New NETWORKS, Part 3: Two Solutions – rev a

By John Benson

August 2021

1. Introduction

This is the last part in a three part series on negative emissions technologies (NET). The first two parts are linked below.

Part 1 of this series was mostly about plants "of the green type, not the product-production type."

https://energycentral.com/c/ec/new-networks-part-1-beccs

Ironically, part 2 (linked below) was about the other type of plants: the product production type, and a simple process that will combine two hazardous industrial wastes, alkaline mineral waste and carbon dioxide (CO_2).

https://energycentral.com/c/ec/new-networks-part-2-mineralization-ghg-capture

California has two challenges. One is the yearly batch of wildfires that keep getting worse every year. In 2020 the acreage burned was more than double any previous year, and other metrics were similarly dire. See the post below for details.

Fires and Storms – Part 1, Rev c:

https://energycentral.com/c/ec/fires-and-storms-%E2%80%93-part-1-rev-c

The other challenge is that we have the most ambitious goals for mitigating climate change in the U.S. These include:

- The 2030 greenhouse gas (GHG) emissions reductions target is 40 percent below 1990 levels.
- The 2050 goal is GHG emissions reduced by 80% below 1990 levels.
- By 2025, 50% of California's electricity is to be powered by renewable resources, 60% by 2030, and 100% renewable electricity by 2045.
- The California Air Resources Board will develop regulations to mandate that 100 percent of in-state sales of new passenger cars and light trucks are zero-emission by 2035.
- All operations of medium- and heavy-duty vehicles should be 100 percent zero emission by 2045 where feasible, with the mandate going into effect by 2035 for drayage trucks.

Also consider that California has the fifth largest economy in the world (if compared with all nations), so the above is definitely a heavy lift.

One might think that the challenge from wildfires would be detrimental to our climate change goals, and indeed in most ways it is, but there is at least one synergy between these as described in the following sections.

2. Mitigating Wildfires through Fuel Reduction

The wildfires do one positive deed – they reduce fuels (mostly flammable brush and trees) that would feed future wildfires. This is why controlled (or prescribed) burns are frequently used to reduce fuels in overgrown areas, especially far from the wildland urban interface (WUI):

Respondents strongly agreed on the need for fuel treatments and fire suppression to protect human infrastructure within and adjacent to the wildland urban interface (WUI). There is a strong consensus that preventing undesired human-set fires in the WUI is essential to reducing societal vulnerability. The strategies for managing fire may be different within and adjacent to the WUI than in areas far from the WUI. However, what fire managers do beyond the WUI has implications for fire behavior approaching the WUI, forest resilience, smoke production and its human impacts, water quality, and many other ecosystem services people value.[1]

However, as pointed out by the above reverenced document, even controlled burns ("fuel treatments") distant from the WUI have negative impacts. This post will suggest a different type of "fuel treatment".

As wildfires worsen, there is a clear need for reduced fuels around populated areas (read: in the WUI). These are frequently bushland (called Chaparral in California). There are also increased needs for firebrakes (also called "fireroad", "fire line" or "fuel break") around these areas and in other areas. These can be created by fuel reduction followed by ongoing maintenance of these areas. The latter can be performed in WUI zones by converting these areas to grass-lands plus grazing early in the fire season, or by planting slow-burn crops (like vineyards). For an example of a landscape that has used these techniques, see the text from an earlier post repeated below.

Chaparral fires are tougher than forest fires. My forest home is in Arnold, CA (4,000 foot elevation and a population of about 4,000). The significant towns below Arnold and the Low Sierras are Murphys (2,200 feet elevation and a population of about 2,200) and Angels Camp (1,400 feet elevation and a population of about 3,800). These are both in Sierra Foothills in south-central Calaveras County. These have had no major chaparral fires that originated in this area in the 22 years that I've owned my forest home (although one major fire spread in from the north). There are large stands of chaparral, but these are separated by large belts of grassland and other less flammable vegetation. It should be noted that these grasslands are dry (our golden hills) by early summer and are also subject to fire, but these fires are much easier to contain and extinguish than chaparral fires. Both Angels Camp and Murphys have volunteer fire departments.

The grassland around Angels Camp is mostly used for grazing, and Murphys is at the center of a medium-sized group of about 20 wineries (part of the Sierra Foothills Viticultural Area). Vineyards are not totally immune to wildfires, but they probably provide reasonable firebreaks verses chaparral, and are probably a bit better than grasslands for most of the fire season. Thus both of these small towns have reasonable slow-burn zones around them to mitigate any chaparral fires.

The most effective strategy for reducing catastrophic losses from wildfires is to minimize the management effort spent on the bulk of the chaparral landscape and focus on

[1] Fire Research Consensus Working Group, "A Statement of Common Ground Regarding the Role of Wildfire in Forested Landscapes of the Western United States, Final Report", September 2018, https://wildfiretoday.com/documents/WildfireCommonGround.pdf

strategic locations. The worst fires predictably follow landscape features, and these patterns can be used to select buffer zones at the urban-wildland interface for more intensive fuel management.[2]

There is also a need for aggressive local fire-fighting when fires do erupt. In the area described above, this function is performed by a combination of local fire departments, CAL FIRE (California Department of Forestry and Fire Protection), and professional firefighters from the U.S. Forest Service. These fire-fighting efforts need to be boosted over time through a combination of improved fire-fighting technology plus increased rapid-response teams.

2.1. Mechanized Fuel Harvesting

In chaparral WUI areas there is a need for increased firebrakes and other slow-burn areas. There is a better way than controlled burns to clear chaparral and small trees. This is various types of automated tree harvesting and brush clearing machines that can quickly clear dangerous chaparral.

Regarding existing tree harvesting machines, go through the link below and you will see seven videos, each of an existing machine in action.

https://www.popularmechanics.com/technology/g2289/tree-eating-machines/

Specific sites for some of the candidate tree harvesting and brush clearing machines are below.

The following link is to the **Brush Crusher** attachment for widely used skid steer loaders. This is made by Westendorf Mfg. Co. Inc., and there is a video on the site to show how it operates.

https://www.loaders.com/Brush-Crusher/Brush-Crusher/Universal-Skid-Steer-Brush-Crusher

There is a class of mechanized tree harvesters that are called **tethered logging systems**. These are for hilly areas where operating conventional tracked harvesting machines would be difficult. The site below is a U.S. Forest Service site that has a video that shows one of these in action.

https://www.fs.fed.us/forestmanagement/equipment-catalog/tethered.shtml

The site below is a good article on **tree harvesting systems**.

https://northernwoodlands.org/articles/article/three-logging-systems-matching-equipment-to-the-job

The following link is a second attachment for skid steer loaders (see the Brush Crusher above for the first). This one is an **Extreme Heavy-Duty Brush Mower**. The site linked below has videos of this in action.

https://quickattach.com/collections/skid-steer-brush-mowers/products/xtreme-mower-hd-extreme-heavy-duty-brush-mower

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[2] Jon E. Keeley, C. J. Fotheringham, Marco Morais, Science, "Reexamining Fire Suppression Impacts on Brushland Fire Regimes", June 11, 1999, https://pdfs.semanticscholar.org/f2b8/6087c57259f43bc1e4a664b92f961186ce42.pdf?_ga=2.266725070.13244638.1604355672-152210487.1604355672

The site linked below has a third type of attachment for skid steer loaders: **mulchers**. These basically clears brush and small trees down to ground-level and mulches everything into woodchips and leaf debris. This site has some videos.

https://fecon.com/product/bull-hog-mulching-head-ssl-ctl/

2.2. Wood Chip Preparation

Once chaparral landscape has been cleared as required, the resulting biomass should be reduced to woodchips and leaf debris. These need to be separated, and the leaf debris can then either be converted to biomethane via anaerobic fermentation or used in some other beneficial manner.

Woodchips should be dried for the best conversion to energy in a biomass boiler and steam turbine. *The usable calorific value of woodchips depends much more on the woodchip's moisture content than on the species of wood. Fresh wood chips with a water content of 55% provide roughly 2000 kWh in energy per ton.* [3]

By drying woodchips to 20% moisture content, the calorific value is doubled to around 4000 kWh per ton…

For woodchip boilers, dry woodchips equate to higher efficiency, clean and more consistent combustion that in turn ensures simple operation and an extended lifetime of the heating system.

In addition, only woodchips below 30% moisture content are suitable for storage. Woodchips above the 30% threshold are liable to microbial decomposition.

There are any number of ways to dry the woodchips. The simplest way, given a reasonable amount of land area is to put them in a drying-yard in the hot, dry California Central Valley for summer into early autumn, with occasional mixing, and then move them to storage or the process described in the next section. The link below (Stronga), provides information on forced air drying solutions.

3. Woody Biomass to Energy

The dried woody biomass would be combusted in a specialized process, and the hot exhaust would flow through a boiler to create steam. The steam would pass through a conventional steam turbine generation set to generate electricity.

3.1. Combustion & Steam Generation

There are basically two technologies for combusting dried woody biomass as described in the following subsections.

3.1.1. Multi-zoned Grates

With a multi-zoned grate an auger pushes the fuel into each zone: preheat, direct burn, charcoal and charcoal burn. *Each zone has an external valve allowing you to put more air where combustion takes place and less air farther from the fire. The total amount of*

[3] Stronga Ltd. (UK), https://stronga.com/en/products/drying-stations/

underfire air is metered by an electrically controlled master valve as a function of the power demanded by the boiler.[4]

This design controls the underfire air through the combustion chamber, unlike designs such as the underfeed stoker that can provide only a single zone in the chamber. With the multizone air system you have a greater degree of control and the fire burns better. Once the initial adjustments to the airflow in each zone have been made, the firebox will burn a spectrum of wood fuels…

The firebox auger gradually pushes the fuel over the grate and across each underfire air zone. Underfire air passes through the underfire manifolds which typically consists of more than a thousand nozzles. The grate is constructed of durable high temperature refractory floor tiles which are locked in place but can easily be removed if necessary. The grates are cooled by the under-fire air for durability and to prevent slagging.

This underfire air system is more expensive to manufacture than competing systems but has several important benefits:

The grates are stationary and have no moving parts to wear or jam.

The feed method keeps fuel in proportion to oxidation rates because fuel quantity and airflow are both controlled. Step or traveling grates may move too fast or too slow and fuel may not burn efficiency as a result.

The fuel's slow movement keeps bed turbulence low. The object is not to disturb the fuel but allow it to burn on the grate without becoming airborne or blowing up the stack.

Better control of under-fire air promotes better turndown.

During combustion, the under-fire air gasifies the wood fuel and the over-fire air burns off the resulting gas. The separate front and rear manifolds create an air curtain through which the flue gas must pass.

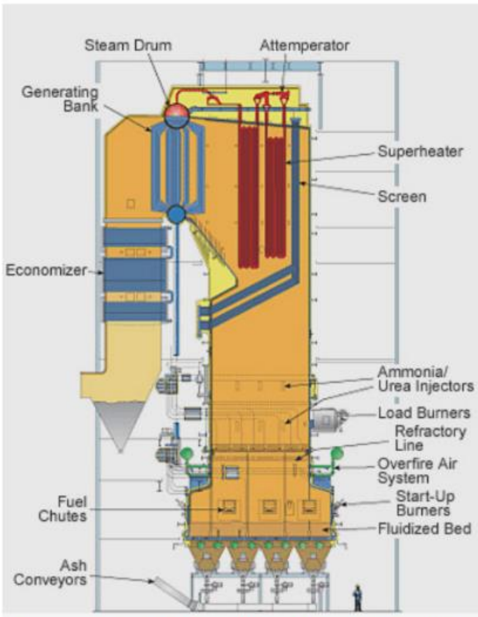
This air curtain is specifically designed to maximize the turbulence above the fire, use the entire firebox volume and minimize any turbulence on the surface of the pile which would cause unburned fuel to become airborne.

Two fans are provided, one for each over-fire manifold, so that an adjustment to one manifold will not affect the air flow to the other. This makes it easier to establish optimum burning conditions.

[4] Messersmith Manufacturing, Bark River, MI, https://burnchips.com/products/combustion-systems/dry-fuel-systems/

3.1.2. Fluidized Bed

Fluidized-bed boilers are the most common type of boiler recommended for biomass fuel, which is burned within a hot bed of inert particles, typically sand. The fuel-particle mix is suspended by an upward flow of combustion air within the bed. As velocities increase the gas/solid mix exhibits fluid-like properties. According to the EPA's "Combined Heat and Power Partnership Biomass CHP Catalog," the scrubbing action of the bed material on the fuel also enhances the combustion process by "stripping away the CO_2 and solids residue (char) that normally forms around the fuel particles . . . allowing oxygen to reach the combustible material more readily and increase the rate and efficiency of the combustion process."[5]



Top supported bubbling fluidized bed (BFB) boiler.
Image source: Babcock.com

This process also increases heat transfer and allows for lower operating temperatures: bed temperatures range about 1,400° F to 1,600° F, far less than the 2,200° F for a spreader stoker boiler. Lower boiler temperatures also produce less nitrogen oxide, an environmental and regulatory benefit when burning high nitrogen-content wood and biomass fuels. Suflur dioxide emissions from wood waste and biomass are generally insignificant; however, if sulfur is a contaminant it can be neutralized by adding limestone to the fluid bed.

Note that the above pictured design incorporates the boiler into the fluidized bed combustor.

3.2. Steam Turbine / Generator Set

The steam turbine and generator is relatively conventional, however it is good to have a vendor for these components that is familiar with biomass. Such a vendor is my former employer, Siemens, who is active in the U.S. market and is familiar with biomass. Go through the link below.

https://www.siemens-energy.com/global/en/offerings/power-generation/steam-turbines/biomass-to-power.html

3.3. Carbon Dioxide Separation & Sequestration

Several prior posts covered this subject, and a recent one covered the subject of this subsection. In section 3.1 of the post linked below we focused on the back-end of the in-plant process (capture of the CO_2). Just before this subsection we referenced a couple of earlier papers on sequestration.

[5] The American Society of Mechanical Engineers, "Fluidized-Bed Combustors for Biomass Boilers" Aug 30, 2012, https://www.asme.org/topics-resources/content/fluidized-bed-combustors-for-biomass-boilers

https://energycentral.com/c/ec/tough-love-%E2%80%93-part-2

The above linked paper/section covered a recent discovery that was made by the University of California (Berkeley) working with ExxonMobil in an eight year project to improve the efficiency of amine CO_2 capture and release. This project looked at exhaust typical of combined-cycle plants, but I would guess this can be adapted to clean biomass plants.

4. Additional Development

When I started writing this paper, I assumed that much development would be required to make the above concept work. As I researched this subject I was surprised to learn that most of the above described technologies already exist, although some work might need to be done (as in the prior subsection) to adapt existing technologies to the above applications.

The one area where little work will need to be done is with the brush and tree harvesting machines (mainly skid steer loaders). Many of these are diesel-powered, and initially biodiesel can be used with no development. In future decades as earth-moving equipment evolves to electric power, the equipment used for clearing and mulching brush and trees, and also in drying yards, transport, and biomass power-plants will follow suit.