The Energy Source with Least Environmental Impact: Agricultural Plant Biomass to Electric Power

Introduction

Burning agricultural plant biomass to generate electricity is the greenest: it is 100 percent renewable, absolutely net zero carbon emission. The reason the term “agricultural plant biomass” is used here is that we don’t want people to think that we are suggesting to cut down trees to burn to generate electricity. No, we are not talking about deforestation, not open burning, not burning in a fireplace to provide heat for a building, not bio-waste or construction waste burning, we are talking about large-scale power generation using modern coal-firing power plant technology with state-of-the-art exhaust control, fuel materials supplied by agriculture.

All energy sources have their own drawbacks to cause harm to the environment. We know fossil fuel causes global warming. It is not renewable and is depleting very fast. Wind energy might cause inland drought and other extreme weather.[9, 10] Also, wind power is very unreliable. Solar energy is unreliable too, because the solar conversion rate is very low, solar power is very expensive too, comparing to other types of energy. Manufacturing the solar panels also produces huge environmental pollutions. If wind and solar energies are combined with an energy storage bank, it will substantially increase the cost. The storage bank is normally made of lithium ion batteries. Mining and refining lithium causes detrimental environment harms, the lithium resources can be depleted fast too. Nuclear energy is not really clean and renewable either. Mining and refining uranium harms the environment, the radioactive nuclear waste lasts thousands of years. Combustion of agricultural plant biomass to generate electricity, on the other hand, has the following advantages.

The Benefits

Renewable: Plants grow every year, it is a never-exhaust energy source.

Zero-carbon: Photosynthesis converts carbon dioxide in the air into plant materials, burning the plant materials only puts the absorbed carbon dioxide back into air. Therefore, it is a net-zero carbon emission process.

Help reducing methane emission: Dead plants decompose in nature by two means: aerobic decomposition or anaerobic decomposition. The former generates carbon dioxide and water, the later generates methane and water. Methane is more than 25 times potent global warming gas comparing to carbon dioxide. [1]

The Math

The following calculations is based on the data for the country of United States.

Heating value for woods is about 20MJ/kg,[2] since any agricultural plant biomass is considered here, a more conservative number is used in this calculation: 15MJ/kg.

2020 US electricity usage: 3800 Terawatt hours[3]. Again, to be conservative, 4000 Terawatt hours is used here, which is $1.44X10^{19}J$

Thermal efficiency of coal fired power plants has been reported to range from 32% to 45%.[4] An average number of 38% is used here.

Assume: 1 acre of farmland can yield 10 tons (metric ton) of dry agricultural plant biomass annually.

Then: $0.25X10^{9}$ acres of farmland is required to generate the 4000 Terawatt Hours [$(1.44X10^{19}J)/0.38/(15X10^{6}J/kg)/(10000kg/acre)$]. US has $0.915X10^{9}$ acres of farmland[5].

Conclusion: Less than 30 percent of US farmland is required to grow enough plant biomass for combustion to generate electricity to meet the current needs for the entire country.

The Process

First, coal-fired power plant process:

Coal mining → Selection and washing →Grinding (making powder) → Injection into combustion chamber → Heat exchange + exhaust + ashes (waste) → Steam → Turbine → Electricity

Now, plant biomass fired power plant process:

Plant growing → Harvesting and high-pressure pressing into wood blocks (for easy storage and transportation) →Grinding (making powder) → Injection into combustion chamber → Heat exchange + exhaust + ashes (topsoil) → Steam → Turbine → Electricity

Comparing these two processes, one can see there is not much technology barrier between these two processes, a coal fired power plant can be easily converted to biomass fired power plant.

The Pollution

Plant biomass is the greenest energy source, but it doesn't mean pollution free. Incineration of plant biomass will still generate exhaust.

There are several wood burning power plants currently operating in the USA, for an example, Ryegate Vermont plant. It should be pointed out that not the best technologies are utilized in this plant, evidenced by the report that its thermal efficiency is only 23%.[6] Data for major pollutants for this plant are compared with conventional coal-fired power plant here.

	Coal fired power plant	Wood burning Ryegate plant
NOx	~0.07	0.15
CO	~0.1	0.3
PM10	~0.01	0.017
Sox	0.1 – 0.25	0.019

Unit: lb/mmbtu of heat input to boiler (heat exchanger).

Considering the thermal efficiency of Ryegate plant is currently at 23%, it can be reasonably expected that once the efficiency is increased to the average of coal fired power plant (38%), the pollution level will be substantially reduced, especially carbon monoxide. Plants contain more nitrogen and less sulfur than coal does, therefore, it is logic for plant burning to have more NOx emission and less SOx emission. NOx is not as nasty as SOx in terms of damages to the environment. A thunderstorm generates huge quantity of NOx. When dissolved in water, NOx serve as nutrient for plants. Also, there are mature NOx abatement technologies available.[7]

The Economics

Commodity prices fluctuated wildly. In this study, some conservative numbers are taken for our calculations: Coal for electric power is about $40/ton in US, heat value of dry agricultural biomass: 60% of power plant coal heat value, average net profit for farming is $100/acre[11].

We assumed 10 tons/acre of dry plant biomass, this is a reasonable assumption considering 135 bushels/acre of corn yield (135 bushels/acre X 56 lb/bushel = 7560 lb = 3.4 metric ton), while the agricultural biomass for power generation can be the whole plant. Some brushes can no-doubt grow 10 tons per acre annually. In terms of heat value, 1 ton of dry agricultural biomass is equivalent to $24 of coal, therefore, annual gross revenue for a farmer is $240/acre. Without land cost in consideration, $240 gross revenue can easily make $100 net profit for farming something that simple. Comparing the two processes: growing corn and growing plants for power generation, the former requires: herbicide, cultivation, fertilizer, seeding and harvesting with complicated expensive machines in a very specific few days, while the latter can be much simpler, especially for perennials, not much input and attention needed after first-planting. The net profit for the latter could be even higher. However, in the US, the land cost is about $200/acre, This cost will add 2 cents to very kilowatt hour of electricity or $80 billion for the entire country if all the electricity is generated by the agricultural plant biomass. The question is: is the Country ready to spend $80B to protect the environment? Or, are people in US willing to pay 2 cents more per unit of electricity they use? On the other hand, if hidden cost is considered, some research reveals that in the United States alone, air pollution from burning fossil fuels is linked to an estimated $600 billion in economic losses annually.[12] Then, $80 billion is a fraction of the $600 billion, burning agricultural plant biomass for electricity becomes more economical on a national scale.

Also, the government has to guarantee to the energy companies that there will be stable supply of agricultural plant biomass, and guarantee to farmers that there will be a market for what they grow, also provide farmers with guidance as what kind of plants have the highest yield and suitable for power generation combustion.

The Conclusion

Combustion of agricultural plant biomass to generate electricity is the greenest renewable energy. One third of US farmland is capable of generating all the electricity the country needs. Large scale utilizing this method to generate electricity can reduce our dependence on fossil fuel, therefore relieve the current energy crisis, abate human impacts on environment.

Reference

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