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COP28's Goal is to End the Fossil Fuel Era

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> COP28, Section 28.d (December 13, 2023) -- **Transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science.**

Section 28.d codifies that the transition to a decarbonized future must be rational and pragmatic[1] and that it is a future in which solid, liquid, and gaseous fossil fuels are not combusted (or at least the carbon dioxide emissions are not allowed into the atmosphere).

This white paper shows that there is strategy that is already well-developed that will be part of the just and orderly transition to a decarbonized future.

Fossil Fuels have been Critical to Civilization's Growth but are also the Cause of Ecological Disequilibrium

Life as we know it is based on a relatively stable balance in the earth's dynamic systems. The interdependencies that are fundamental to the earth's support of advanced life forms are critical.

> "The earth is isolated, ancient and the site of ceaseless change. This means that everything that happens on and below its surface is part of a cycle. For every change which uses things up, there must be another which supplies those things anew. The basic elements of life, such as carbon and nitrogen, cycle endlessly in and out of living things, the seas, the land and the atmosphere. Even the planet's crust is recycled." (The Economist, November 20, 2023)

Rapid changes in the composition of the atmosphere from, for example, major sustained volcanism or meteor strikes, have never ended well for many life forms. Rapid changes are happening now.

But this time what is forcing the rapid change is different. Since industrialization, over a period of a few hundred years, coal, petroleum, and methane (so-called natural gas) that contains millions of years of sequestered carbon is being cycled out of the ground and into the air.

As a result, the earth's systems are critically out of balance. As Figure 1 shows, the earth's systems are unable to fully recycle the carbon dioxide (CO_2) emitted from the use of fossil fuels.

[1] This phrase is part of the title of a June 2016 white paper by FutureMetrics.

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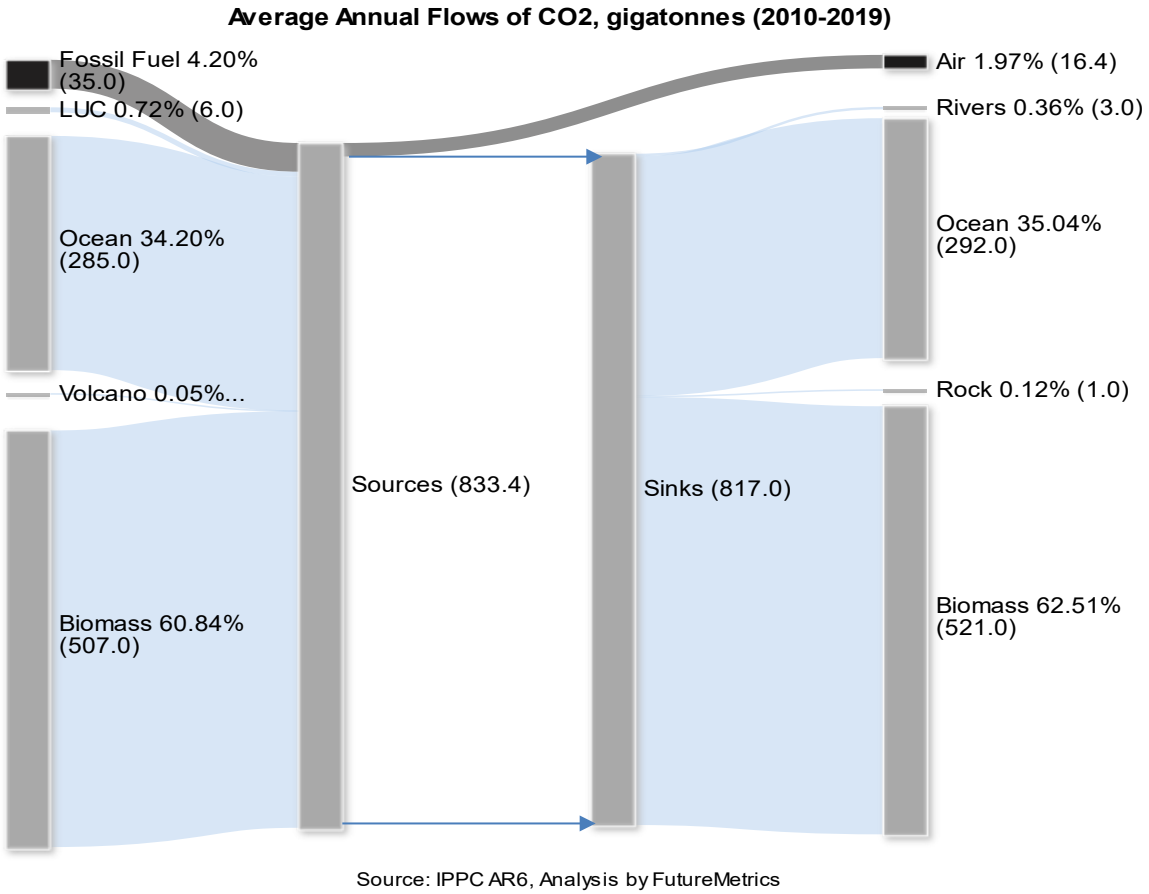

Figure 1 - Average Annual Flows of CO_2

Adding to the significant CO_2 sources from fossil fuel combustion, land use change (LUC) that eliminates biomass affects the structure and function of the plant's ecosystems with a net positive addition of CO_2 into the system.

Sources now exceed sinks; and this disequilibrium condition will persist if humankind continues to do business-as-usual.

There are clear and present consequences to the unmitigated use of fossil fuels. For example, as Figure 2 shows, the oceans have been steadily warming[2]. But most troubling is the excursion seen in 2023. There are many metrics showing that fossil fuel CO_2 emissions are causing rapid changes in environmental variables. Figure 2 shows not only steady warming but it signals that in 2023 we may have crossed a tipping point that results in even more rapid change combined with increasing variability (more extreme highs and lows).

[2] See the May 2023 FutureMetrics white paper with more details HERE.

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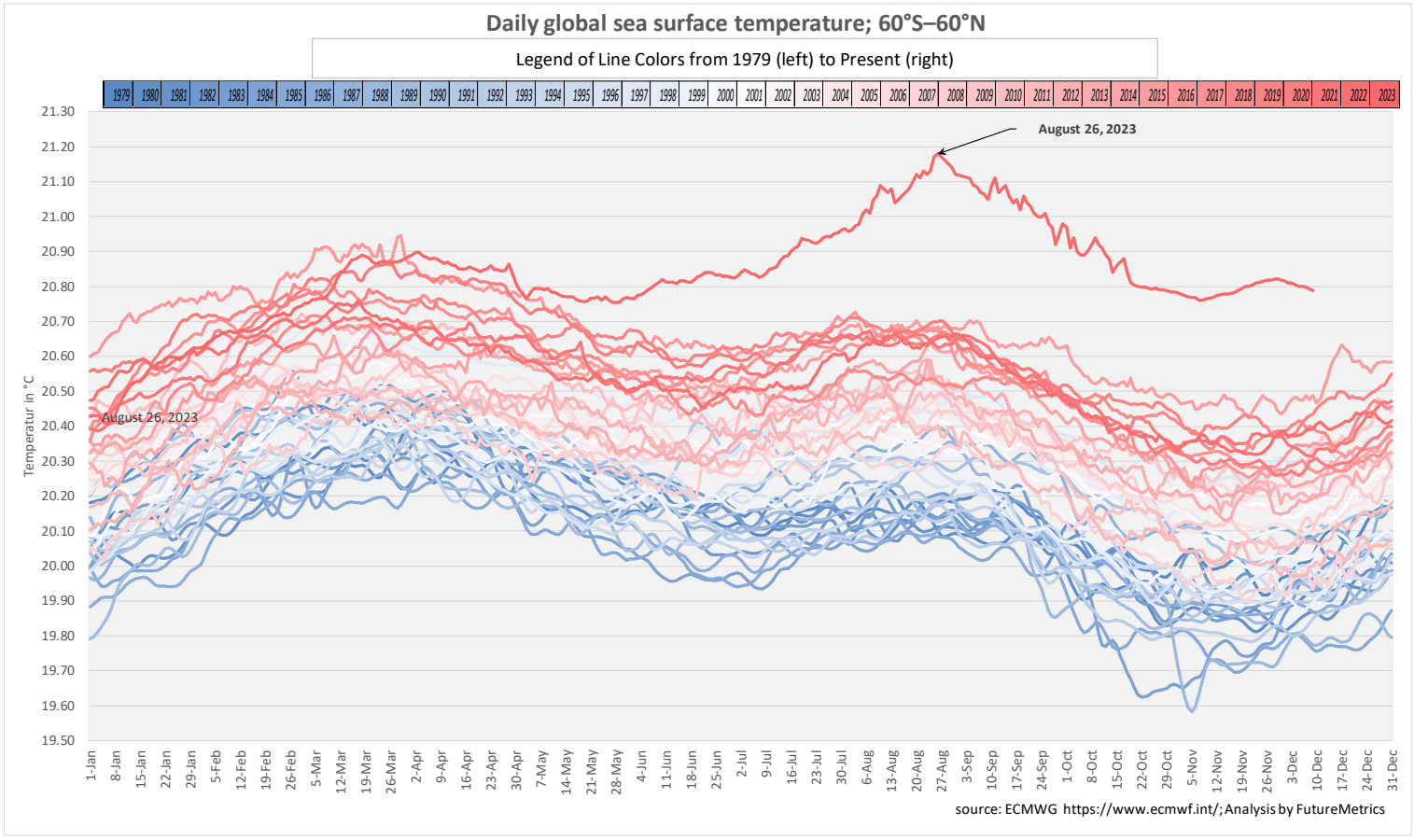

Figure 2 - Sea Surface Temperatures 1979 to Present

The message the earth is sending should be loud and clear. In some jurisdictions it is listened to. In some it is ignored or denied.

Further muting the urgency to control CO_2 emissions is the fact that CO_2 pollution is not obvious in everyday life. Unlike many already regulated pollutants, it does not cloud the air or smell bad. We cannot see it, smell it, feel it, touch it, or taste it. And, until very recently, the consequences of the rapid increase CO_2 emissions were hard to map directly to changes in the ecosphere.

The imbalance in the carbon cycle can no longer be disconnected from climate change. If the future is going to be what we hope it will be, action is needed now. COP28's agreement is explicit about the phase out of fossil fuels. But will there be meaningful action?

Seeking "a just, orderly, and equitable" Solution

There is huge inertia in our civilization around the use of oil, gas, and coal that has to be overcome. The great leap upward in overall standards of living is directly related to industrialization and the use of concentrated and easily transported energy carriers. Today's socioeconomic systems are based on the energy we derive from fossil fuels.

Thus, the search is for "drop in" replacements that can continue to power the infrastructure we rely on with minimum disruption. COP28's wording: "…in a just, orderly and equitable manner…" captures this.

There are already so-called drop in solutions that are being deployed in the power, heat, and transport sectors. Energy dense liquid fuels made from renewable feedstocks are gaining in use and coming down in cost. The use of ammonia and/or hydrogen (produced from renewable power) as non-carbon energy carriers will be part of the transition. Heating from sustainably sourced wood chips and wood pellets is commonplace in many EU countries and north America.

However, power generated from wind and solar sources cannot be fully qualified as a drop-in because the generation from wind and solar is variable. Thus, no matter how many megawatts of solar and wind generation are deployed, sometimes it will generate less than the grid needs.

Over the next few decades, it is likely that energy storage solutions will be developed and deployed at a scale that will sufficiently buffer intermittent and variable supply and keep the power grids stable most (not all) of the time.

But at least over the next few decades, to make the transition to a decarbonized future as seamless as possible, the power grids will need CO_2 beneficial generation that is on-demand and load-following.

As many FutureMetrics white papers have explained over the years, the use of pellet fuel produced from perpetually renewing biomass solves part of that problem[3]. And it is a drop-in solution that can complement the intermittency and variability of wind and solar generation. Existing coal-fueled utility power stations can, with relatively low cost and little downtime, make modifications and replace coal with upgraded densified biomass-derived solid fuel (called "pellet" fuels) produced from perpetually renewing (not depleting) sources.

The result is renewable electricity that can be generated on demand.

Pellet Fuel is an Energy Dense Storage Solution

The energy carrier (pellet fuel) is part of the biomass cycle shown in Figure 1. Plants grow and reach some density equilibrium at which the mortality rate more or less equals the growth rate. The idea that forests will be net positive CO_2 sinks forever is wrong. They will always reach saturation. But if well managed, they can be continuously used without lowering the net quantity of carbon they are storing.

If the stock of biomass is not depleted over time, excess CO_2 is not created and thus cannot accumulate in the atmosphere. For forest biomass, if the quantity of wood in the landscape is not depleted (i.e., the removal rates never exceed the growth rates) the quantity of CO_2 released from any wood that is combusted is less than or equal to the quantity of CO_2 captured. This logic only works if the resource is continuously and perpetually renewing.

Sustainability is the absolute necessary condition for the use of pellet fuels as a carbon beneficial coal replacement in power generation.

The vast majority of the primary harvest of woody biomass for forest products industries is not for the production of pellet fuels. The primary users, as Figure 3 shows, are sawmills (lumber, flooring, furniture, etc.) and pulp and paper mills (printing paper, cardboard boxes, toilet paper, etc.). These mills have been operating in some locations for more than a century because they only take in an amount of wood each year that is less than or equal to what grows

[3] FutureMetrics white papers are free to download from the FutureMetrics website.

in the working forests around them. The mills can, if well maintained, essentially operate forever. Properly managed pellet mills benefit from the same forest resource stewardship.

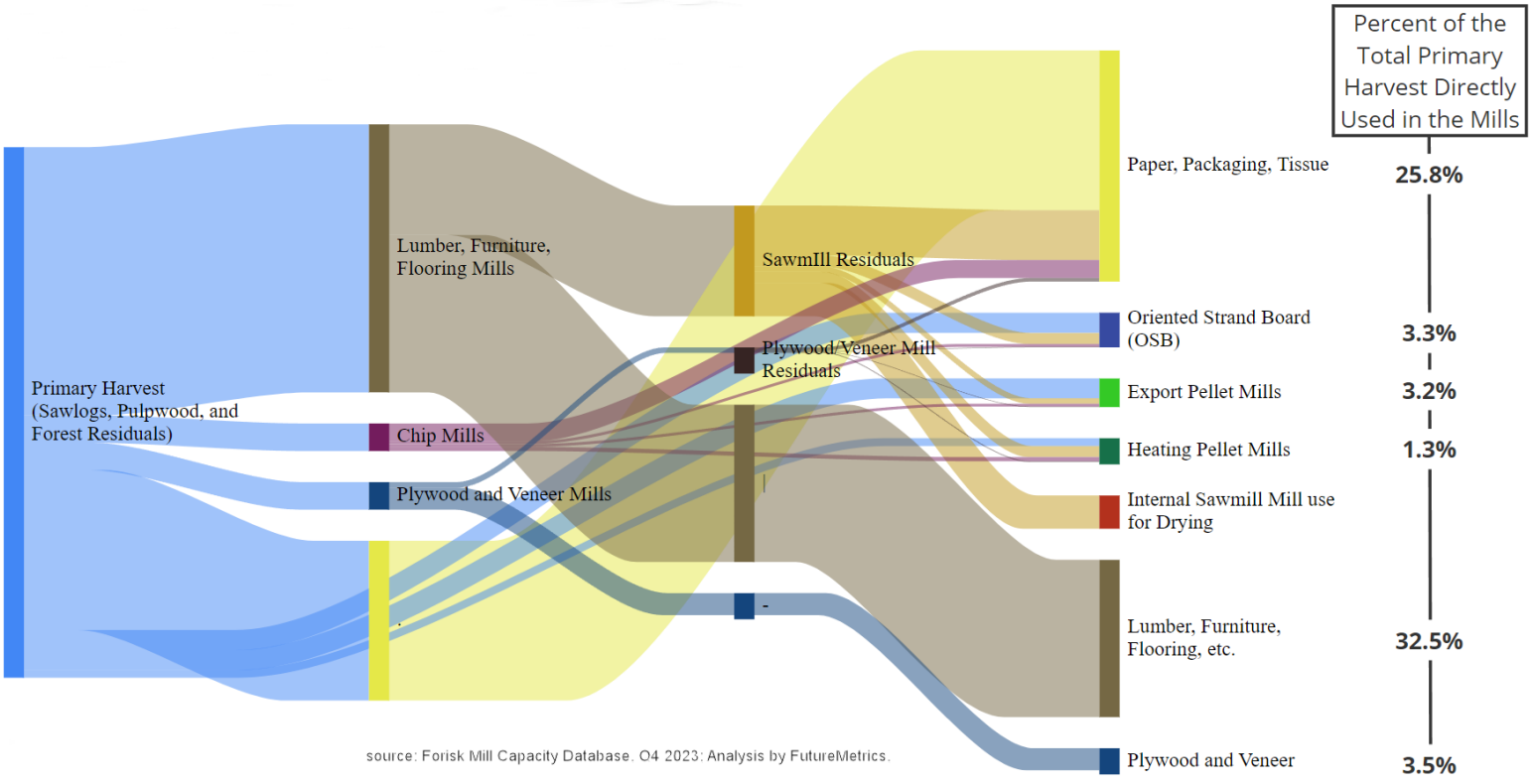

Figure 3 - Wood Flows in North American Mills

The future will have many forms of energy storage; and perhaps in two or three decades, producing heat and power from combustion will be history. Energy storage is the key to a decarbonized future that is primarily dependent on wind and solar generation. Nuclear power is a baseload solution but cannot be load-following over the significant and rapid variations wind and solar produce. Nor is it on-demand.

What is the strategy for the two, three, or more decade transition that provides a seamless and low carbon input to the power grid that can be baseload or load-following and is available on-demand?

Leveraging the Natural Conversion of Solar Energy into Biomass-Derived Fuels

We already have large-scale energy storage that can be part of the solution. The biomass cycle captures solar energy and stores it. Forests are the world's largest solar battery.

Every year about 5.7 x 10^{24} joules of solar energy irradiates the earth's surface[4]. That solar energy is an essential part of our planet's ecosystems. Plants and photosynthetic organisms utilize that energy to convert large amounts of CO_2 into $C_6H_{12}O_6$ (glucose)[5]. The chemistry of plant growth transforms the glucose into other sugars (hemicelluloses),

[4] Source: FAO http://www.fao.org/docrep/w7241e/w7241e06.htm#TopOfPage

[5] Photosynthesis can be described by the simplified chemical reaction $6H_2O + 6CO_2 + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$. Source: Wikipedia.

cellulose, lignin, and other plant matter. Every year solar energy and photosynthesis convert billions of tonnes of CO_2 and water into plant matter and produces oxygen as a by-product.

A portion of that plant matter is trees. While some forests are not used and should not be used to supply the forest products industry outlined in Figure 3, many millions of hectares of forests are managed and cultivated to continuously produce logs that turn into lumber, furniture, and many other products that are part of everyday life. Those forests also produce wood chips for the manufacturing of paper, packaging, tissue, and a variety if engineered wood products. As Figure 3 shows, some of the by-products of sawmills and the parts of the rest of the trees that are not suitable for higher value use may find their way to pellet factories to produce solid fuel and to factories that create renewable liquid fuels from cellulosic feedstock.

These managed working forests are in effect tree farms. Each plot on these tree farms cycles through stages of regeneration, growth to maturity, and harvest. But in aggregate, as long as the rates of removal never exceed the rates of growth, the total quantity of wood (and thus stored carbon) does not decline. The growth rate and therefore the cycle time between harvests depends on the climate and species of trees.

Figure 4 shows the time from planting to harvest at selected locations. In general, the nearer to the equator, the shorter the time needed to grow a tree that is ready to be harvested. The yields per hectare at harvest do not vary greatly but harvests are more frequent in the warmer regions.

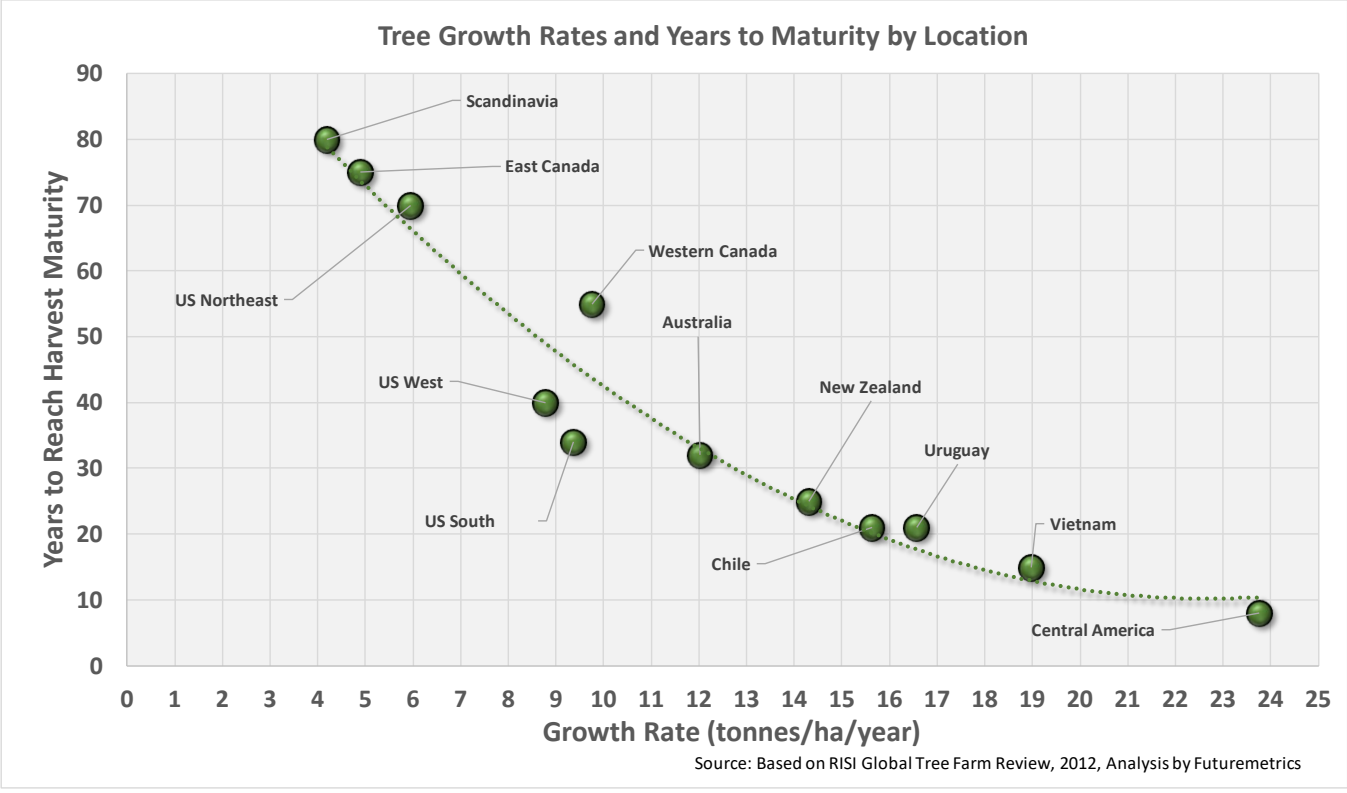

Figure 4 - Tree Growth Rates and Years to Maturity

The average growth rate is about 12 metric tonnes per hectare per year. In northern regions it is less and in some tropical locations with fast growing tree species, it is more than 20 tonnes per hectare per year.

Forests cover 31 percent of the world's land surface[6]. That is about 4 billion hectares. Assuming an average growth rate of 12 tonnes per hectare per year and an average energy content per tonne of about 8.64 gigajoules (GJ)[7], the world's forests store about 415 billion GJ or 115,000,000 gigawatt-hours (GWh's) per year.

The total electricity produced by wind and solar in 2022 was about 3,506,920 GWh's[8]. The forests capture and store about 33 times as many GWh's per year as all solar and wind combined.

Almost all of the power generated by solar panels and wind turbines is consumed as it is produced. Without storage, solar and wind power are not dispatchable. Whereas the solar energy captured by the world's forests is stored.

Clearly only a portion of the world's forests are used to supply the forest products industries. According to the Food and Agriculture Organization, about 30% of the world's total forested area is used for production[9]. Based on Figure 3's estimate of how much of the total north American primary harvest becomes pellets (4.5%) and using that proportion to estimate global GWh's that could be in pellet fuel, about 1,552,000 GWh's could be moved from forest storage into pellet fuel every year without depleting forests and the carbon stock held in the forests.

BloombergNEF forecasts[10] that there will be about 1,880 GWh's of long-duration energy storage by 2030.

In other words, based on forests that are already managed for producing wood for lumber, paper, etc., and only using 4.5% of that material to produce pellet fuel, there is the potential today for pellet fuel to deliver 826 times more stored energy per year than all of the energy storage solutions forecast for 2030.

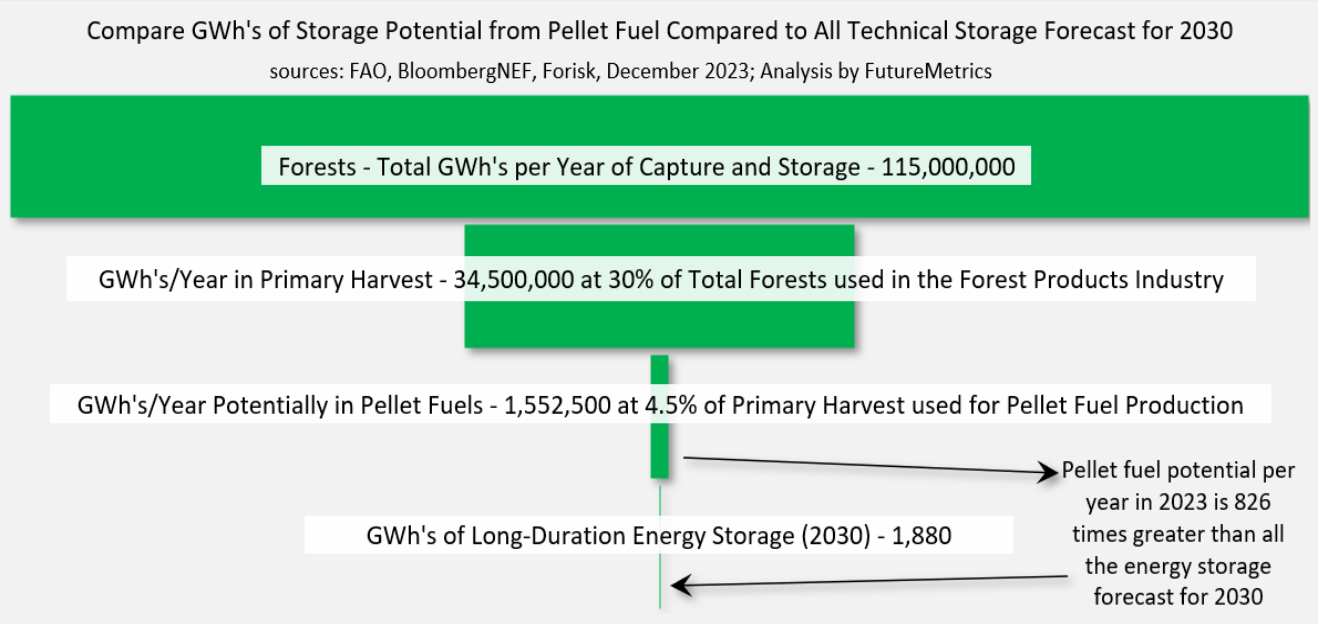

Figure 5 - Compare GWh's of Storage - Pellet Fuels and Technical Storage

[6] See HERE.
[7] The gross energy content per tonne is based on wood with a moisture content of 50%.
[8] https://ember-climate.org/data/data-tools/data-explorer/
[9] See https://www.fao.org/3/ca9825en/CA9825EN.pdf
[10] See https://about.bnef.com/blog/2h-2023-energy-storage-market-outlook/

Finally, if bioenergy carbon capture and storage (BECCS) is added to the analysis, that stored energy is not only put to use to help keep the electricity grids stable, but the stored carbon is permanently removed from the atmosphere.

COP28: Nations Publicly Agree that it is the "beginning of the end" of the Fossil Fuel Era[11] - This paper offers one way to get started now.

Fossil fuels are a finite depleting resource. Of course there will be an end at some point in the future when there are no more fossil fuels to mine from the earth. It is encouraging to see that nearly 200 parties representing most of the world's nations have agreed to take action to force that end point closer.

This white paper has shown that there is already a pathway that can support the COP28 goals. And the ideas presented in this white paper are deployable now. FutureMetrics has spent decades working with pellet fuel producers and end users in what began as a small niche in the renewable energy space. Over time, the industry has matured.

In 2022 the global supply chain filled the equivalent of a Panamax size ship[12] every day of the year with stored energy in the form of carbon beneficial pellet fuel. On the demand side, large utility power stations have successfully completed "bioconversions". For them coal is history; but dispatchable or baseload generation is not.

In the UK for example, baseload generation using coal has been replaced by pellet fuel. Figure 6 shows that in the week December 9-16, 2023, on average about 8% of the UK's electricity was produced using the stored energy in pellet fuel. During off-peak hours, pellet fuel produced an average of almost 16% of all the electricity used in Engand during that week. Note that at this time of year, solar generation is not only intermittent but is almost nonexistent.

[11] See https://unfccc.int/news/cop28-agreement-signals-beginning-of-the-end-of-the-fossil-fuel-era
[12] About 65,000 metric tonnes of pellet fuel per shipload. See HERE.

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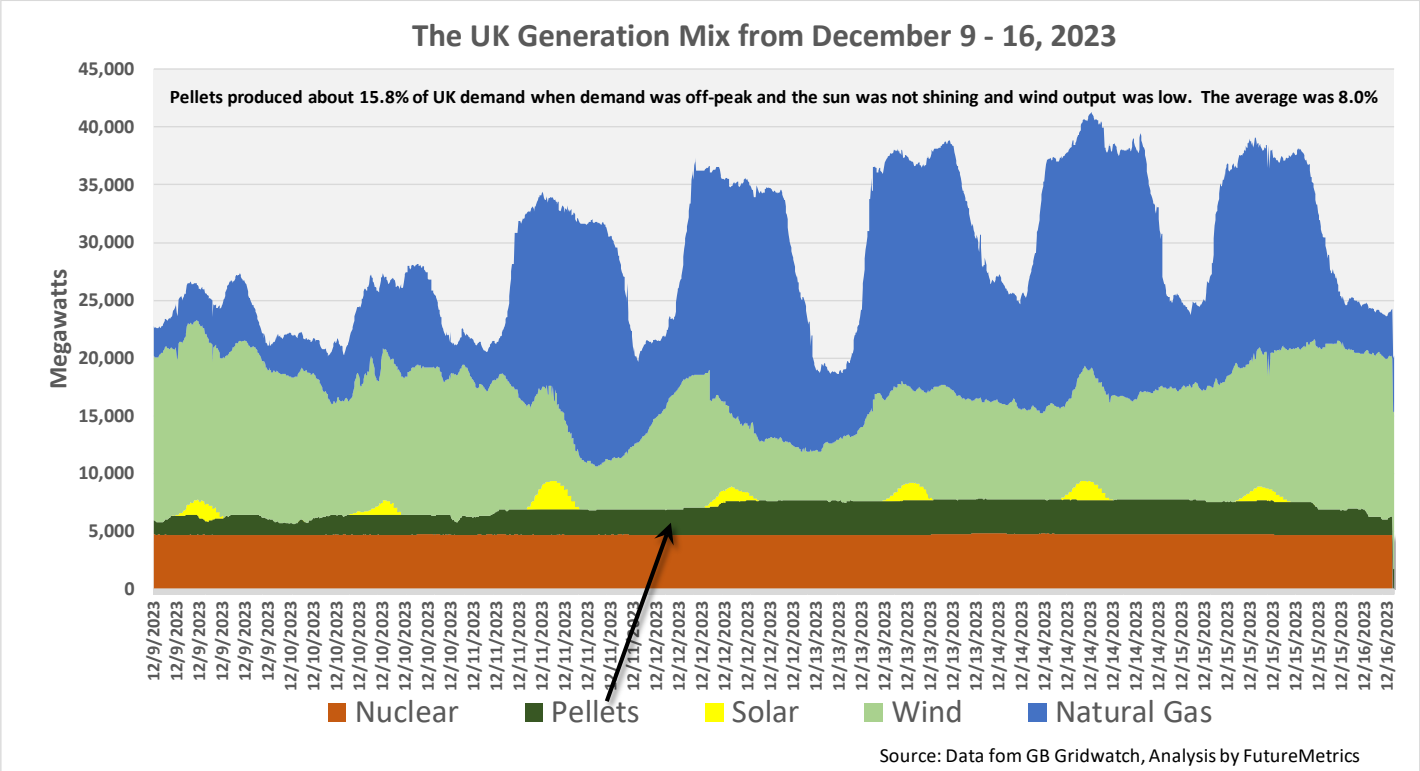

Figure 6 - UK Generation Mix Dec. 9-16, 2023

The orderly transition from today to the desired future should include policies that support the responsible use of solid fuel derived from the stored solar energy in renewing biomass.

There is nowhere close to enough renewable sources of biomass in the world to replace all the coal that is being used. But there is enough to make a significant difference.

The countries that have promised action under COP28 should not ignore this relatively easy to deploy drop-in solution that delivers on every criteria in Section 28.d.

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