREATMENT BIOMASS

While densification is a form of pre-treatment, additional processing options such as Torrefaction, can offer other value-added advantages throughout the Biomass/biogas value chain. Pre-treatment of Biomass can improve chemical and physical elements of the Biomass to increase the heating value, the efficiency of energy conversion, or even make some currently unusable Biomass eligible for processing. This process that be applied to all types of Biomass, but is currently most applicable to Biomass that is intended for gasification, anaerobic digestion or for particularly challenging forms of Biomass (like rice straw).

Torrefaction: The most common form of pre-treatment, Torrefaction is the thermal process that converts Biomass into a more energy dense material similar to coal. Its greatest advantage is the ability to reduce the amount of water or biological activity in the Biomass.

It is commonly used in conjunction with palletization in woody Biomass and often offers similar advantages – in essence increasing the units of energy per truckload of Biomass, since the energy is what conversion technologies pay for. However, Torrefaction also offers other advantages besides energy density such as homogenous composition, hydrophobia, improved conversion efficiency due to grindability, and finally it also stops biological activity like rotting, which has applications for organic forms of Biomass.

Step 1

Receiving and storage

Wood chips are collected and stored so they can be used as biomass fuel.



unprocessed wood chips

Step 2

Drying

The wood chips are dried using a closed-loop belt dryer before undergoing torrefaction.



dried wood chips

Step 3

Torrefaction

The wood chips are heated using microwave technology within a rotating drum reactor, creating a charcoal-like substance.



torrefied wood chips

Step 4

Grinding and pelletizing

The torrefied wood is ground up and made into pellets that produce up to 10% more energy than untreated wood.



final wood pellets

Figure 10 Steps for preparing Biomass (Word of the Day: Torrefaction, 2016)

Other Pre-Treatment Options: Torrefaction is just one of several options for pre-treating Biomass. Several others are listed below. However, their relevance to the eventual production and cost of generating biomethane is minimal.

- Pre-Heating
- Grinding
- Steam Explosion
- Torrefaction
- Ammonia Fiber Explosion
- Alkali Pre-treatment

Call out: Alkali Pre-Treatment

Water leaching, also called rain leaching, is an interesting process by which agricultural silage like rice straw (silage is the term for agricultural residual waste) is exposed to water which leaches potassium and chlorine and changes the properties of lignin and hemicelluloses from the Biomass. The result is a *dramatic* increase in the effectiveness of rice straw as a gasification or pyrolysis feedstock (Sattlewal, 2017). In general, rice straw is underutilized as Biomass in the agricultural residues category in California and can be subject to open burning or other expensive disposal mechanisms. Cultivating this technology might expand the technically and economically recoverable amount of Biomass available for biogas production in California.



Rice is a staple food, and after sugar products is the highest produced agricultural commodity in the entire world. California is the second largest producer with 26% market share in the United States (Miller, Tapping the hidden value of farm waste, 2017). However, rice is arguably the most important agricultural product in Asia where its use as a source of Biomass or bio-oil has been studied extensively by local researchers especially in Korea, Indonesia, and Vietnam. MIT was recently profiled for its work developing a mobile torrefaction and pre-treatment technology to address agricultural residues in India primarily for rice. Some of these technologies, and global research have potential application in California and any progress in leveraging rice straw/silage for energy production could have a global impact (Miller, Mobile Torrefaction Technology that can Convert Biomass into Clean-Burning Fuel, 2017) (Jenkins, 1999).

Who are Experts in this field?

Experts specific to individual types of Biomass or Biomass technologies:

Table 7 Individual and Technology Specific Experts

Industry Experts	Expert	Alternative
California	Stephen Kaffka, UC Davis	Robert (Bob) Williams, UC Davis
	Bryan M Jenkins, UC Davis	Biomass Laboratory , UC Davis
United States	US DOE, Biomass Research and Development Board	
International	Germany, Denmark (Europe)	India
Types of Biomass		
Woody Biomass	G4 Insights	
Agricultural Residue	UC Davis, Bryan M. Jenkins	MIT, Ahmed Ghoniem and Kevin Kung, PhD student
Municipal Solid Waste	California Integrated Waste Management Board	Sierra Energy, Advanced Plasma Power (APP)
Animal Manure	Martha Krebs, CEC PIER	The California Department of Food and Agriculture
Wastewater	The Interagency Wastewater Biogas Working Group, California Association of Sanitation Agencies	State Water Resource Board



Landfills	Sierra Energy	Advanced Plasma Power (APP)
Algae	Stephen Mayfield , California Center for Algae Biotechnology	IEA
Energy Crops	M.W Jenner, S.R. Kaffka, (California Biomass Collaborative, CEC)	Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)
Technologies		
Torrefaction	Michael Wild, International Biomass Torrefaction Council	US Endowment for Forestry and Communities
Pelleting	Jaya Shankar Tumuluru (Idaho National Laboratory) Daniela Thran, IEA Bioenergy	University of California, Division of Agriculture and Natural Resources, IEA Bioenergy

Key technologies to investigate and Timeline?

There are few immediate and critical R&D opportunities from the utility perspective in the improvement of Biomass sourcing. However, some potential projects might include:

1. Investigation of algae potential in conjunction with a wastewater treatment plant for use in a co-located anaerobic digester. This project might determine whether algae can be used as an economic feedstock for anaerobic digestion to biogas.
2. Rain or Water leaching of rice silage might be worthwhile to make this a potential feedstock for co-digestion in an anaerobic digester or for Biomass in a gasification plant. Rice silage/straw is often *already* aggregated for processing of rice for food, so many of the challenges associated with aggregation would not exist in this feedstock.
3. If a cheap, mobile densification or pre-treatment technology became available, it would be worth looking into funding a project creating Biomass from woody Biomass that would otherwise be at risk for fire.

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Appendix C – 8

Biomass Feasibility Assessment

**Prepared for:
The Nevada County Biomass Task Force and
The Fire Safe Council of Nevada County
Grass Valley, California**



**Prepared by:
TSS Consultants
Rancho Cordova, California**



December 1, 2014

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- Frederick Tornatore, Chief Technical Officer
- Matt Hart, Renewable Energy Specialist

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- Appendix C. Senate Bill 1122 Text
- Appendix D. CAL FIRE Draft Guidelines for Sustainable Forest Biomass

List of Abbreviations

Organizations

BLM	Bureau of Land Management
BOE	Board of Equalization
CAL FIRE	Department of Forestry and Fire Protection
CARB	California Air Resources Board
CEC	California Energy Commission
CPUC	California Public Utilities Commission
FSCNC	Fire Safe Council of Nevada County
OSHA	Occupation Safety and Health Administration
PG&E	Pacific Gas and Electric
SPI	Sierra Pacific Industries
Task Force	Nevada County Biomass Task Force
TSS	TSS Consultants
UC	University of California
USFS	United States Department of Agriculture, Forest Service

Other Terms

BDT	Bone Dry Ton
Btu	British Thermal Unit
CEQA	California Environmental Quality Act
CUP	Conditional Use Permit
EPIC	Electric Procurement Investment Charge
FTE	Full Time Equivalent
kW	Kilowatt
kWh	Kilowatt-hour
ICE	Internal Combustion Engine
ITC	Investment Tax Credit
LCOE	Levelized Cost of Electricity
MBF	Thousand Board Feet
MMBtu	Million British Thermal Units
MW	Megawatt
MWh	Megawatt-hour
NEPA	National Environmental Policy Act
NMTC	New Market Tax Credit
O&M	Operations & Maintenance
ORC	Organic Rankine Cycle
PTC	Production Tax Credit
ReMAT	Renewable Market Adjusting Tariff
RPS	Renewable Portfolio Standard
SB	Senate Bill
SIS	System Impact Study
TPY	Tons per Year
TSA	Target Study Area
UC	University of California
WUI	Wildland Urban Interface

EXECUTIVE SUMMARY

Introduction

The Nevada County Biomass Task Force (Task Force) and the Fire Safe Council of Nevada County (FSCNC) include community stakeholders that are interested in the potential for siting a community-scale bioenergy facility (scaled at 3 megawatts (MW) or less) within western Nevada County as part of an effort to:

- Encourage and implement local conservation-based fuel reduction programs to protect the people and communities of western Nevada County from the threat of fire;
- Improve local and regional air quality by finding alternative uses for woody biomass material that would normally be open-burned, which adversely impacts air quality;
- Provide an alternative forest biomass disposal opportunity for homeowners and land managers who are conducting fuels reduction, forest restoration, and forest harvest activities in the region;
- Support renewable energy development, thus diversifying local power generation and providing opportunities to efficiently utilize waste material (wood waste) for cogeneration of both power and heat; and
- Provide employment opportunities in the form of sustainable living wage jobs.

The Task Force, in concert with the FSCNC, retained TSS Consultants (TSS) to conduct a feasibility assessment focused on the potential for bioenergy development in the greater Grass Valley and Nevada City area.

Preliminary Site Analysis

TSS conducted a preliminary site analysis of 19 sites across western Nevada County. Sites were identified based on input from the Task Force, recommendations from the project's two community meetings,¹ and by TSS. In coordination with the Task Force, scoring criteria and weighting factors were developed to include available space, biological resources, cultural resources, heating and cooling load, interconnection requirements, land use zoning, proximity to sensitive receptors, road infrastructure, site infrastructure and environmental cleanup status, and water supply and wastewater discharge.

TSS and the Task Force scored sites using Nevada County, Nevada City, and Grass Valley zoning, parcel, and utility maps, aerial imagery, Pacific Gas and Electric (PG&E) grid infrastructure maps, California State Water Resources Control Board's GeoTracker, and local knowledge when available. Based on the findings, the sites with the top five rankings are shown in Table 1. The rankings indicate an objective preliminary analysis of the site without evaluating the willingness of the site owners to participate in the development of a bioenergy project.

¹ Open house public meetings were held May 29, 2014, at the Grass Valley Grange and October 22, 2014, at the Tahoe National Forest Office.

Table 1. Top-Ranked Potential Sites

Site Name	Site Score (Out of 100)	Site Rank
La Barr Meadows Road Rare Earth Site	76.7	1
Centennial Road Site	73.3	2
Airport Site, Charles Drive & Pike Court	71.7	3
La Barr Meadows Road Nevada County Site	71.7	3
Penn Valley Site	71.7	3
Former Sierra Pacific Industries (SPI) Mill Site	70.0	4
Hansen Brothers Site	70.0	4
East Bennett Road South Site	68.3	5

Biomass Feedstock Availability and Cost Analysis

Using a target study area with a 40-mile radius, TSS identified annual sustainable feedstock available of 113,128 bone dry tons (BDT)² per year from forest, urban, and agricultural sources. Applying the restrictions of Senate Bill (SB) 1122, the feedstock availability and projected feedstock sourcing blend and weighted-average pricing is identified in Table 2.

Table 2. Projected Project Feedstock Blend

Source	Economically Available (BDT/YR)	Projected Feedstock Blend (BDT/YR)	Feedstock Coverage Ratio	Feedstock Average Price (\$/BDT)
Forest	53,920	19,200	2.8:1	\$57.50
Urban	25,407	1,000	25.4:1	\$26.00
Agriculture	33,801	3,800	8.9:1	\$38.00
Totals	113,128	24,000	4.7:1	\$53

Considering the seasonal availability of forest feedstock, there will need to be infrastructure on site at the bioenergy facility in order to assure that some volume of feedstock is stockpiled for use during winter months when access to forest operations is minimal. TSS recommends that a feedstock procurement strategy be developed that assures feedstock sourcing be concentrated at upper elevation locations during summer months and lower elevation locations in the winter. This will optimize and extend the operating season for feedstock suppliers while mitigating the need to stockpile large volumes of feedstock at the bioenergy facility. In addition, agriculture-sourced feedstock is typically available in the winter months (after nut harvest) and aligns well with feedstock procurement to facilitate wintertime delivery.

Bioenergy Technology Review

TSS reviewed commercially available biomass-to-electricity technologies appropriate for community-scale (3 MW) deployment. Direct combustion and gasification configurations were

² A bone dry ton equals 2,000 dry pounds (no moisture content).

reviewed for technological maturity, sensitivity to ambient conditions, water consumption, efficiency, air emissions, and operational costs. Table 3 summarizes the preferred biomass conversion technology. While each technology type offers unique advantages, given the interests communicated from the Task Force related to technology selection, a gasification-to-ICE approach would be preferred.

Table 3. Results of Technology Assessment

Characteristics	Preferred System
Technological Maturity	Direct Combustion
Sensitivity to Ambient Conditions	Direct Combustion
Water Consumption	Gasification
Feedstock Consumption/Efficiency	Gasification
Air Emissions Profile	Gasification
Labor Costs	Gasification

Economic Analysis

The primary product of a biomass gasification system is electricity and by-products include heat, biochar, and carbon credits. There are currently no local heat loads at any of the sites; however, several of the sites have the potential to collocate another enterprise as a potential heat user. For community-scale facilities, there are currently limited market opportunities for carbon credits due to accounting pathways and unreliability of short-term markets.

Using the levelized cost of electricity (LCOE) financial model developed by Black & Veatch for a California Public Utilities Commission (CPUC) analysis of proposed SB 1122 language, TSS performed sensitivity analyses on capital cost, operations and maintenance (O&M) costs, feedstock costs, heat rate, capacity factor, debt percentage, debt rate, debt term, cost of equity, biochar sales, and grant incentive levels. TSS found capital costs, O&M costs, and biochar sales to have the greatest potential impact on project economics. A Nevada County model was developed, and the model projected an LCOE of \$160/megawatt-hour (MWh) without the ITC and \$145/MWh with the ITC (Table 4).

Table 4. Nevada County LCOE Model

	Model Values		Model Values
Capital Cost (\$/kW)	\$5,500	Debt Term (years)	12
O&M Costs (\$/kW)	\$450	Investment Tax Credit (%)	0%
O&M Escalation (%)	2%	Biochar Sales (\$/ton)	\$325
Capacity Factor (%)	85%	Cost of Equity (%)	15%
Heat Rate (Btu/kWh)	16,500	LCOE (\$/MWh)	\$170
Feedstock Cost (\$/BDT)	\$53.10	Grant Funding (\$)	\$2,000,000
Feedstock Cost Escalation (%)	1%	LCOE (\$/MWh)	\$160
Debt Percentage (%)	70%	With Investment Tax Credit (%)	10%
Debt Rate (%)	5%	LCOE (\$/MWh)	\$145

Recommendations and Next Steps

The Task Force has made significant efforts to identify value-added opportunities to promote local economic development, improve public safety, utilize sustainable regionally available resources, and improve air quality. TSS recommends the following next steps to move the project forward:

- Select a Target Site;
- Identify a Technology Developer;
- Commence Land Use Permitting;
- Continue Public Outreach; and
- Identify Synergies with Local Enterprises.

Additionally, grant funding opportunities for pre-development work are available including the U.S. Forest Service (USFS) Wood Innovation Program, Sierra Nevada Conservancy, and the National Forest Foundation Grant program. Each of these organizations regularly changes their grant opportunities, and those should be monitored closely. TSS calls specific attention to the Wood Innovation Program, as it is open now with solicitations due on January 23, 2015. The California Energy Commission's (CEC) Electric Procurement Investment Charge (EPIC) program traditionally offers funding for research and development and commercialization. The EPIC program's focus changes with each round of funding. The next funding cycle is scheduled to be released in July 2015. EPIC is appropriate for funding after the selection of a project developer and the completion of the California Environmental Quality Act (CEQA) review process.

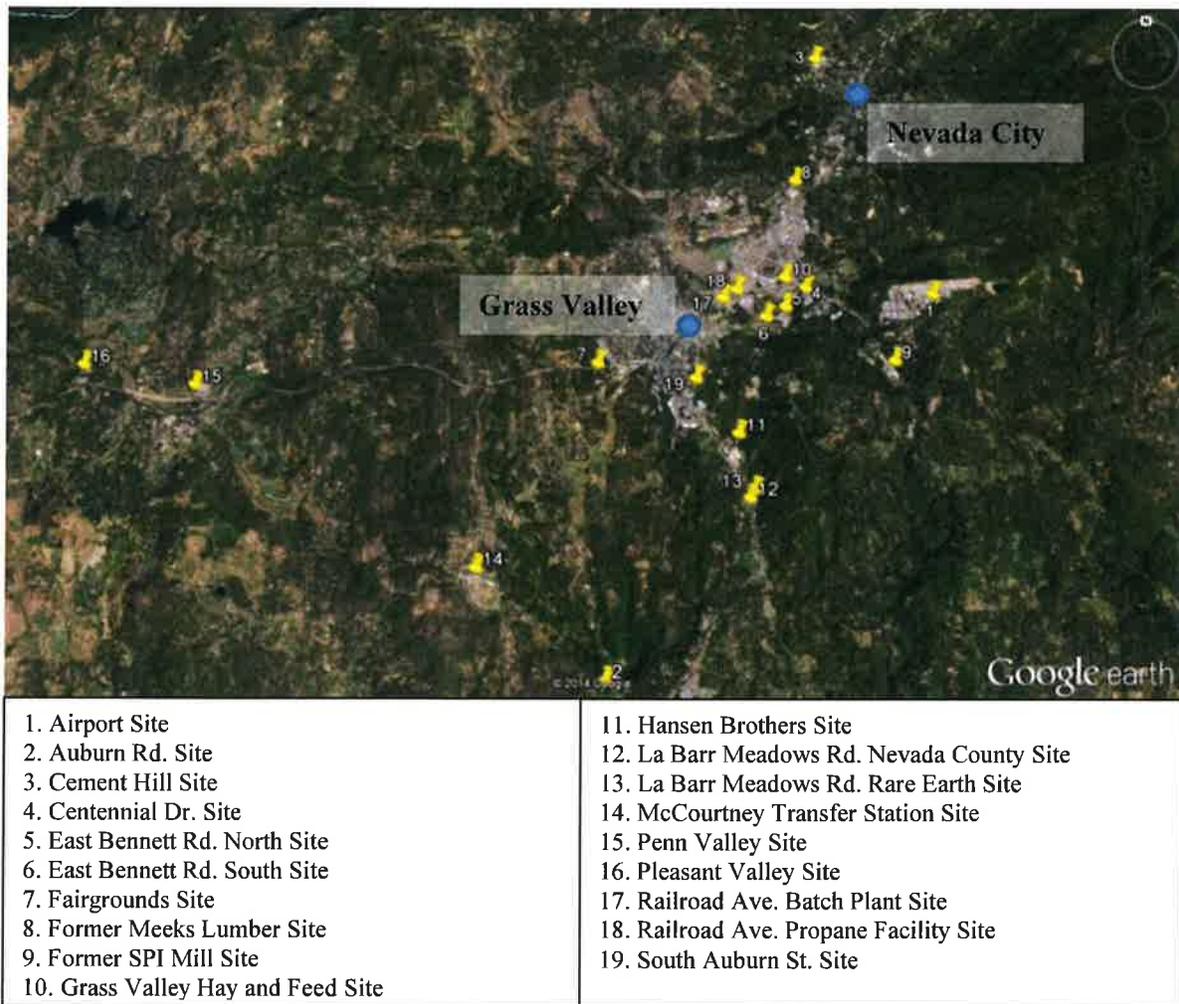
At this stage, TSS recommends that the Task Force focus on developing the framework and relationships necessary to achieve project financing. The next steps, if successfully achieved, will move the project closer to project financing and deployment.

PRELIMINARY SITE ANALYSIS

Site Identification

The process of identifying a successful bioenergy project begins with the identification and preliminary analysis of potential sites. Overall, 19 sites in the greater Nevada City/Grass Valley area were considered for the preliminary analysis based on local knowledge provided by the Task Force and input from the public in response to community outreach.³ In addition, areas with industrial zoning, as indicated by Nevada County, City of Grass Valley, and City of Nevada City, were considered for this analysis. Figure 1 shows locations of the potential sites. Detailed information about each site is provided in Table 5.

Figure 1. Map of Potential Sites



³ Open house public meetings held May 29, 2014, at the Grass Valley Grange and October 22, 2014, at the Tahoe National Forest Office.

Table 5. Potential Sites for Review

Site Information	Aerial Photograph	Site Information	Aerial Photograph
<p>Name: Airport Site</p> <p>Location: Charles Dr. & Park Ct.</p>		<p>Name: Auburn Rd. Site</p> <p>Location: 14940 Auburn Rd. Grass Valley</p>	
<p>Name: Cement Hill Site</p> <p>Location: Intersection of Cement Hill Rd. & Hwy. 49 Nevada City</p>		<p>Name: Centennial Dr. Site</p> <p>Location: 1020 Whispering Pines Ln. Grass Valley</p>	
<p>Name: E. Bennett Rd. North Site</p> <p>Location: 11352 E. Bennett Rd. Grass Valley</p>		<p>Name: E. Bennett Rd. South Site</p> <p>Location: Southwest of E. Bennett Rd. & Slow Poke Ln. Grass Valley</p>	
<p>Name: Fairgrounds Site</p> <p>Location: North of the Grass Valley fairgrounds parking lot</p>		<p>Name: Former Meeks Lumber Site</p> <p>Location: 2347 Nevada City Hwy. Grass Valley</p>	
<p>Name: Former SPI Mill Site</p> <p>Location: South of the E. Bennett Rd. & Brunswick Rd. intersection, Grass Valley</p>		<p>Name: Grass Valley Hay and Feed Site</p> <p>Location: 1025 Idaho Maryland Rd. Grass Valley</p>	

Site Information	Aerial Photograph	Site Information	Aerial Photograph
<p>Name: Hansen Brothers Site</p> <p>Location: End of Amsel Way Grass Valley</p>		<p>Name: La Barr Meadows Rd. Nevada County Site</p> <p>Location: 12536 La Barr Meadows Rd., Grass Valley</p>	
<p>Name: La Barr Meadows Rd. Rare Earth Site</p> <p>Location: 12270 La Barr Meadows Rd., Grass Valley</p>		<p>Name: McCourtney Transfer Station Site</p> <p>Location: 14741 Wolf Mountain Rd. Grass Valley</p>	
<p>Name: Penn Valley Site</p> <p>Location: Northeast of Cattle Dr. & Gray Oak Dr. intersection Grass Valley</p>		<p>Name: Pleasant Valley Site</p> <p>Location: South of Pine Shadow Ln. Grass Valley</p>	
<p>Name: Railroad Ave. Batch Plant Site</p> <p>Location: End of Railroad Ave. Grass Valley</p>		<p>Name: Railroad Ave. Propane Facility Site</p> <p>Location: Adjacent to 335 Railroad Ave., Grass Valley</p>	
<p>Name: South Auburn St. Site</p> <p>Location: Southeast of the S. Auburn St. & Adams Ln. intersection, Grass Valley</p>			

Siting Criteria

TSS worked with the Task Force to develop ten site criteria to be used as a basis for the preliminary analysis. Of the ten criteria, three were identified as critical. Critical criteria are defined as components that could potentially make a site infeasible and are summarized below.

- **Land Use Zoning:** The time and cost for a land use zoning change will prohibit bioenergy project development on sites without the potential for securing a Conditional Use Permit (CUP).
- **Space:** A site without sufficient space (identified as one acre for this project) will prohibit bioenergy development, as the equipment will not fit safely on the site.
- **Proximity to Sensitive Receptors:** Potential sites proximate to extra-sensitive receptors (e.g., schools and hospitals) were excluded from further analysis due to potential impacts to sensitive populations.

In addition to critical criteria, seven criteria were identified as secondary criteria, which are defined as components that affect the potential to site a project but do not necessarily impose prohibitive constraints. These secondary criteria include:

- Grid Infrastructure;
- Heating and Cooling Load Potential;
- Road Infrastructure;
- Site Infrastructure and Environmental Cleanup Status;
- Water Supply and Discharge;
- Biological Resources; and
- Cultural Resources.

Based on these criteria, TSS developed a scoring system offering a discrete score from 0 to 3 for each criterion. The Task Force independently identified a weighted score for each criterion subject to the priorities of the Task Force (Table 6). The scoring system, along with weight factors, is shown in Appendix A.

Table 6. Site Criteria with Weighted Scoring Factors

	Selection Criteria	Weighting Factor
Critical Criteria	Land Use Zoning	15%
	Space	10%
	Proximity to Sensitive Receptors	25%
Secondary Criteria	Grid Infrastructure	10%
	Heating and Cooling Load Potential	5%
	Road Infrastructure	10%
	Site Infrastructure and Environmental Cleanup Status	10%
	Water Supply and Discharge	5%
	Biological Resources	5%
	Cultural Resources	5%

Findings

TSS, with assistance from the Task Force, reviewed the sites using Nevada County, Nevada City, and Grass Valley zoning, parcel, and utility maps, aerial imagery, PG&E grid infrastructure maps, California State Water Resources Control Board's GeoTracker, observations from site visits, and local knowledge when available. Final site rankings are shown in Table 7, with details available in Appendix B. The rankings indicate an objective preliminary analysis of the site without evaluating the willingness of the site owners to participate in the development of a bioenergy project.

Table 7. Site Analysis Rankings

Site Name	Site Identifier (Figure 1)	Site Score (Out of 100)	Site Rank
La Barr Meadows Road Rare Earth Site	13	76.7	1
Centennial Road Site	4	73.3	2
Airport Site, Charles Drive and Pike Court	1	71.7	3
La Barr Meadows Road Nevada County Site	12	71.7	3
Penn Valley Site	15	71.1	3
Former SPI Mill Site	9	70.0	4
Hansen Brothers Site	11	70.0	4
East Bennett Road South Site	6	68.3	5
East Bennett Road North Site	5	66.7	6
Grass Valley Hay and Feed Site	10	66.7	6
McCourtney Transfer Station Site	14	65.0	7
Railroad Avenue Batch Plant Site	17	63.3	8
Pleasant Valley Site	16	60.0	9
Railroad Avenue Propane Facility Site	18	60.0	9
South Auburn Site	19	51.7	10
Fairgrounds Site	7	50.0	11
Auburn Road Site	2	43.3	12
Cement Hill	3	0.0	13
Former Meeks Lumber	8	0.0	13

BIOMASS FEEDSTOCK AVAILABILITY AND COST ANALYSIS

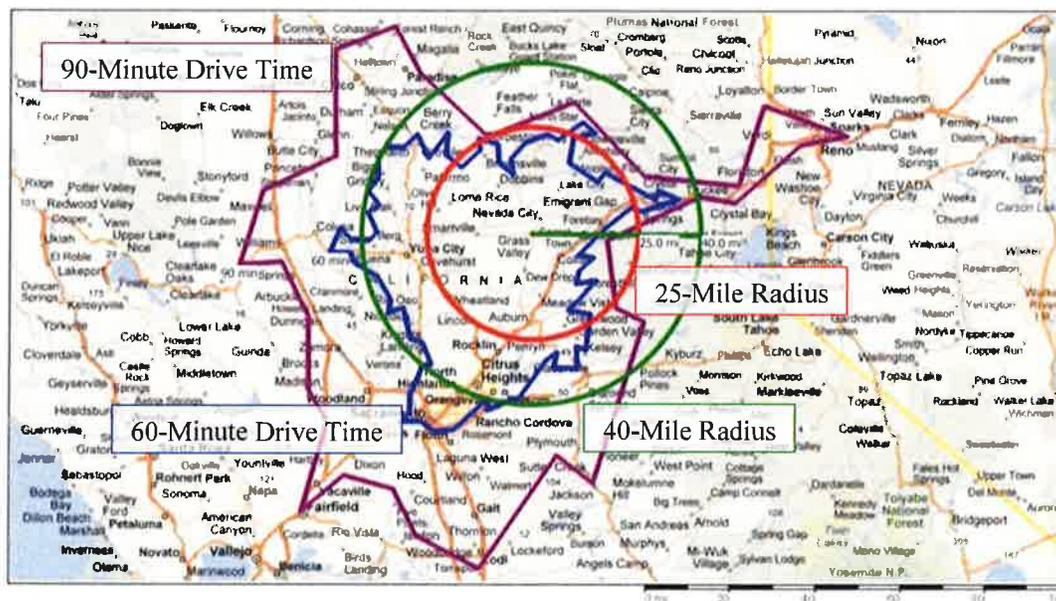
Woody biomass material sources considered in this feedstock availability analysis include a range of forest, urban, and agricultural material.

- Forest-sourced biomass:
 - Timber harvest residuals generated as a by-product of forest management activities (residuals that are typically piled and burned).
 - Excess forest biomass material generated as a by-product of fuels treatment and plantation thinning activities.
- Urban-sourced wood waste, including clean construction, demolition wood waste, and green waste from residential tree trimming and brush removal.
- By-product of commercial agricultural operations.

Target Study Area

Consistent with the objectives of the feedstock availability analysis, the Target Study Area (TSA) was defined by economic haul zones. Figure 2 identifies the 25-mile and 40-mile radius TSA and the 60-minute and 90-minute drive time zones from Grass Valley.

Figure 2. Drive Time Zones

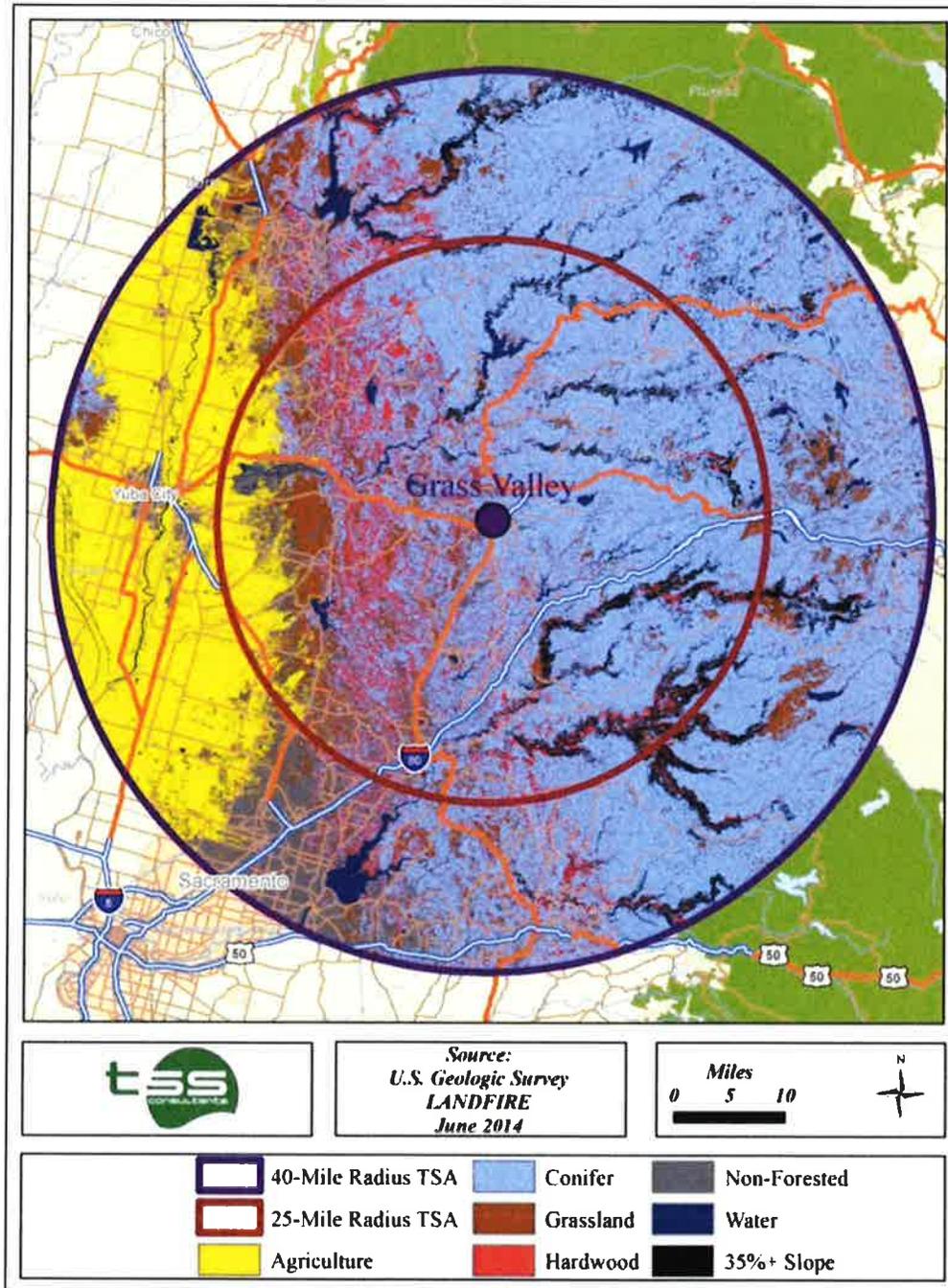


A 25-mile radius encompasses the majority of the 60-minute drive time zone through the forested regions proximate to Grass Valley. While the 60-minute drive time zone extends further east from the 25-mile radius, the focus of this project is to beneficially utilize local forest-sourced woody biomass material. The 40-mile radius captures much of the 90-minute drive time zone and the remainder of the 60-minute drive time zone in the Sacramento Valley. The TSA analysis will include an area equivalent to a 40-mile radius to capture economically viable transport zones in the forest settings.

Vegetation Cover

Woody biomass availability for any given region is heavily dependent on vegetation cover, topography, land management objectives, and ownership. Figure 3 shows the vegetation cover type for the TSA using U.S. Geological Survey LANDFIRE data. The vegetation cover types are categorized as agricultural, conifer, grassland, hardwood, non-forested areas, and water.

Figure 3. Vegetation Cover within the Target Study Area

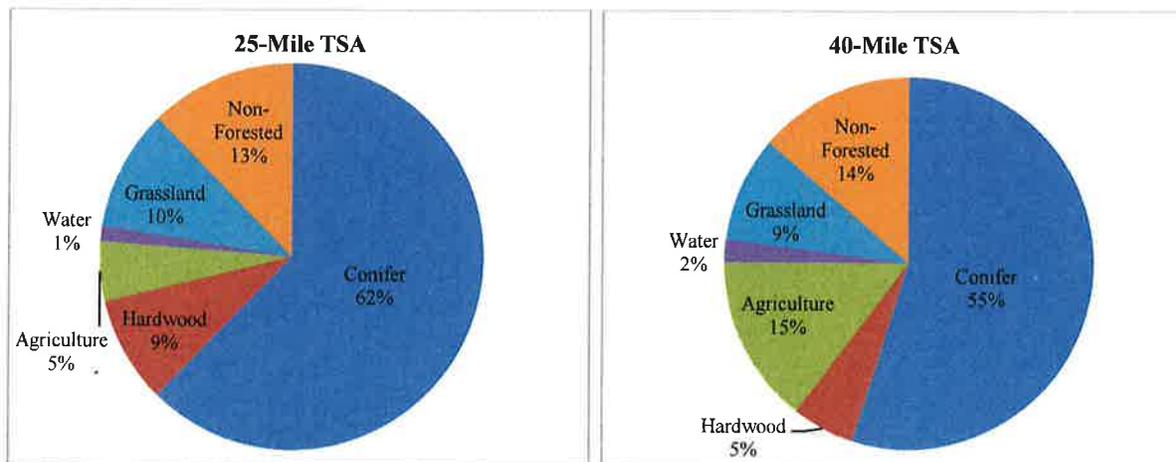


Forest biomass recovery activities are generally restricted to topography that will allow ready access for equipment and crew. Steep topography over 35 percent slope gradient is considered to be the breakoff point for ground-based logging and/or biomass recovery equipment on federally managed⁴ lands. Private land managers typically utilize ground-based equipment on slopes up to 50 percent, but the cost of operating on sustained slopes above 35 percent are typically quite high and are considered prohibitive. Areas with 35 percent slope or higher have been excluded from the TSA and are shown in Figure 3. Note that most of the landscape with 35 percent-plus slope conditions is concentrated in riparian areas that are typically considered critical habitat and are not usually treated at the same level of vegetation removal or treatment as other (non-riparian) forest acreage.⁵ Table 8 and Figure 4 summarize vegetation cover by category within the TSA.

Table 8. Vegetation Cover within the TSA

Cover Categories	25-Mile TSA		40-Mile TSA	
	Acres	Percent of Total	Acres	Percent of Total
Agriculture	59,925	5.0%	454,896	14.6%
Conifer	750,137	62.3%	1,706,269	55.0%
Grassland	121,684	10.1%	284,471	9.2%
Hardwood	107,296	8.9%	169,831	5.5%
Non-Forested	148,839	12.4%	427,687	13.7%
Water	15,862	1.3%	60,771	2.0%
Totals	1,203,743	100.0%	3,103,925	100.0%

Figure 4. Vegetation Cover Distribution



⁴ Primarily U.S. Forest Service and Bureau of Land Management.

⁵ Fuels reduction activities within riparian areas are starting to become of interest due to recognition that typically high stocking levels in riparian areas create conditions that can lead to high intensity fire behavior.

The combination of conifer and hardwood vegetation types makes up the majority of both TSAs (71.2 percent of the 25-mile TSA and 60.5 percent of the 40-mile TSA). The forested landscape is concentrated in the eastern portion of the TSA with conifers as the primary cover type in the higher elevations and hardwoods as the primary cover type in the lower elevations. Agriculture makes up the predominant vegetation cover in the western portions of the TSA and amounts to almost 15 percent of the 40-mile TSA.

Land Ownership/Jurisdiction

Within the forested portions of the TSA, land ownership drives vegetation management objectives. Figure 5 highlights the locations of the various ownerships and jurisdictions. Table 9 and Figure 6 summarize land ownership and jurisdiction within the forested areas of the TSA.

Figure 5. Land Ownership/Jurisdiction within the TSA

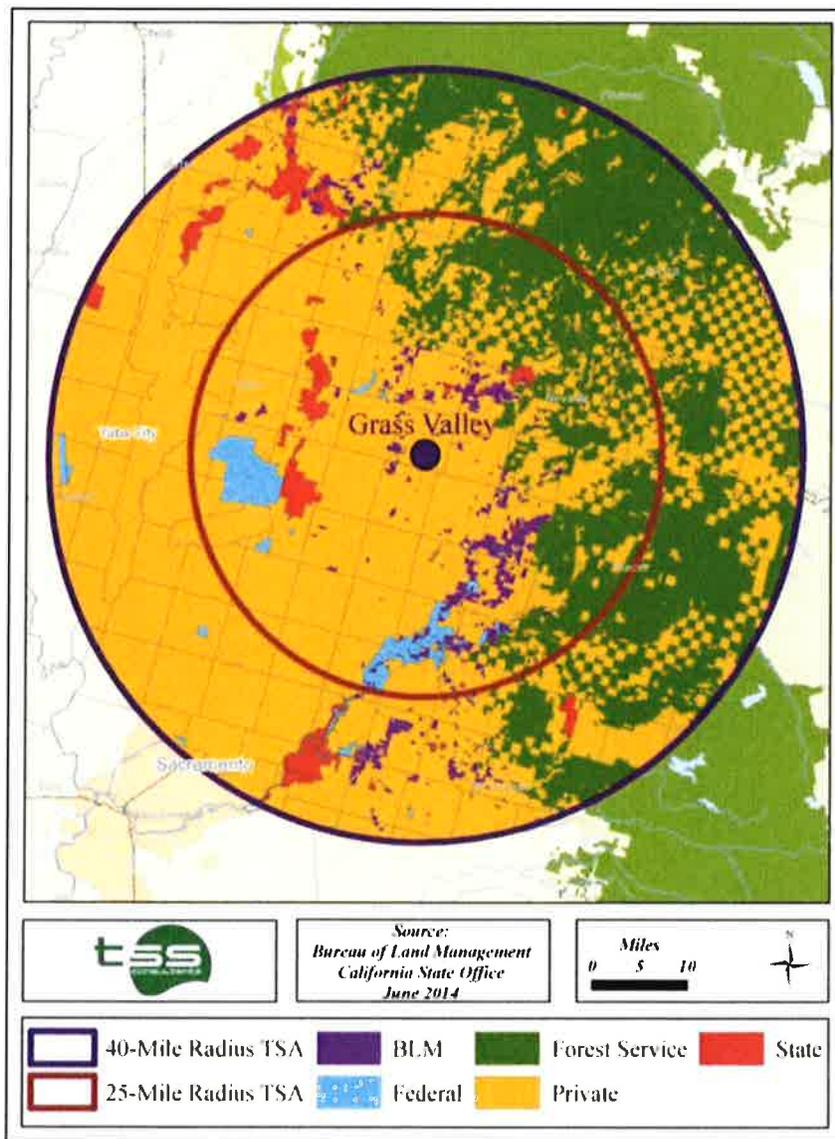


Table 9. Land Ownership and Jurisdiction of Forest Vegetation Cover

Land Owner/ Manager	25-Mile TSA		40-Mile TSA	
	Forested Acres	Percent of Total	Forested Acres	Percent of Total
BLM	33,757	3.9%	46,715	2.5%
Other Federal	15,554	1.8%	16,807	0.9%
U.S. Forest Service	216,199	25.2%	727,914	38.8%
Private	573,387	66.9%	1,052,247	56.1%
State	18,538	2.2%	32,416	1.7%
Totals	857,435	100.0%	1,876,099	100.0%

Figure 6. Land Ownership and Jurisdiction Distribution

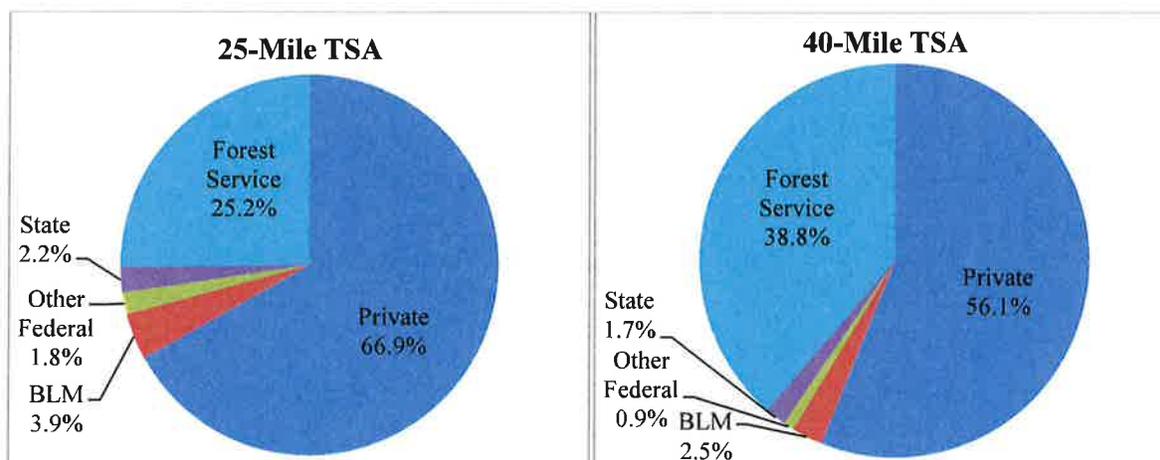


Table 9 and Figure 6 demonstrate the variety in ownership types between the 25-mile and 40-mile TSA. More than half of the private forested ownership and less than one-third of the USFS-managed lands are located within the 25-mile radius. This trend suggests that private forestland management practices will be an important driver of cost-effective feedstock availability, as illustrated in Figure 6, where private landownership represents 67 percent of the ownership within the 25-mile TSA (one-hour haul zone). Extending the TSA to the 40-mile radius will access significantly more USFS-managed land.

For the purposes of this feedstock availability analysis, TSS focused on the 40-mile TSA as the target study area due to its proximity to feedstocks (agricultural and forest) available within an economic haul distance of Grass Valley.

Forest-Sourced Biomass

Timber Harvest Residuals

Timber harvest residuals can provide significant volumes of woody biomass material. Typically available as limbs, tops, and unmerchantable logs,⁶ these residuals are by-products of commercial timber harvesting operations. As such, they have no market value, though they can be a relatively economic raw material feedstock source for bioenergy production. Once collected and processed using portable chippers or grinders, this material is an excellent biomass feedstock.

Timber harvest activity within the State of California is monitored by the Board of Equalization (BOE). The BOE levies timber harvest taxes based on annual timber harvest levels. A review of the 2009 through 2013 BOE timber harvest data was conducted to confirm historic timber harvest activities within the TSA. The BOE data are provided for commercial timber harvests on both private and public lands. Table 10 provides results for private timber harvests, and Table 11 provides results for public timber harvests, expressed in thousand board feet (MBF)⁷ per year.

Table 10. 2009 Through 2013 Timber Harvest Volume Estimates for Private Sawtimber Generated within the TSA

County	2009 (MBF/YR)	2010 (MBF/YR)	2011 (MBF/YR)	2012 (MBF/YR)	2013 (MBF/YR)	Percent of County in TSA	Weighted Average (MBF/YR)
Butte	70,688	31,739	41,978	43,164	37,034	40.9%	18,371
El Dorado	20,120	15,588	34,559	36,847	57,728	32.9%	10,852
Nevada	22,827	10,237	14,855	13,950	25,239	82.6%	14,398
Placer	9,317	33,657	18,657	11,733	33,483	77.9%	16,648
Plumas	45,257	51,618	53,546	71,954	84,330	7.7%	4,743
Sierra	8,131	11,623	12,984	20,663	13,763	50.7%	6,808
Yuba	12,371	13,946	20,461	21,317	14,253	100.0%	16,470
Totals	188,711	168,408	197,040	219,628	265,830	—	88,290

⁶ Unmerchantable logs are typically too small or defective (diseased or dead) to manufacture into lumber.

⁷ MBF = thousand board foot measure. One board foot is nominally 12" long by 12" wide and 1" thick.

Table 11. 2009 Through 2013 Timber Harvest Volume Estimates for Public Sawtimber Generated within the TSA

County	2009 (MBF/YR)	2010 (MBF/YR)	2011 (MBF/YR)	2012 (MBF/YR)	2013 (MBF/YR)	Percent of County in TSA	Weighted Average (MBF/YR)
Butte	0	0	639	2,034	1,067	40.9%	306
El Dorado	61	4,244	5,908	11,700	11,490	32.9%	2,199
Nevada	1,201	1,950	1,292	581	51	82.6%	839
Placer	1,775	8,414	10,046	9,218	25,779	77.9%	8,606
Plumas	18,485	37,378	20,824	12,698	45,408	7.7%	2,085
Sierra	501	9,132	9,060	10,085	9,844	50.7%	3,915
Yuba	0	4,900	3,611	435	1,073	100.0%	2,004
Totals	22,023	66,018	51,380	46,751	94,712	—	19,954

The TSA is made up of portions of seven counties and using GIS analysis, TSS was able to determine the portion of each county that lies within the TSA (as shown in Table 10 and Table 11). Using these data, a weighted average timber harvest figure was calculated for each county. The 2009 through 2013 historic record of timber harvest across all seven counties results in a weighted average annual harvest of 108,244 MBF.

Results of historic timber harvest data review confirm that total harvest levels within the TSA have been inconsistent, ranging from a low harvest in 2009 of 210,734 MBF to a high of 360,542 MBF in 2013. A primary driver is the demand for sawlogs, which was significantly diminished in 2009 and 2010 due to a general downturn in the economy which impacted housing starts and concomitantly, the demand for lumber products and sawlogs. Harvest levels in 2013 suggest that demand for sawlogs has rebounded.

TSS's experience with forest biomass recovery confirms that a recovery factor of 0.9 BDT per MBF of sawlogs harvested would apply for commercial timber harvests in mixed conifer stands within the TSA. This amounts to a gross potential availability of 97,420 BDT per year of timber harvest residuals as feedstock based on historic five-year weighted average timber harvest volume.

Not all road systems will accommodate biomass recovery operations. Based on interviews with land managers⁸ and for the purposes of this feedstock analysis, it is assumed that 60 percent of the timber harvest operations on publicly managed lands and 70 percent on privately managed lands within the TSA are located on road systems that will support biomass feedstock transport using conventional chip vans.

Forest biomass that qualifies as feedstock consistent with SB 1122 must be sourced as "by-products of sustainable forest management" as designated by the Department of Forestry and Fire Protection (CAL FIRE). Appendix C includes the full text of SB 1122. CAL FIRE

⁸ Mark Brown, Silviculturist, Tahoe National Forest; Clarence Draper, Road Engineer, Tahoe National Forest; Tim Feller, District Manager, Sierra Pacific Industries; Steve Andrews, Forester, Applied Forest Management.

convened a series of workshops during the fall of 2013 and developed suggested guidelines to meet the intent of SB 1122. These guidelines suggest that forest biomass material sourced from even-age management activities does not qualify as by-product of sustainable forest management. The guidelines recommend that 80 percent of the feedstock utilized be sourced from uneven-age management activities. The remaining 20 percent of the feedstock can be made up of by-products from even-age management activities, agricultural by-products or urban wood waste (no treated or painted wood). TSS recommends that due to the more cost-effective nature (as noted in Table 18) and wintertime availability of agricultural by-products and urban wood waste, the 20 percent feedstock blend not include material sourced from even-age forest management activities (even though this is currently allowed by SB 1122 guidelines).

The draft guidelines (Appendix D) were delivered to the CPUC in April 2014. The CPUC is currently deliberating and has not reached a proposed decision, but for the purpose of this feedstock availability analysis, TSS assumes that these guidelines will be implemented.

Interviews with foresters managing private forest lands within the TSA confirmed that about 50 percent of the timber harvested is from even-age management activities. Interviews with foresters managing public lands confirmed that no even-age management activities occur on publicly managed forests within the TSA.

Forest biomass feedstock considered technically available has been screened for road systems that allow biomass transport (60 percent on public lands and 70 percent on private lands), and for SB 1122 compliancy (50 percent on private lands) within the TSA.

Table 12 shows the gross availability along with the technical potential based on the screens previously described.

Table 12. Total Timber Harvest Residual Availability within the TSA

County	Gross Available (BDT/YR)		Technically and Economically Available (BDT/YR)	
	Private	Public	Private	Public
Butte	16,534	275	5,787	165
El Dorado	9,767	1,979	3,419	1,188
Nevada	12,958	755	4,535	453
Placer	14,983	7,745	5,244	4,647
Plumas	4,269	1,876	1,494	1,126
Sierra	6,127	3,523	2,144	2,114
Yuba	14,823	1,803	5,188	1,082
Subtotals	79,461	17,956	27,811	10,775
Totals	97,417		38,586	

The final screening tool, volume considered economically available, is directly tied to existing competition for forest biomass feedstock. Due to the fact that existing biomass power generation facilities are not held to SB 1122-compliant feedstock availability screens, TSS anticipates that the availability of forest biomass from even-age forest management activities will more than

sustain existing biomass power generation facilities. Thus, technically available timber harvest residuals amounting to 38,586 BDT per year are also considered economically available. If there were no SB 1122 sustainability screens, then approximately 66,397 BDT per year of timber harvest residual feedstock would be technically and economically available. Approximately 27,811 BDT per year are not considered available for an SB 1122-compliant bioenergy facility at Grass Valley.⁹

Fuels Treatment, Plantation Thinning, and Utility Line Clearance

The Grass Valley region is home to numerous communities, with residential neighborhoods situated within the wildland urban interface (WUI). Due to high fire danger conditions within the WUI, there are concerted efforts across all forest ownerships to proactively reduce hazardous forest fuels in support of defensible communities. In addition, forest landowners are conducting pre-commercial thinning activities within plantations in order to achieve fuels treatment and stocking control (reducing the number of trees per acre as plantation age and tree size increase). Utility line clearance activities are also a potential source of forest feedstock.

Discussions with the Tahoe National Forest,¹⁰ Fire Safe Councils,¹¹ Natural Resource Conservation Service,¹² PG&E,¹³ and foresters¹⁴ managing private lands provided data on fuels treatment, plantation thinning, and utility line clearance projects and confirmed plans for future treatments. Summarized in Table 13 are the results of those interviews.

Table 13. Forest Fuels Treatment Activities Planned within the TSA

Source	Forest Treatment Activities	
	Low Range (BDT/YR)	High Range (BDT/YR)
Fire Safe Council of Nevada County	150	200
Private Landowners	10,300	14,550
USFS – Yuba River and American River Ranger Districts	10,000	15,000
Utility Line Clearance	1,440	2,500
Yuba County Watershed Protection & FSC	250	375
Totals	22,140	32,625

Due to very limited value-added markets for woody biomass material generated as a by-product of forest fuels treatment activities, most of the fuels treatment operations are processing (mastication or chipping) excess forest biomass and leaving it on site or piling and burning as the

⁹ Due to even-age management land techniques.

¹⁰ Mark Brown, Silviculturist, Tahoe National Forest.

¹¹ Joanne Drummond, Executive Director, Nevada County Fire Safe Council; Glenn Nader, Yuba County Watershed Protection and Fire Safe Council.

¹² Matt McNicol, Forester, Natural Resources Conservation Service.

¹³ Rand Smith, Supervisor, Program Manager, Vegetation Management, PG&E.

¹⁴ Steve Andrews, Forester, Applied Forest Management; Tim Feller, District Manager, Sierra Pacific Industries; Dan Kruger, President, Soper Wheeler Company.

primary disposal technique. Discussions with project coordinators and foresters indicated that if a ready market for biomass existed, with values high enough to recover most of the processing and transport costs, significant biomass volume would be diverted away from current business-as-usual activities (e.g., mastication, chip, pile and burn).

Interviews with forest managers and fiber procurement foresters confirmed that between 10 and 15 BDT per acre of biomass is considered recoverable during fuels treatment and plantation thinning activities. Figures shown in Table 13 assume an average recovery factor of 12.5 BDT per acre. In addition to fuels treatment and plantation thinning operations within the TSA, PG&E conducts power distribution and transmission line clearance activities. Discussions with PG&E vegetation management staff¹⁵ confirmed that power distribution and transmission line clearance in support of hazard tree trimming and removal is conducted regularly within the TSA. Based on operations over the last five years, approximately 1,440 BDT to 2,500 BDT per year are generated from utility line clearance activities within the TSA.

Gross availability of fuels treatment and plantation thinning material assumes no screens. Technical availability is screened based on topography and road systems similar to the timber harvest residual screen (70 percent technical availability on private lands and 60 percent technical availability on private lands). There is currently very little market demand or competition for this biomass material, as reflected in the fact that most of this volume is masticated, chipped and scattered, or piled/burned. The economic screen assumes that 80 percent of the fuels treatment and plantation thinning material is available due to the competitive feedstock pricing that an SB 1122-compliant facility will likely be able to provide. In addition, a primary objective of the Task Force is recovery and utilization of forest feedstocks sourced from fuels treatment activities. TSS assumes that a bioenergy facility located at Grass Valley will provide a competitive price for fuels treatment and plantation thinning material. Table 14 summarizes findings regarding availability of fuels treatment and plantation thinning material sourced from within the TSA.

Table 14. Fuels Treatment, Plantation Thinning, and Utility Line Clearance Material Availability within the TSA

Source	Gross Availability (BDT/YR)	Technically Available (BDT/YR)	Economically Available (BDT/YR)
FSC of Nevada County	175	123	98
Private Landowners	12,425	8,698	6,958
USFS – Yuba River Ranger District and American River Ranger District	12,500	8,750	7,000
Utility Line Clearance	1,970	1,379	1,103
Yuba County Watershed Protection and Fire Safe Council	313	219	175
Totals	27,383	19,169	15,334

¹⁵ Rand Smith, Vegetation Management, Distribution and Eric Brown, Vegetation Management Transmission, PG&E.

Summarized in Table 15 are findings regarding forest-sourced feedstock availability within the TSA.

Table 15. Forest-Sourced Biomass Feedstock Availability within the TSA

Source	Gross Availability (BDT/YR)	Technically Available (BDT/YR)	Economically Available (BDT/YR)
Timber Harvest Residuals	97,418	38,586	38,586
Forest Treatments	27,383	19,168	15,334
Totals	124,801	57,754	53,920

Urban-Sourced Biomass

Construction and Demolition Wood

Wood waste generated by local residents, businesses, and tree service companies (not including utility line work) within the TSA regularly generate wood waste in the form of construction debris, demolition wood, industrial by-products (e.g., pallets), and tree trimmings. Within the TSA resides an estimated population of approximately two million residents.¹⁶ Based on TSS's experience with urban wood waste generation, approximately 11.5 pounds per capita of waste is generated daily, with 10.5 percent of the solid waste stream made up of wood waste. Gross annual availability, using this generation factor and assuming a 20 percent moisture content factor (based on previous assessments), is calculated at approximately 113,610 BDT of urban wood waste within the TSA. Of this material, about 65 percent is recoverable as clean wood waste and is considered technically available at 86,847 BDT per year. Economic availability was calculated assuming that 75 percent of the technically available urban wood is utilized as landscape cover, alternative daily cover (at landfills) or as biomass fuel in existing biomass power generation facilities (see feedstock competition discussion below). Approximately 21,712 BDT per year of clean urban wood waste is considered economically available in the TSA.

Tree Trimming Material

Working from previous studies performed by TSS, it is estimated that approximately 100 dry pounds of tree trimmings (not including utility line clearance) suitable for feedstock is generated annually per capita. Based on a population of just over 2 million residents, approximately 37,895 BDT per year of tree trimmings, (gross availability) are generated within the TSA. TSS assumes approximately 65 percent of this wood waste is actually recoverable as biomass feedstock, with technical availability of about 24,632 BDT per year. Existing uses for tree trimming material, including firewood, soil amendment (e.g., mulch), alternative daily cover, and fuel at biomass power plants are well established. TSS assumes that 85 percent of this material is currently utilized. Therefore, TSS calculates that approximately 3,695 BDT of tree trimming material is economically available as biomass feedstock each year sourced from within the TSA.

¹⁶ Per 2013 data provided by the U.S. Census Bureau.

Summarized in Table 16 are findings regarding urban-sourced feedstock availability within the TSA.

Table 16. Urban-Sourced Biomass Feedstock Availability within the TSA

Source	Gross Availability (BDT/YR)	Technically Available (BDT/YR)	Economically Available (BDT/YR)
Construction and Demolition	133,610	86,847	21,712
Tree Trimming	37,895	24,632	3,695
Totals	171,505	111,479	25,407

Agriculture-Sourced Biomass

As noted in the vegetation cover analysis (see Table 8), almost 15 percent of the TSA includes land dedicated to commercial agriculture (approximately 454,896 acres). Many of these acres are dedicated to raising commercial crops that produce significant volumes of wood waste from orchard removal activities and annual pruning practices. Table 17 summarizes commercial orchard acreage currently in production¹⁷ within the TSA.

Table 17. Commercial Orchard Acreage by Crop within the TSA

Crop	Acreage	Percent of Total Orchard Acres in TSA
Almond	7,953	8.0%
Grape	3,445	3.5%
Peaches	3,148	3.2%
Pears	1,107	1.1%
Plums	30,173	30.5%
Walnuts	51,376	52.0%
Other Tree Crops	1,660	1.7%
Totals	98,862	100.0%

Woody crops are removed on a rotational basis that varies by crop. TSS, in collaboration with the University of California (UC) Davis Agricultural Extension and local orchard removal contractors, has identified replacement intervals and biomass recovery rates for major tree crops within the TSA (Table 18). Crop replacement intervals help provide an assessment of average expected biomass availability, assuming acreage is consistently replanted to commercial orchards.

¹⁷ Data courtesy of National Agricultural Statistics Service.

Table 18. Commercial Crop Replacement Interval and Biomass Recovery Rates

Crop	Replacement Interval (Years)	Biomass Recovery (BDT/Acre)	Average Recovery Rate (BDT/Acre-Year)
Almond	28	28.5	1.02
Grape	22.5	3.7	0.16
Peach	11.25	18.6	1.65
Pear	75	20.9	0.28
Plum	11.25	18.5	1.64
Walnut	30	28	0.93

Using the replacement interval and biomass recovery rates identified in Table 18, TSS calculated gross availability of agriculture-sourced feedstock within the TSA. TSS did not include the potential biomass from the “Other Tree Crop” (considered minor at 1.7 percent of the total) or grape vines, as grape vines removed are contaminated with trellis wire and metal stakes that are impractical to remove.

In addition to orchard removals, there is pruning material generated that if recovered, could be processed into biomass feedstock. Discussions with UC Agricultural Extension staff confirmed potential pruning volumes available by crop. Table 19 summarizes potential pruning feedstock available by crop and the potential harvestable percentage (not all pruning material is considered technically recoverable).

Table 19. Commercial Crop Pruning Material and Biomass Recovery Rates

Crop	Annual Pruning Biomass Yield (BDT/Acre)	Harvestable Percentage
Almond	0.65	70%
Peach	1.3	50%
Pear	1.5	50%
Plum	0.98	50%
Walnut	0.5	70%

Utilizing orchard crop acreage data, crop rotation interval, and pruning yield per acre, TSS estimates gross annual availability of 177,355 BDT for orchard removal and pruning material within the TSA.

Not all pruning material is harvestable, so for the technically available calculation, TSS assumed harvestable fractions for the pruning, as shown in Table 19. Technically available orchard removal and pruning material amounts to about 138,094 BDT per year within the TSA.

The economically available calculations take into account competing uses (e.g., firewood, bioenergy) and recovery costs (no pruning due to high collection costs). TSS found that

approximately 75 percent of the technically available material (after removing pruning material) is currently utilized as firewood and biomass fuels, leaving 33,801 BDT of agriculture-sourced feedstock as economically available per year within the TSA. Table 20 provides an overview of gross, technical, and economic availability of orchard material.

Table 20. Agriculture-Sourced Biomass Feedstock Availability within the TSA

Source	Gross Availability (BDT/YR)	Technically Available (BDT/YR)	Economically Available (BDT/YR)
Almond	13,265	9,646	2,024
Peaches	9,296	7,250	1,301
Pears	1,968	1,138	77
Plums	79,188	64,403	19,382
Walnuts	73,639	55,657	11,017
Totals	177,356	138,094	33,801

Biomass Feedstock Availability Findings

Current feedstock availability for the TSA is significant. Table 21 highlights feedstock availability findings.

Table 21. Current Biomass Feedstock Availability by Source within the TSA

Source	Gross Availability (BDT/YR)	Technically Available (BDT/YR)	Economically Available (BDT/YR)
Forest	124,800	57,753	53,920
Urban	171,505	111,479	25,407
Agriculture	177,356	138,094	33,801
Totals	473,661	307,326	113,128

SB 1122-compliant forest feedstock considered economically available totals 53,920 BDT per year. Assuming the community-scale bioenergy facility is scaled at 3 MW (the maximum scale allowed by SB 1122) and utilizes 24,000 BDT per year of forest feedstock, there is a feedstock coverage ratio of 2.25:1. The private financial sector typically requires a feedstock coverage ratio of at least 2:1 as a critical feedstock availability screen for bioenergy project financing. If urban and agriculture sourced feedstocks are included in the calculation (113,128 BDT available), then a feedstock coverage ratio of 4.7:1 is representative of economic availability.

Biomass Feedstock Competition Analysis

Current Competition

Currently there are very limited markets for forest biomass material generated within the TSA. Existing biomass power generation facilities procuring biomass feedstock in the region that may occasionally source feedstock from the TSA are summarized in Table 22.

Table 22. Facilities Currently Sourcing Forest Biomass Feedstock from the TSA

Facility	Location	Scale (MW)	Distance from Grass Valley (miles)¹⁸
Rio Bravo Rocklin	Rocklin	25	36
Sierra Pacific Lincoln	Lincoln	18	37
DTE Woodland	Woodland	25	70
Buena Vista Biomass Power	Ione	18	73

Interviews with fuel procurement managers in the region confirmed that very little forest biomass feedstock is currently sourced from the TSA. Only Rio Bravo Rocklin and SPI Lincoln have occasionally procured forest feedstock that is tributary to Grass Valley. Both facilities have ready access to more cost-effective urban feedstock, forest products residuals, and agriculture feedstocks that minimize the need to procure more costly forest-sourced feedstocks. In addition, the Buena Vista Biomass Power facility is constrained in its ability to procure forest biomass feedstock due to its commitment with the Center for Biological Diversity to source no more than 15 percent of its total feedstock needs (averaged over a three-year period) from forest operations.

TSS estimates that between 15,000 and 20,000 BDT of forest-sourced feedstock may be procured annually from within the TSA as feedstock for existing biomass power plants that are located tributary to the TSA. Note that none of these facilities are held to the SB 1122 forest feedstock screen of material sourced from “sustainable” forest management operations. There will likely be minimal competitive impacts on forest feedstock volume considered economically available for a project at Grass Valley because existing biomass power plants have ready access to all forest biomass (subject to no SB 1122 screens) generated within the TSA.

Urban and agriculture feedstocks are also utilized by existing biomass power plants and other enterprises as landscape cover, soil amendment, alternative daily cover, and firewood. As part of the economically available screens, TSS assumed that 15 percent of the tree trimmings and 25 percent of the construction/demolition wood (for more details see discussion in Urban-Sourced Biomass section) is available after adjustment for existing competition. For agriculture-sourced feedstock, TSS assumed that 25 percent of the orchard removal material (for more details see the discussion in the Agriculture-Sourced Biomass section) is available after adjustment for existing competition.

Potential Competition

There are several community-scale bioenergy facilities (see Table 23) and one existing biomass power plant restart that may compete for feedstock with the proposed Grass Valley bioenergy facility. Of the four facilities that may compete for feedstock, only the Camptonville facility is likely to require SB 1122-compliant forest feedstock. The Camptonville Community Partnership is the project sponsor and is planning to solicit proposals to complete a bioenergy project

¹⁸ Distance figures were derived from general locations as opposed to specific street addresses, as the bioenergy project site location may change.

feasibility study in the next few months.¹⁹ Table 23 identifies potential bioenergy facilities that may compete for forest biomass feedstock generated within the TSA.

Table 23. Facilities Potentially Competing for Feedstock

Facility	Location	Scale (MW)	Distance from Grass Valley (Miles)
Camptonville	Celestial Valley	2–3	27
Foresthill	Foresthill	3–5	42
Cabin Creek Biomass Power	Truckee	2	58
Loyalton	Loyalton	20	93

At this time, it is too early to predict how the potential Camptonville facility might compete with a bioenergy project at Grass Valley. Due to feedstock transport challenges (e.g., Highway 49), feedstock competition from a bioenergy project at Camptonville (if developed) should be minimal. The location of the biomass power generation facilities is considered to be current and potential competition is highlighted in Figure 7.

¹⁹ Per discussions during the August 21, 2014, community workshop.

Biomass Feedstock Availability Forecast

Summarized in Table 24 are the current, five-year, and ten-year forecasts of biomass feedstock considered economically availability from the TSA.

Table 24. Current, Five-Year, and Ten-Year Forecast of Biomass Feedstock by Source Economically Available within the TSA

Source	Current (BDT/YR)	Five-Year (BDT/YR)	Ten-Year (BDT/YR)
Forest	53,920	57,155	61,727
Urban	25,407	26,169	27,478
Agriculture	33,801	34,477	36,201
Totals	113,128	117,801	125,406

Assumptions used for the five-year forecast include:

- General improvement in the local and regional economy (more urban wood waste generated) with slight increase in population;
- Slightly improved saw timber markets (mild increase in timber harvest on public and private forest lands); and
- Increased forest fuels reduction activities and plantation thinning due to improvement in market prices for forest feedstocks.

Assumptions used for the ten-year forecast include:

- Continued improvement in the local and regional economy (more urban wood waste generated) and increase in population;
- Continued improvements in saw timber markets;
- Reduced regional competition for biomass feedstocks due to Wheelabrator Shasta and Rio Bravo Rocklin curtailment (current power purchase agreements terminate in 2018); and
- Continued increased rates of forest fuels reduction activities and plantation thinning due to improvement in market prices for forest feedstocks.

Costs to Collect, Process, and Transport Biomass Material

Commercial-scale infrastructure to collect, process, and transport biomass material currently exists within the TSA. TSS relied on interviews with local contractors in addition to TSS's past experience to analyze these costs. Table 25 provides results of the cost analysis.

Table 25. Biomass Collection, Processing and Transport Costs with Grass Valley as Destination

Biomass Material Source	Delivered Material	Low Range	High Range
Timber Harvest Residuals	Chips	\$45/BDT	\$60/BDT
Forest Treatments – USFS/FSC/Private	Chips	\$55/BDT	\$70/BDT
Urban	Chips	\$22/BDT	\$30/BDT
Agriculture	Chips	\$34/BDT	\$42/BDT
Local Homeowners (delivering unprocessed clean wood waste)	Limbs, Construction Debris, Misc. Wood	\$10/BDT	\$15/BDT

Assumptions used to calculate range of costs:

- No service fees or cost share arrangement is available from public agencies or private landowners.
- One-way transport averages 30 miles for biomass feedstocks.
- Forest biomass is collected and processed (chipped) into the truck at the landing at a cost of \$30 to \$44/BDT.
- Haul costs are \$100/hour for a walking floor chip trailer.
- Local homeowners deliver raw wood (limbs, small trees, clean construction wood) with processing costs ranging from \$10 to \$15/BDT.
- Delivered costs for urban and agriculture feedstocks are based on current biomass feedstock market prices.
- Biomass feedstocks average 14 BDT/load delivered to Grass Valley.

Note that topography, stand density (pre-treatment), stem size, and road systems all have significant impacts on the costs to collect, process, and transport forest feedstocks. Harvest equipment (e.g., feller bunchers and skidders) does not operate as cost effectively on steep topography (e.g., 25 percent-plus slope conditions) as on level topography. Forest stands that are considered dense (removal rates of 14 to 20 BDT per acre) allow harvest equipment to operate efficiently and cost effectively. Forest stands considered less dense (e.g., 8 BDT or less per acre) require more travel time between trees by the feller bunchers and longer distances between biomass bundles for skidders.

As shown in Table 25, the delivered cost of forest feedstock from fuels treatment activities is significant (\$55 to \$70 per BDT). There is potential for cost-share funding (federal and state) from existing programs that are designed to support fuels reduction, forest health improvement, and watershed protection. Programs administered by the USFS, CAL FIRE, and the Natural Resources Conservation Service may provide cost-share funding that reduces the delivered cost of forest feedstocks.

The most cost-effective forest feedstock will be sourced from timber harvest residuals stockpiled at the landing. As a by-product of commercial timber harvests, this material (limbs, tops) has been harvested and skidded to the landing in conjunction with sawlog harvesting. The current fate of this material is disposal, using open burning as the preferred technique. In addition to

being the most cost-effective forest feedstock, utilizing this wood waste as biomass feedstock for bioenergy significantly reduces air emissions²⁰ when compared to the current pile/burn technique.

Local homeowners generate significant quantities of limbs and small stems consistent with fuels reduction activities near homes. In addition, miscellaneous wood waste (e.g., clean construction wood) is potentially available and could be utilized as feedstock. TSS recommends that the Grass Valley bioenergy facility (if developed) consider accepting woody material from Nevada County homeowners and tree service companies. This material can be stockpiled on site, and a mobile chipper can be utilized from time to time (e.g., every 60 days) to process this material for use as a feedstock.

Current Market Prices

Demand for woody biomass material currently exists within the TSA. Several biomass power plants are actively procuring biomass fuel in the form of delivered chips. Current prices range from approximately \$38 to \$46 per BDT for forest-sourced feedstock, \$24 to \$28 per BDT for urban-sourced feedstock, and \$34 to \$38 per BDT for agriculture-sourced feedstocks. Note that in some cases, the feedstock suppliers' costs to deliver biomass feedstock to a bioenergy facility exceed market prices (e.g., forest-sourced feedstocks). In these cases, the feedstock is either located in close to the bioenergy facility (low transport costs) or the landowner is paying a service fee (usually assessed per acre) to the feedstock supplier.

Time of Year Availability

Discussions with Grass Valley area foresters confirm that the typical season for field operations is April 15 through November 15. A variety of factors impact this, including inclement weather patterns, snow depth, and wet conditions (e.g., concerns regarding potential soil disturbance). Considering the seasonal availability of forest feedstock, there will need to be accommodations on site at the bioenergy facility in order to assure that some volume of feedstock is stockpiled for use during winter months when access to forest operations is minimal. TSS recommends that a feedstock procurement strategy be developed that assures feedstock sourcing be concentrated at upper elevation locations during summer months and lower elevation locations in the winter. This will optimize the operating season for feedstock suppliers while mitigating the need to stockpile large volumes of feedstock at the bioenergy facility. In addition, agriculture-sourced feedstock is typically available in the winter months (after nut harvest) and aligns well with feedstock procurement to facilitate wintertime delivery. SB 1122 draft guidelines currently allow for up to 20 percent of the annual feedstock volume utilized can be made up of by-products from even-age management activities, agricultural by-products, or urban wood waste (no treated or painted wood). TSS recommends that most of the 20 percent feedstock considered for the Grass Valley facility be sourced during winter months from urban and agriculture sources. There may be an opportunity to recommend to local residents that tree pruning be conducted during late fall and winter when there are optimal conditions (trees are typically dormant), and the bioenergy facility has room for additional feedstock.

²⁰ Bruce Springsteen, Ton Christofk, Steve Eubanks, Tad Mason, Chris Clavin, and Brett Storey, "Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning," *Journal of the Air and Waste Management Association*, Volume 61, January 2011, pp. 63–68.

State and Federal Environmental Compliance

Commercial forest operations on private lands such as timber harvests require a State of California approved Timber Harvest Plan, in compliance with CEQA. CAL FIRE is the lead state agency that administers Timber Harvest Plans.

On federally managed lands, vegetation management activities must be compliant with the National Environmental Policy Act (NEPA). The USFS and the Bureau of Land Management (BLM) conduct a NEPA analysis before commencement of vegetation management activities. Forest biomass utilized as feedstock is primarily a by-product of forest management activities that will occur, with or without a ready market for the by-product material. As noted earlier, the current business-as-usual practice is to pile and burn this material.

Five-Year Biomass Feedstock Cost Forecast

The optimized feedstock blend for the facility is shown in Table 26 and represents an SB 1122-compliant feedstock mix. Noting that there is more than enough feedstock to sustain a bioenergy facility scaled at 3 MW, TSS assumed an annual feedstock demand of 24,000 BDT.

Table 26. Optimized Feedstock Blend

SOURCE	VOLUME (BDT/YR)	PERCENT OF TOTAL
Forest	19,200	80%
Urban	1,000	4%
Agriculture	3,800	16%
TOTALS	24,000	100%

Table 27 represents a five-year biomass feedstock cost forecast for a community-scale bioenergy facility at Grass Valley. The five-year forecast commences in 2017, as this would likely be the earliest that a community-scale bioenergy facility at Grass Valley could attain commercial operations.

The starting cost of \$53.10 per BDT is based on the weighted average (Table 26) of feedstock availability (Table 24) and cost (Table 25).

Table 27. Five-Year Feedstock Cost Forecast 2017 to 2021

	2017	2018	2019	2020	2021
Base Case	\$53.10	\$53.63	\$54.05	\$54.62	\$55.16
Worst Case	\$55.90	\$57.58	\$59.30	\$61.09	\$62.93

The feedstock cost forecast presented in Table 27 is based on the following assumptions.

Base Case:

- The feedstock supply chain is fully developed with feedstock available from forest-based operations.
- Diesel fuel prices remain near \$4.25 per gallon through 2017, then escalate at 1.5 percent per year.
- Labor rates remain stable through 2017, then climb at 2 percent per year.
- The Wheelabrator Shasta Energy and Rio Bravo Rocklin facilities curtail operations in 2018 (as current power purchase agreements terminate), causing regional urban and agriculture feedstocks to drop slightly in market value.
- Biomass feedstock costs escalate at a 1 percent annual rate due to increased diesel fuel and labor costs from 2017 through 2021.

Worst Case:

- Feedstock supply chain is fully developed with feedstock available from forest-based operations.
- Loyaltan biomass power facility is restarted in 2015, Camptonville community-scale bioenergy facility commences commercial operations in 2017 causing market response and elevated market prices for feedstocks.
- Diesel fuel prices remain near \$4.25 per gallon through 2017, then escalate at 4 percent per year.
- Labor rates remain stable through 2013, then climb at 2 percent per year.
- Biomass feedstock costs escalate at 3 percent annual rate due to increased diesel fuel and labor costs from 2014 through 2017.

Forest-Sourced Biomass Collection, Processing and Transport Jobs

A 3 MW bioenergy facility will utilize approximately 19,200 BDT of forest feedstock per year (Table 26). This equates to approximately ten truckloads per weekday for seven months. A forest feedstock collection, processing, and transport enterprise scaled at ten truckloads per day and focused on utilization of timber harvest residuals will require approximately six skilled equipment operators (including truck drivers) and one field supervisor. Urban and agriculture feedstocks collection, processing, and transport will require skilled operators as well, but to a lesser degree, considering the optimized feedstock blend (Table 26).

BIOENERGY TECHNOLOGY REVIEW

There are a variety of options for the conversion of woody biomass feedstocks to energy, including biomass-to-heat and biomass-to-electricity. In addition, significant research has been focused on the conversion of woody biomass to produce biomethane, advanced biofuels, biochemicals, and bio-products. However, these advanced conversion alternatives have not yet reached commercial deployment, particularly at the community-scale level.

Biomass-to-heat is the most fundamental and widespread conversion technology, as shown by the basic campfire. Now, commercial boiler systems have developed high-efficiency systems to capture and transport heat in a clean-burning environment. Biomass-to-heat projects typically replace high-cost propane and fuel oil and are found throughout the northern U.S., particularly in New England (where there is significant demand for thermal energy).

Commercial biomass-to-electricity conversion technologies entered California in the 1980s with the development of large-scale biomass power plants rated to generate 20 MW to 50 MW of renewable electricity. These installations utilized various direct combustion technologies, including stoker boilers, bubbling fluidized bed boilers, and circulating fluidized bed boilers. In 2010, the first community-scale commercial biomass-to-electricity product was developed using gasification technology at a scale of 0.5 MW. Interest in gasification technology has developed throughout California due to the technology's relatively small footprint, clean emissions profile, limited water demand, and efficiencies at the community scale (3 MW or less).

Woody biomass feedstock for these processes can be in the form of ground or chipped material, torrefied wood, or pellets. In California, processed material is the most common feedstock resource in the biomass-to-electricity sector. While the pellet market has grown significantly over the last decade, growth in the market is primarily driven by European demand for woody biomass feedstock to reduce greenhouse gas emissions.

As identified in the Preliminary Site Analysis, there are no significant heat loads identified during the site selection process within western Nevada County. TSS will focus the technology review on technologies designed for the conversion of biomass to electricity.

Technology Opportunities

Woody biomass cannot be directly converted to electricity. Two pathways are common with current technological innovations:

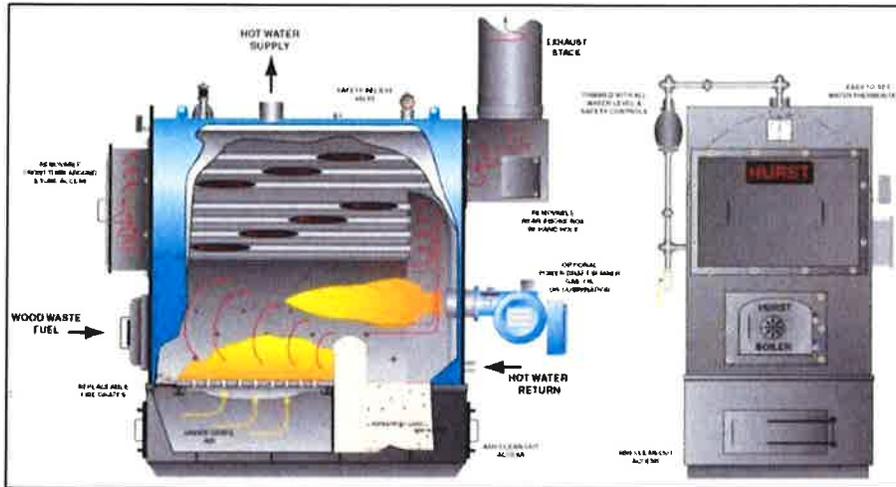
- Biomass-to-Heat
- Biomass-to-Gas

Biomass-to-Heat

Biomass-to-heat can occur with both direct combustion technologies and gasification technologies. The biomass-to-heat process in a direct combustion configuration results from the

combustion of wood to produce heat that is transferred to a liquid solution. This process is depicted in Figure 8, with the biomass combustion at the base of the equipment and the heat exchanger shown as the piping in the top-half of the equipment.

Figure 8. Direct Combustion Schematic



Source: Hurst Boiler (http://www.hurstboiler.com/boilers/solid_fuel_fired/firebox_lpd_hf)

The biomass-to-heat process in a two-stage combustion²¹ or gasification configuration results from the biomass being converted to a gas that is subsequently combusted to produce heat, which is captured with a liquid solution. As shown in Figure 9, a two-stage combustion configuration gasifies the feedstock in the left chamber and ignites the gas for combustion in the right chamber, where the heat exchanging pipes are located.

Figure 9. Two-Stage Combustion Schematic

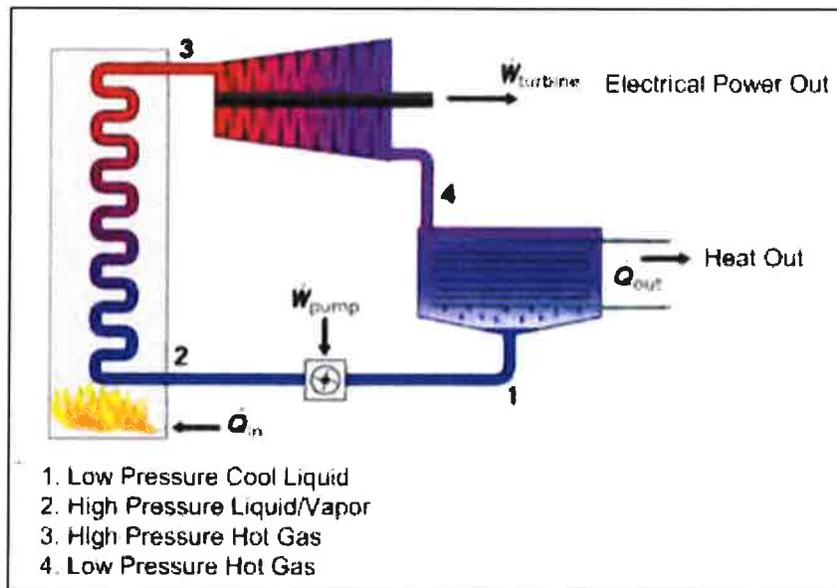


Source: Chiptec (www.chiptec.com)

²¹ The definition of *gasification* can be complex. Some technologies have the ability to capture the gas while others direct the gas to an alternate chamber where it is combusted without the potential for capture and diversion. For the purposes of this report, *two-stage combustion* is defined as a system configuration that has a gasification step but is not configured to capture and divert the gas. Gasification technologies offer the ability to capture and divert gas.

The heated liquid solution is utilized in a closed-loop system with an evaporating, expanding, and condensing side. In a traditional simple-cycle boiler system, the liquid solution is primarily water. Heat creates steam which expands through the steam turbine and is subsequently condensed for return to the boiler. An organic Rankine cycle (ORC) unit utilizes similar technology but uses a working fluid (e.g., toluene, ammonia, refrigerants) to increase efficiencies. ORC units typically have higher efficiencies in small applications. Figure 10 illustrates an ORC cycling with the heat source located on the left, which heats the liquid solution. The liquid solution runs through a turbine and then is cooled and condensed. The pump in Figure 10 between step 1 and step 2 is not present in a simple-cycle steam turbine.

Figure 10. Organic Rankine Cycle Schematic



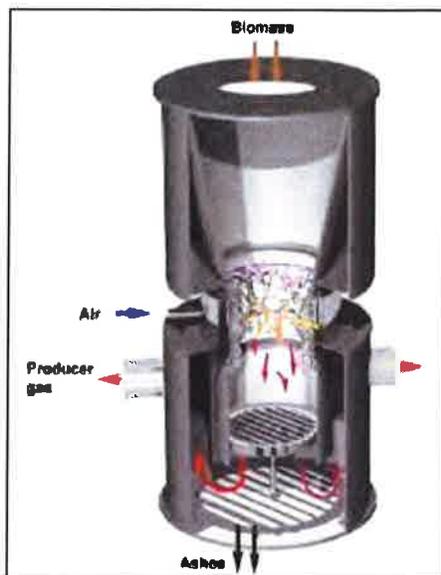
Source: ForceField Energy (<http://www.forcefieldenergy.com/orc.htm>)

Biomass-to-Gas

Biomass-to-gas is unique to gasification configurations. While gasification is not a new technology, it has only recently entered the commercial markets. Figure 11 shows a schematic of a down-draft gasification system. Biomass enters in the top chamber where it is heated without the presence of oxygen by the heat generated in the combustion zone in the middle. Air input is carefully regulated to maintain proper temperature and combustion levels within the combustion zone. Gases from the biomass are released in the high-temperature environment and do not combust due to the lack of oxygen. The gas is pulled through the gasification system and removed in the lower chamber. The remaining material also drops through the gasifier (with help from gravity) and is removed from the bottom grate. While Figure 11 shows the residue as ash, the by-product of the gasification product is biochar.²²

²² Biochar is a carbon-rich by-product with a high percentage of fixed carbon. The biochar market is currently immature but includes filtration and agricultural application.

Figure 11. Gasification System Schematic



Source: Ananta Gasifier Energy Pvt. Ltd.
(www.anantagasificer.com/technology)

The biomass-to-gas process typically requires a gas conditioning system to remove non-combustible material (e.g., water) and contaminants (e.g., tars which are recycled back into the gasifier). The conditioned gas (also known as *synthetic gas* or *syngas*) is subsequently used in an internal combustion engine (ICE) to power a generator.

At the community-scale level, gasification technology with gas conditioning is typically the most efficient conversion technology due to the relatively high efficiency of the ICE compared to comparably-sized steam turbines and ORC engines. However, the required gas conditioning components add extra costs.

Technology Comparison

Table 28 provides a comparison of the technologies outlined above and ranks each configuration relative to the other technology configurations. Technology screens considered include:

- **Technological Maturity:** How long has the specific technology configuration been commercially deployed?
- **Sensitivity to Ambient Conditions:** How much does the technology's performance depend on ambient conditions (e.g., humidity, temperature)?
- **Water Consumption:** How much water is required to operate the system?
- **Feedstock Consumption/Efficiency:** How much feedstock is required to generate a fixed amount of electricity?
- **Air Emissions Profile:** While air emissions can be mitigated, a review of air emissions offers insight into the cost of mitigation necessary to meet local air quality standards.
- **Operational Costs:** An indication of the labor requirements to operate a facility (e.g., number of personnel, special certifications necessary).