

# Why Not Biomass For Electricity or Heat as Part of a 100% Wind-Water-Solar (WWS) and Storage Solution to Global Warming, Air Pollution, and Energy Security

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## 3.4. Why Not Biomass for Electricity or Heat?

**Biofuels** are solid, liquid, or gaseous fuels derived from organic matter. Most biofuels are derived from dead plants or from animal excrement. **Solid biofuels**, such as wood, grass, agricultural waste, and dung, are burned directly for home heating and cooking in developing countries and for electric power generation in most all countries. **Liquid biofuels** are generally used for transportation as a substitute for gasoline or diesel. **Gaseous biofuels**, such as methane, are used either for electricity, heat, and transportation.

Here, **biomass** (or **bioenergy**) is defined to be a biofuel that is used for electricity or heat generation. Biofuels for transportation are discussed in Section 3.5.

Biomass combustion for electricity or heat is not recommended in a 100 percent WWS world for several reasons, discussed herein. Similarly, **bioenergy with carbon capture and sequestration (BECCS)** also represents an opportunity cost in comparison with WWS options. Biomass combustion without and with carbon capture is discussed next.

### 3.4.1. Biomass Without Carbon Capture

The main sources of biomass for energy include agricultural residues, forestry residues, energy crops, industry residues, park and garden wastes, and contaminated wastes (Kadiyala et al., 2016).

**Agriculture residues** include dry crop residue, such as straw and sugar beet leaves, and livestock waste (solid or liquid manure).

**Forestry residues** include bark; wood blocks; wood chips from treetops and branches; and logs from forest thinning.

**Energy crops** include dry wood crops (e.g., willow, poplar, eucalyptus, and short rotation coppice), dry herbaceous crops (e.g., miscanthus, switchgrass, reed, canary grass, cynara, cardu, and Indian shrub), oil energy crops (e.g., sugar beet, cane beet, sweet sorghum, Jerusalem artichoke, sugar millet), starch energy crops (e.g., wheat, potato, maize, barley, triticae, corn, and amaranth), and other energy crops (e.g., flax, hemp, tobacco stems, aquatic plants, cotton stalks, and kenaf).

**Industry residues** include wood industry residues (e.g., bark, sawdust, wood chips, slaps, and cutoffs from saw mills), food industry residues (e.g., beet root tails, used cooking oils, tallow, yellow grease, and slaughterhouse waste), and industrial products (e.g., pellets from sawdust and wood shavings, bio-oil, ethanol, and biodiesel).

**Park and garden wastes** include grass and pruned wood.

**Contaminated wastes** include demolition wood, municipal waste, sewage sludge, sewage gas, and landfill gas.

The primary reason biomass combustion is not proposed for use in a WWS world is that biomass combustion, like coal and natural gas combustion, produces air pollution. A 100 percent WWS energy infrastructure is designed to eliminate air pollution. The air pollution problems from biomass combustion are similar to those from biofuel combustion, which are discussed in Section 3.5. The problem is worse for some types of biomass, such as municipal waste, which often contains toxic chemicals. In sum, whereas biomass is partly renewable, it is not clean, and a 100 percent WWS world requires both clean and renewable energy rather than just renewable energy.

The second reason for not including biomass is its higher CO<sub>2e</sub> emissions compared with WWS technologies. Biomass grows during photosynthesis by converting CO<sub>2</sub> and H<sub>2</sub>O from the air into organic material and O<sub>2</sub>, which is released back to the air. Although growing biomass takes CO<sub>2</sub> out of the air, some or all of that CO<sub>2</sub> may be returned to the air because collecting, transporting, separating, incinerating and growing the biomass require fossil fuel energy. In addition, biomass has emissions associated with the time lag between planning and operation of a biomass plant. It also has heat and water vapor emissions from biomass combustion and water vapor emissions from water evaporated to cool steam turbines. Finally, it has carbon emissions due to covering soil with a biomass energy facility or with a low carbon intensity crop instead of a high carbon intensity forest.

Table 3.5 shows that the overall range of CO<sub>2e</sub> emissions from biomass used for electricity is 86 to 1,788 g-CO<sub>2e</sub>/kWh, or 10 to 373 times the emissions per unit energy as onshore wind. These emissions are mostly due to lifecycle emissions (43 to 1,730 g-CO<sub>2e</sub>/kWh). A review by Kadiyala et al. (2016) of numerous lifecycle emission studies suggests that combustion of forestry residues and industry residues may result in the least emissions (43 to 46 g-CO<sub>2e</sub>/kWh) among biomass fuels. Combustion of agricultural residues and energy crops may result in higher emissions (200 to 300 g-CO<sub>2e</sub>/kWh), and combustion of municipal solid waste may result in the highest emissions (mean at 1,730 g-CO<sub>2e</sub>/kWh). The low emissions from forestry and industry residues are due to the fact that the feedstock does not need to be produced actively as it does with agricultural residues or energy crops. The high emissions from burning municipal solid waste are due to emissions from producing and consuming the energy required to collect, segregate, sort, transport, and incinerate the waste.

Table 3.5 also indicates that biomass energy facilities have an opportunity cost emissions of 36 to 51 g-CO<sub>2e</sub>/kWh due primarily to the fact they take 4 to 9 years between planning and operation versus 2 to 5 years for onshore wind or utility PV. During the additional time, the background grid is emitting.

The main other source of emissions from biomass is the 6.6 g-CO<sub>2e</sub>/kWh resulting from the combined heat and water vapor emitted from biomass combustion. Because biomass combustion is less efficient than even coal combustion (Section 3.4.2), biomass combustion releases more heat per unit electric power produced than does coal combustion (Table 3.5).

A third problem for some types of biomass, particularly energy crops, is the much greater land requirement for them than for WWS technologies. Section 3.5 discusses this issue. Given that photosynthesis is only 1 percent efficient at converting sunlight to biomass energy, whereas solar PV panels are 20 percent efficient at converting sunlight to electricity, a solar panel needs only 1/20<sup>th</sup> the land to produce the same energy as a biomass crop.

An alternative to burning biomass for electricity or heat is to extract landfill gas, which contains mostly methane, and use the methane to produce hydrogen by steam reforming (Section 2.2.2.1). As discussed in Section 2.9.2, the use of methane captured from landfills and methane digesters to produce hydrogen is one method of consuming methane that would otherwise leak to the air. The hydrogen would then be used in a fuel cell (e.g., in a vehicle) to produce electricity, thereby avoiding fossil fuel production of the same energy. Steam reforming of methane to produce hydrogen plus the use of the hydrogen in a fuel cell to generate electricity, creates very little air pollution. As such, capturing methane from a landfill or digesters and using it to produce hydrogen for a fuel cell is the one exception to not using bioenergy in a WWS world.

In sum, combusting forest and industry residue and other forms of biomass to provide electricity and heat results in higher CO<sub>2</sub>e emissions and much more air pollution emissions than does using WWS technologies. Some forms of biomass also require much more land than do WWS technologies. As such, using biomass for energy represents an opportunity cost. The exception is to use landfill and digester methane to produce hydrogen by steam reforming, where the hydrogen is subsequently used in a fuel cell.

#### **3.4.2. Biomass with Carbon Capture**

A proposed method of reducing biomass CO<sub>2</sub>e emissions, and even possibly creating negative carbon emissions, is to combine it with carbon capture and storage to form **bioenergy with carbon capture and storage or use (BECCS/U)**. **Negative carbon emissions** arise if a process removes more carbon from the air than it adds to the air. BECCS can theoretically result in negative carbon emissions if, for example, forest wood residue (containing CO<sub>2</sub> from the air) is collected, little energy is used to collect, transport, and incinerate the wood, and the CO<sub>2</sub> is captured from the exhaust stream and pumped underground. If it were successful, this method would be a one-way conduit for CO<sub>2</sub> to go from the air to underground, thereby resulting in negative carbon emissions.

The problems, however, are several-fold. As with natural gas and coal with CCS/U, the carbon capture system with BECCS/U requires 25 to 55 percent more energy than without it. If that energy comes from natural gas, coal, or biomass, 25 to 55 percent more air pollution occurs than with no BECCS/U. Biomass combustion without carbon capture already results in high air pollution levels compared with WWS. Air pollution with BECCS/U is even higher than without it.

Similarly, as with CCS/U for coal and natural gas, the CO<sub>2</sub> reductions are much lower than anticipated due to the high energy requirements of BECCS/U. Leakage of CO<sub>2</sub> from underground storage is also an issue.

Second, like with gas and coal, few reliable underground storage facilities exist for BECCS. Because of the high cost of carbon capture, bioenergy with carbon capture facilities are likely to be coupled with for-profit uses of the CO<sub>2</sub>, such as enhanced oil recovery. Thus, BECCU will be favored over BECCS. This will encourage more combustion of and emissions from oil products.

Third, the efficiency of biomass combustion for electricity (electricity output per unit energy in the fuel) is low (20 to 27 percent), even compared with coal combustion (33 to 40 percent). Thus, a large mass of biomass is needed to produce a small amount of electricity. As such, if BECCS/U were to provide negative

emissions on a large scale, substantial land areas dedicated to bioenergy crops would be needed to maintain a continuous energy supply. Consequently, a share of agricultural land would be used for fuel instead of food, increasing the price of food. Higher food prices trigger deforestation, as high-carbon-storage forestland is turned into low-carbon-storage agricultural land.

Fourth, removing agricultural residues usually means crops need to be fertilized more since the residues contain nutrients that are no longer available once they are removed. Fertilizers contain a greenhouse gas, nitrous oxide (N<sub>2</sub>O) and a major pollution, ammonia (NH<sub>3</sub>), which are emitted to the air.

Finally, the cost of BECCS/U is very high as of 2019, even compared with CCS for fossil fuels. To date, only six BECCS/U facilities have survived, and each has been at a high cost. One has been for capturing CO<sub>2</sub> at an ethanol refinery. The others have been for capturing CO<sub>2</sub> as municipal solid waste plants.

Thus, paying for BECCS/U instead of WWS means less energy production, a longer time lag between planning and operation, more air pollution, greater land use (for some crops), and less carbon removal (because less BECCS/U than WWS technologies can be installed for the same money).

## References

Kadiyala, A., R. Kommalapati, and Z. Huque, Evaluation of the lifecycle greenhouse gas emissions from different biomass feedstock electricity generation systems, *Sustainability*, 8, 1181-1192, 2016.