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A Strategy for the Biden Administration

for Fighting Climate Change

The goal of attaining a carbon free electricity generation sector is necessary.

But the path from today to that goal needs to be pragmatic.

This white paper offers guidance for near and long-term solutions that <u>the Biden administration can incorporate into their strategy</u>.

[This white paper is based on a previous FutureMetrics white paper, but with added material and a redefined focus.]

November 16, 2020

By William Strauss, PhD, President, FutureMetrics

<u>Introduction</u>

Prior to the Trump administration, the US had promulgated the "Clean Power Plan" (CPP). Essentially, the CCP would have required states to achieve lower carbon emission goals in the power generation sector by 2030. This would have contributed to the US's commitments in the Paris Agreement. In aggregate, the US would have reduced greenhouse gas (GHG) emissions produced by electricity generation by about 32% from 2005 levels by 2030.

FutureMetrics research and analysis, discussed in several white papers from around the year 2015[1], showed that a part of a strategy for reaching those goals should be support for co-firing sustainably produced wood pellets with coal in existing power plants.

<u>This is not a novel idea</u>. The US is the world's largest producer and exporter of sustainably produced wood pellets that are used in power plants in many nations as part of their GHG reduction strategies[2]. Global trade in pellets that are replacing coal for power generation will be about 24 million metric tonnes in 2020. That is more than a panamax shipload (about 65,000 metric tonnes) every day. Under the CPP, the US would have begun to use the pellet fuel produced in the US for meeting US targets for GHG reduction.

The Clean Power Plan, along with cooperation in fighting climate change with most of the world, was scrapped by the Trump administration. The <u>incoming Biden administration</u> is expected to reverse many of Trump's policies. And the new administration is expected to reenergize the US's commitment to fighting

[1] One of the papers is <u>HERE</u>.
[2] See the free FutureMetrics' interactive pellet exports map <u>HERE</u>.

climate change and reducing carbon emissions. Under Biden, the US Environmental Protection Administration's (EPA) leadership will actually work to protect the environment. The US's reenergized attention to climate change will put a focus onto how energy is produced and used for transportation, heating, and power generation. This white paper focuses on power generation.

As was made clear in several white papers by FutureMetrics in 2015, a policy that integrates some of the existing coal fueled power stations as part of the decarbonization strategy produces a strong net positive for sustaining and creating jobs (paradoxically, some of those jobs are in the coal mining sector as is explained in another white paper from 2015[3]) while effectively and economically lowering net CO_2 emissions toward target levels.

Notwithstanding the environmental benefits of such a policy, because of the economic efficiency and the job supporting characteristics of the strategy, even those US policymakers who have supported Trump's anti-environmental policies should support the strategy outlined in this white paper.

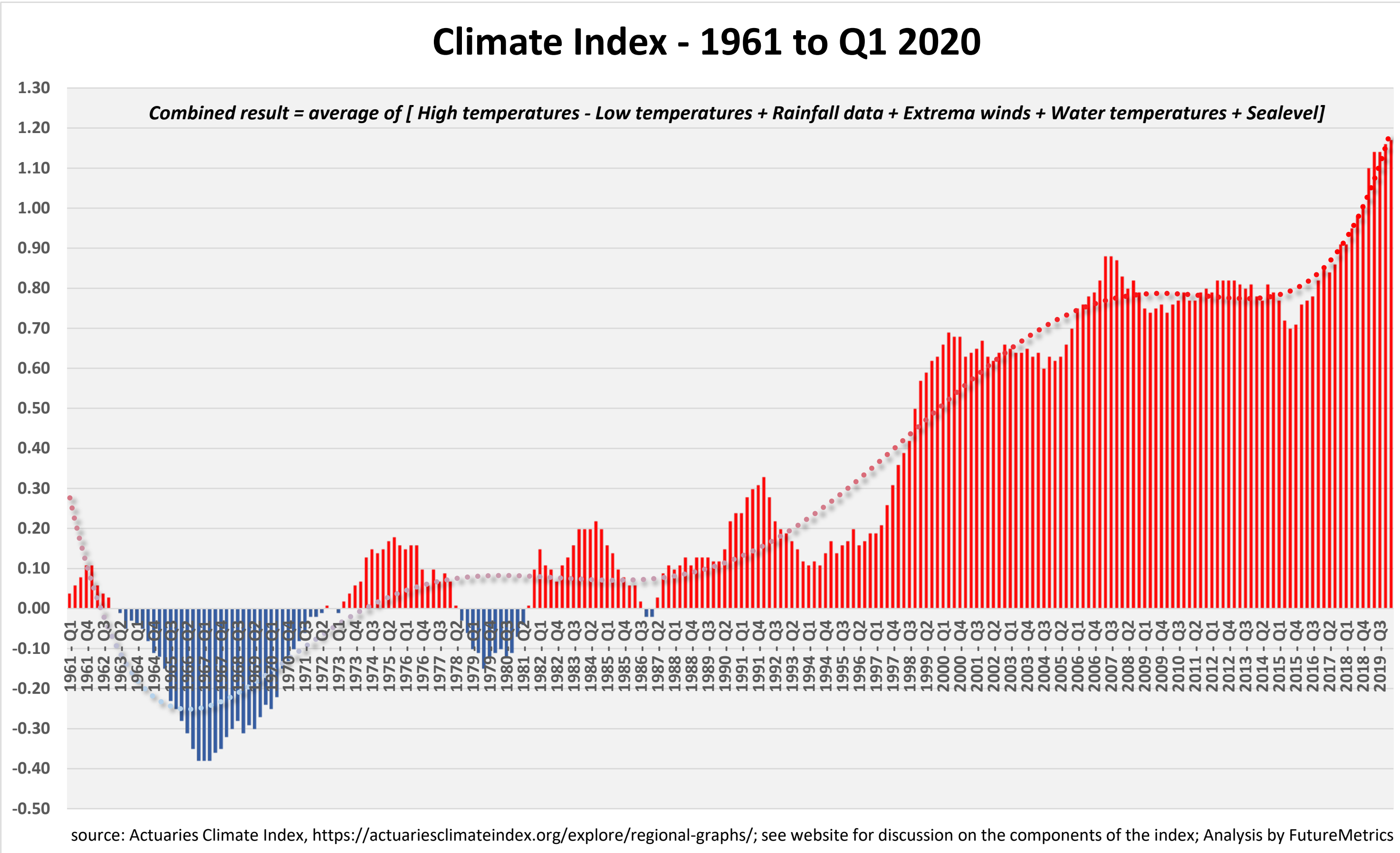
First, Climate Change Requires Attention Now

FutureMetrics has published several papers, and Dr. Strauss, the author of this paper, has made numerous presentations that transmit the urgency for creating and acting on effective environmental policy[4]. While most of the rest of the world, both developed and developing nations, recognize the importance of meaningful action, recent US leadership has not.

But, in fact, all policymakers should be motived by the increasing costs of the consequences of a rapidly warming planet. As the white paper referenced in footnote four suggests, business-as-usual will result in increasing magnitude and frequency of extreme events. Graphic evidence of GHG emissions changes over time can be viewed on the interactive chart on the FutureMetrics homepage.

The chart below should be a call to action for everyone regardless of political affiliation. It is produced by the actuaries that advise insurance companies about how to price risk[5]. The trajectory in the chart is not conducive to the cost of doing business.

[3] Click HERE to read a paper about how a pellet co-firing strategy under the CPP was not a war on coal.
[4] See a recent June 2020 white paper on the topic HERE.
[5] The data is from this consortium - https://actuariesclimateindex.org/sponsoring-organizations/ .



It is obvious to most that strategies and policies for slowing and eventually reversing the ecological impacts and the costly consequences of climate change are needed now more than ever. To get from where we are today to future goals for lower carbon dioxide (CO_2) emissions and control over anthropogenic global warming will require a portfolio of complementary solutions.

The Evolution of the Power Sector Toward a Goal of Zero Carbon Emissions

As is the case in many countries already, the Biden administration should embrace a portfolio of solutions that optimize the tactics for an effective path to GHG reduction goals for the future.

A pragmatic policy for lowering the CO_2 intensity of the power generation sector with a transition to renewable energy needs to be tempered with the need to maintain reliability and stability in the delivery of electricity.

Moving to more renewable generation is more complicated than simply building lots of wind turbines and solar farms. But that is often the offered solution; with a reference to solving the intermittency and variability of wind and solar with battery or hydrogen storage. The future for power generation relying heavily on electricity generated from wind turbines and solar farms is a worthy goal that should define the destination. But, as is shown in the next section of this paper, deploying more wind turbines and solar farms will require massive energy storage at a scale that is orders of magnitude from where we are today.

The analysis in the next section of this white paper is based on battery storage. Hydrogen and/or ammonia are also candidates for storing energy, but as yet they are not deployed. H_2 and NH_3 for energy storage have their own sets of challenges to become economical. But assuming they can be cost competitive with batteries and reliable, the same issues with capacity arise that are discussed in detail below with respect to battery storage.

Grid level energy storage sufficient to support the reliable supply of electricity in a decarbonized power sector without on-demand so-called “thermal” generation is probably a decade (or more!) away. That is not to say that a goal of a power grid mostly based on the energy in the wind and sun is not a worthy one. It is. But the transition to that goal will take a long time and will require continued improvements in storage technology and density.

In the meantime, one strategy for maintaining grid reliability during this long transition from where we are today to a 100% carbon free generation portfolio is to do what is already being done in many nations: use sustainably produced solid fuel produced from renewing biomass to replace coal in utility power boilers. Trees and other potential sources of biomass are nature’s natural solar battery.

Of course, as is discussed in detail in several past FutureMetrics white papers, when it comes to the management of the sources for the biomass there are clear-cut sustainability boundaries that cannot be crossed. The foundational and absolutely necessary conditions are that the net stock of carbon held in the landscape cannot be depleted by the harvesting rate exceeding the growth rate, by deforestation, or by improper land use change[6].

As noted above, using sustainable upgraded solid fuel made from biomass is not a novel idea. The strategy is proven as effective and economical, and the strategy is deployable now with no need to invest in new generation infrastructure or hope for continued improvements in energy storage efficiency and density.

The wood pellets that fill panamax vessels very day are ready to be used in large utility-scale pulverized coal boilers. Below is a photo of a panamax vessel being loaded with about 65,000 metric tonnes of wood pellets in Vancouver, British Columbia. Those pellets were destined for England’s largest power station.

[6] All delivered power generation fuels use fossil fuels in the supply chain. However only pellets sourced from renewing feedstocks are carbon neutral in combustion. A few slides explaining this and a link to the FutureMetrics carbon footprint dashboard is HERE.

The supply chain carbon footprint for pellets made in the US and used in the US will be much lower than for those that have to be shipped across the oceans. Use the link in the PDF accessed in footnote six to experiment with changes in supply chain logistics.

Later in this paper is a look at the United States' coal fueled power plants and how existing units could be put to work lowering the carbon intensity of electricity generation. In 2015 FutureMetrics advocated this strategy as a component in the pathway to compliance to the Clean Power Plan.

But first, why energy storage, while critical to the future of power generation, has a long way to go.

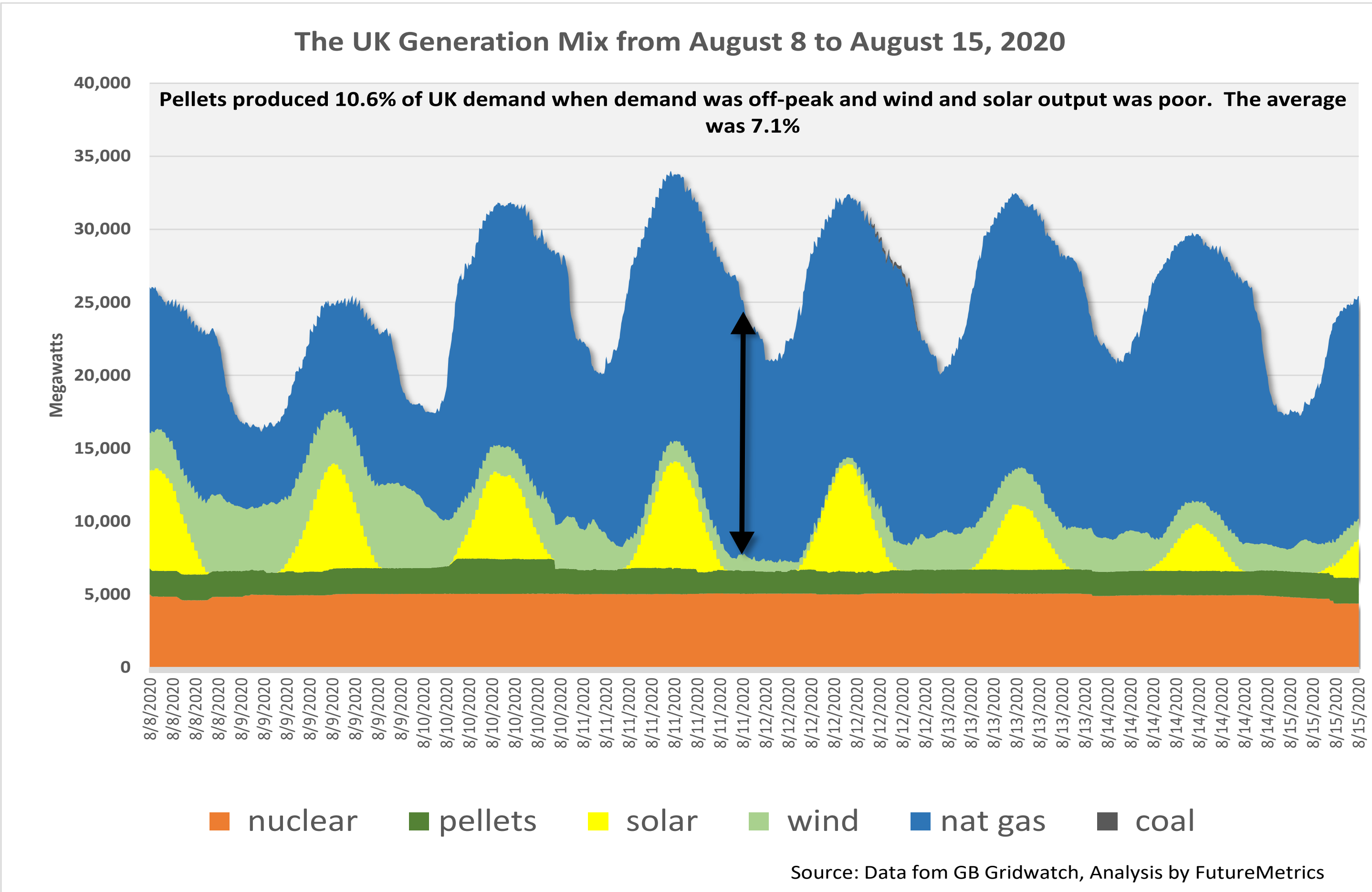
Solar and Wind Require Massive Power Storage if They are to Independently Power the Grid

For the power generation sector, the expected pathway to decarbonization is via the use of wind power and solar power supported by grid-scale energy storage. The storage is needed to buffer the variability and intermittency of those sources.   But the on ramp from here to there is long. Grid-scale battery storage sufficient to meet the reliability standards[7] of our power grids is probably a decade or more away. This is quantified over the next few pages of this white paper.

The chart on the next page shows the power mix for England (UK) for one week in August 2020. The arrow shows a period in which both wind and solar generation were very low. The difference between total

[7] Utilities are expected to hold a more or less constant voltage for all users even as demand constantly fluctuates. As is quantified later in this paper, wind and solar need massive energy storage solutions to be capable of independently and reliably powering a stable grid.

demand and the supply from the low-carbon baseload generation (nuclear and wood pellets) plus what wind and solar added to the stack was about 19,400 megawatts. That gap was satisfied with natural gas. Natural gas (methane, CH_4), a carbon emitting fossil fuel, was necessary to keep supply matching demand.



If natural gas was eliminated, battery storge would not only have to supply some 19,400 megawatt-hours for many hours but it would have to depend on being charged up by wind and solar generation during other hours. There is no time in the chart or anywhere in the UK's history where there was more power from wind and solar than there was total demand. In other words, eliminating natural gas is not possible unless a lot more wind and solar generating capacity is installed, and very large battery or other energy storage systems are deployed. How large? Massive. This is discussed below.

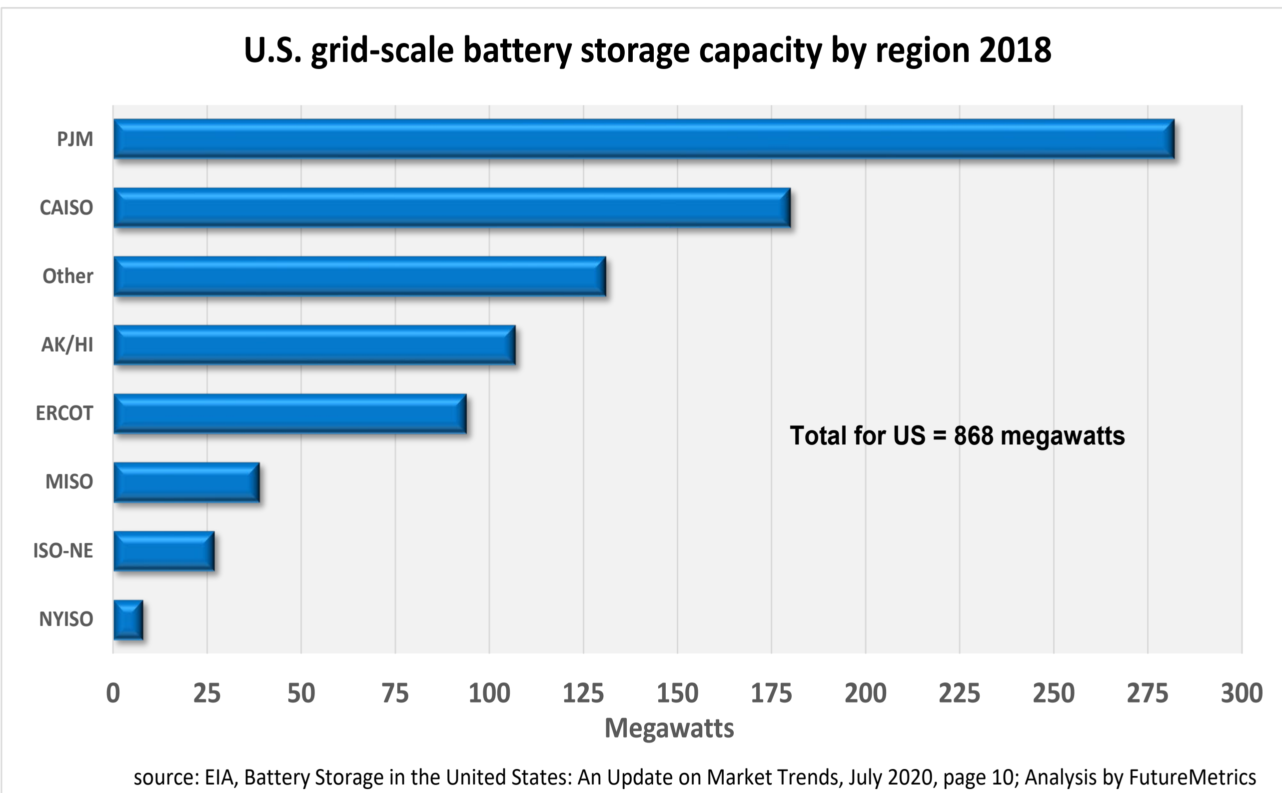
The potential for prolonged windless days and the certainty of long winter nights adds to the capacity contingency needed for grid reliability. That is, the energy storage solutions must have excess capacity to meet reliability requirements when there is little or no generation from wind and solar. The generation sources need to not only power the grid (after non-carbon emitting baseload nuclear and pellets in the UK), they also need to have the capacity to recharge the energy storage while simultaneously powering the grid. The amount of new infrastructure that will be needed to accomplish this is massive.

The UK is used as an example because it is a nation that has incorporated the use of pellets as a substitute for coal into their decarbonization strategy. The UK renewable generation mix is supported by the steady reliability of power generated by two large generating stations that use wood pellets rather than coal. A significant proportion of the UK's total power demand, and of its reduction in CO_2 emissions in the power sector, are based on using wood pellets[8].

So even though deploying lots of wind and solar generation is easy to envision, it is the necessary energy storage component that presents a major challenge if the grid is to become decoupled from fossil fuels.

The concept of having a large stock of stored power in batteries or in massive tanks holding compressed hydrogen that can supply power when wind and solar cannot seems straight forward. But there is a vast gap between where we are today and a system that can provide reliable power based on energy storage.

In North America, the regional transmission organization (RTO[9]) with the largest battery storage capacity is PJM[10]. The chart below shows this. The PJM region covers all or parts of 13 states in the US northeast.



[8] Used in two large power stations: Drax https://www.drax.com/ and Lynemouth https://www.lynemouthpower.com/. The ship pictured above carried fuel for the Drax power station. See a number of FutureMetrics white papers about the net CO_2 benefits of substituting pellets for coal at www.FutureMetrics.com.

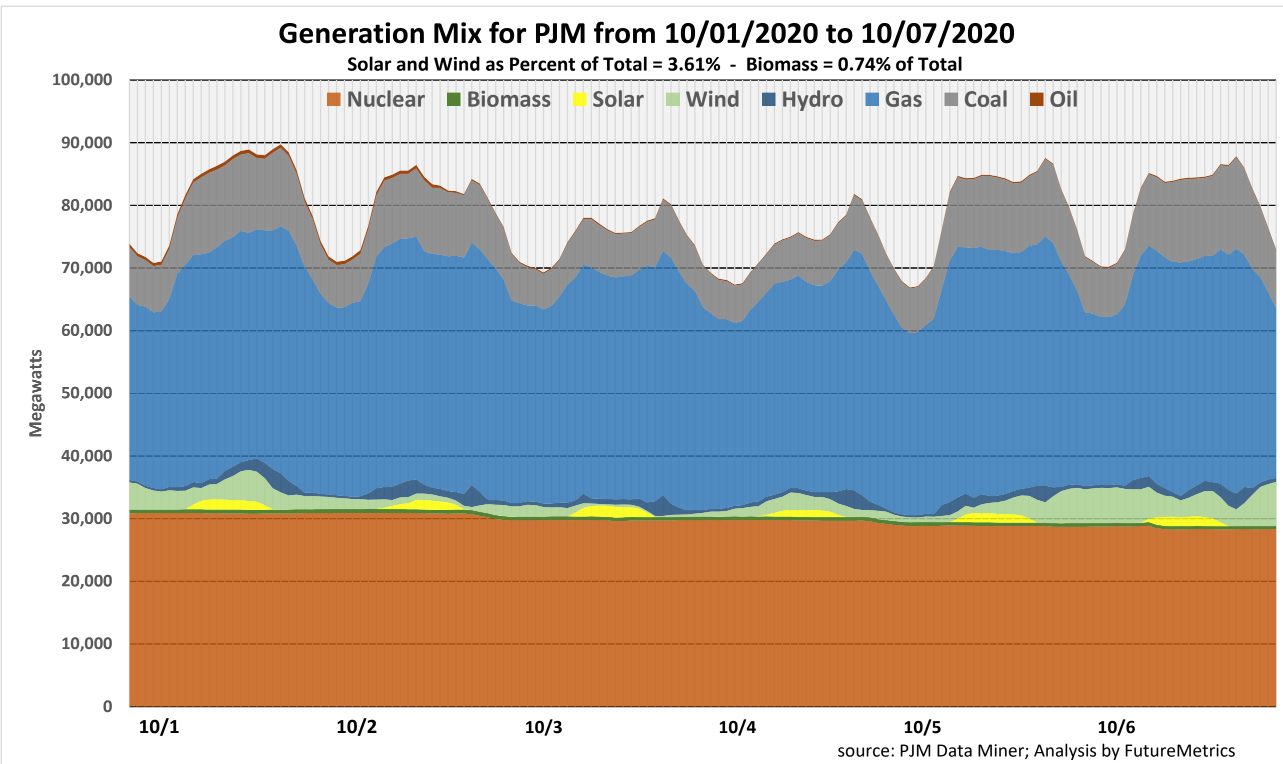
[9] https://en.wikipedia.org/wiki/Regional_transmission_organization_(North_America)

[10] PJM territory served => https://www.pjm.com/-/media/about-pjm/pjm-zones.ashx?la=en

Even though PJM leads in the deployment of battery storage, the PJM region still has an exceptionally long way to go if its goal is to replace fossil fuels with wind and solar complemented with energy storage.

Fossil fuels add well over 50,000 megawatts to PJM's supply (see chart below). Wind and solar combined average output in the period in the chart was 2,836 MWs; far insufficient to recharge the massive and as yet unbuilt power storage capacity while simultaneously powering the grid.

The gap is massive. This is good news for developers of wind and solar generation and for the suppliers of storage solutions. Over the next decade or more, investment in these technologies will have to be substantial.



How Long can Battery Storage Power the Grid?

It is megawatt-hours (MWh's) that define how long the storage solutions can provide power. When the batteries are called upon to provide power, they deplete and have a limited amount of time that they can supply power. In the US in 2018 there was 868 MWs of instantaneous grid level battery storage that held about 1,236 MWh's of energy capacity[11].

PJM's battery storage in 2018 was about 282 megawatts. Assuming that the batteries have to carry most of the load other than the other non-fossil fuel generation (nuclear and, if daytime, solar and, if the wind is blowing, wind) which is about 52,000 MWs at peak and about 32,000 off peak, and assuming MWh's = 1.4 x

[11] https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf MWh's are calculated to be about 1.4 times the rated instantaneous MWs.

MWs, then <u>282 MWs of battery will last between 23 and 44 **seconds**</u> depending on if the demand is during peak or off-peak. If the wind is not blowing and it is night, it would be a even less. If all of the 868 MWs of US grid dedicated battery storage that was in place in 2018 were supplying the PJM area they would last between 1.4 and 2.3 minutes (peak or off-peak).

The US Energy Information Administration (EIA) forecasts that the US will have 1,623 MWs of grid-scale battery storage by 2023[12]. If all of that battery capacity were dedicated to PJM and required to keep the lights on if there were no fossil fuel generated power, it would last about 2.6 or 4.3 minutes at current peak and off-peak demand. This is assuming that nuclear continues to generate at around 30,000 MWs and wind and solar are generating at the average output that they produce now.

And then the batteries would require recharging. That would be impossible from renewable sources.

Once the batteries are depleted, if there were no fossil fuel generation, the lights would go out in large areas.

There is a long way to go to be 100% dependent on wind and solar (and nuclear).

Note that PJM's total biomass generation (primarily waste-to-energy) was less than 1.0%. Coal was about 11.8% during the period in the chart above and natural gas was about 44.3%.

The coal fired generating units in the PJM RTO and in the rest of the US (and the world) offer a ready to use potential to supplement baseload power with low carbon generation that is there when it is needed. The experience in the UK, illustrated in the grid mix chart above, and in other jurisdictions that use pellets in what were once 100% coal burning power plants, proves that a strategy for substituting sustainably produced wood pellets[13] for coal is technically feasible. With relatively minor modifications, there is no derating or loss of reliability in existing coal fueled boilers that substitute pellets for coal.

To make the substitution of pellets for coal economically feasible requires that the external costs of CO_2 emissions be internalized into how energy is priced. Policy that recognizes the costs of carbon pollution and prices carbon emissions, as discussed in the next section of this white paper, is necessary.

Polluters Pay but Society Benefits

Most economists, including the author of this paper, agree that putting a cost on carbon emissions is the most efficient and potentially most equitable way to incentivize a transition away from fossil fuels.

Carbon trading schemes such a "cap and trade[14]", can also be effective. A trading scheme sets a limit on the quantities of CO_2 that can be emitted, and the regulator issues permits that allow a specific quantity of

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[12] See HERE.
[13] Sustainability is a fundamental and necessary requirement to gaining a carbon benefit. Rigorous certification schemes such as the Sustainable Biomass Program https://sbp-cert.org/ certify that the fuel is sourced so that the combustion of the fuel does not add net new CO_2 to the atmosphere.
[14] https://en.wikipedia.org/wiki/Emissions_trading

emissions. The price of carbon is set by trading carbon credits in the markets. That price will vary with supply and demand. Cap and trade is more or less the opposite of a carbon tax scheme where the cost of GHG pollution is set by policy and it is up to businesses to work out the profit maximizing solutions. Both can be effective, but a carbon tax is a more precise instrument that clearly places a known cost of carbon pollution on the polluter while generating easily defined revenues.

In discussions about policy, suggestions of any tax is a "third rail[15]". However, as in all cases with any tax policy, the revenues from the taxes are used to fund government spending. So what matters is how the funds are spent, and who within society benefits and who pays. Taxes are a necessary and fundamental component for supporting and maintaining social well-being if the spending programs they support are defined with aggregate socio-economic welfare as the primary objective.

A well-crafted carbon pollution cost policy phased in over several years will result in a net positive to social and environmental welfare over time. But care has to be taken to protect some segments of society from short term economic impacts.

The impacts of any policy that will change energy costs will be spread over much of society. There will be negative social welfare impacts from the higher cost of using fossil fuels that will have increasing marginal costs as we move into lower percentile aggregate income segments. Lower income households tend to spend a higher proportion of disposal income on energy (transportation, electricity, heating fuels). Furthermore, increases in the cost of production and transportation will likely increase the cost of some final goods. Thus, without an equitable strategy for how the carbon tax revenues are spent, a carbon tax would be regressive in the short term.

In a study from 2015[16], it was calculated that a $40 tax per short ton[17] of CO_2 equivalent emitted would add about $0.36 cents to price of gallon of gasoline (about $0.095 per liter). A $40/ton tax, based on the same 2015 paper, would be expected to add about $0.02/kWh to the average price of electricity. Changes in the power grid's generation source mix since the study in 2015 will likely lower that impact in 2021 (more natural gas, more renewables, and less coal). But there will still be an impact on power costs that, for lower income households, would be a real burden.

Using the substantial revenues from a carbon tax[18] for rebating lower income households based on a measure of per capita income could reverse the regressiveness. Lowering income taxes for lower income households could also be part of an equitable policy.

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[15] https://en.wikipedia.org/wiki/Third_rail_of_politics
[16] "Carbon Taxes and Corporate Tax Reform", Marron, Donad, and Toder; from *Implementing a US Carbon Tax*, pages 141-158.
[17] A short ton is 2000 pounds and a metric tonne is 1000 kg.
[18] In December 2016 the US Congressional Budget Office estimated that starting at $25/ton in 2017 and increasing the tax by 2% over inflation over 10 years would raise nearly $1 trillion in new revenue after accounting for some lost tax revenues. See HERE. By way of comparison, the US GDP in 2019 was about $21.4 trillion.

Some of the revenue could be dedicated to R&D in critical technologies for effectively fighting climate change. For example, support for the growth of energy storage, support to lower the cost of on and offshore wind and solar, the development of energy crops for expand the supply of sustainable biomass, and biomass carbon capture and sequestration (BCCS)[19].

If well-crafted, and not distorted by special interests, a carbon tax will not harm economically vulnerable households, will accelerate decarbonization, and will be a net job creator.

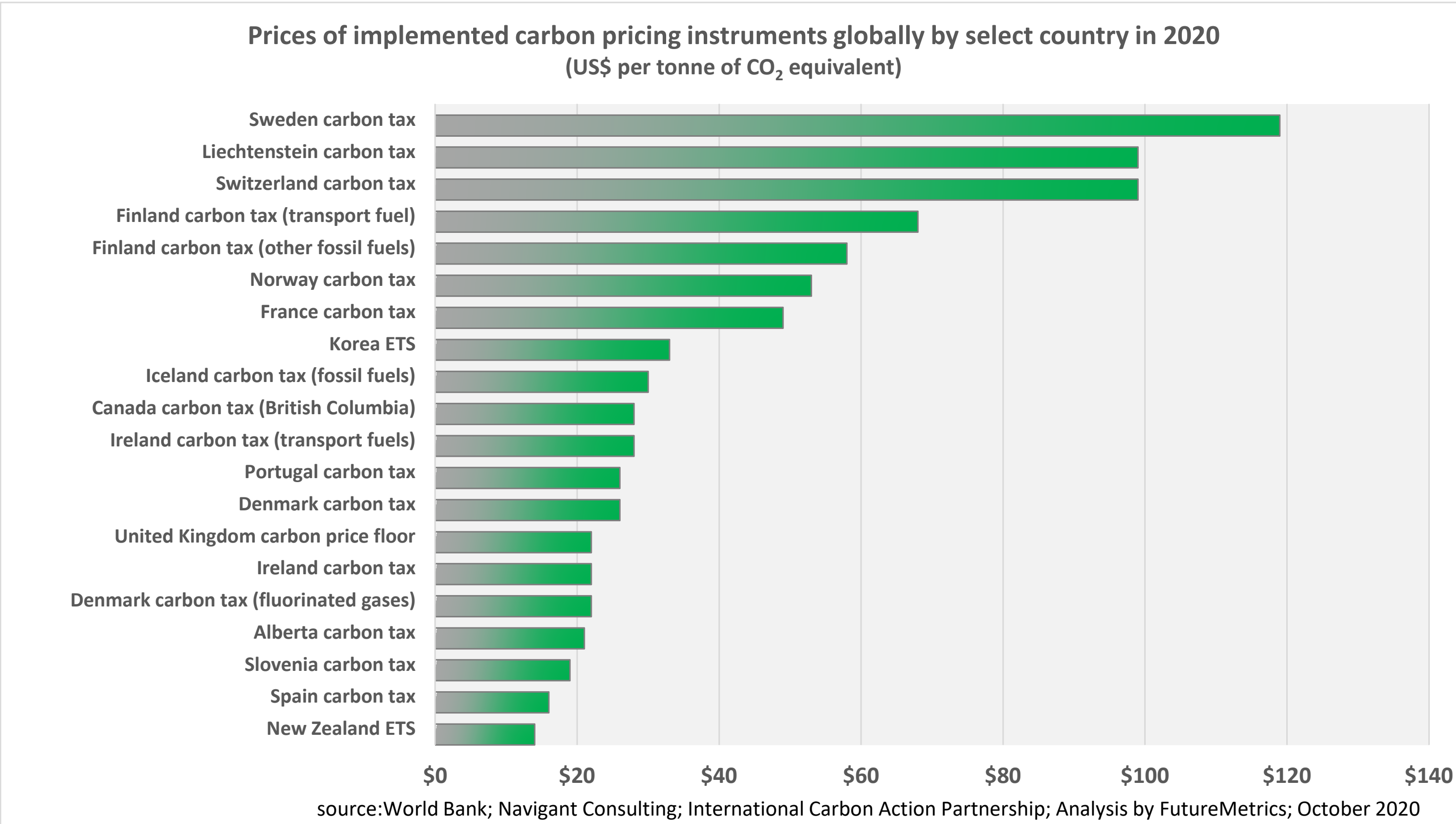
The fundamental purpose of the carbon pricing policy would not change: Polluters would still pay, and the use of fossil fuels would be gradually reduced. How energy is produced and used for manufacturing, transportation, and heating will evolve. The efficiency of energy use will improve. The amount of energy a household needs for a decent standard of living will decrease[20]. The renewable energy sector will grow, and the fossil fuel sector will decline.

If anthropogenic CO_2 emissions are to be curbed, a carbon tax is the most practical, effective, and equitable option for guiding meaningful action with results that are soon enough to matter.

Carbon taxes or carbon trading schemes are already in place in many countries that are taking climate change seriously. The chart below shows the most recent data (the US is notably missing).

[19] BCCS is carbon negative while also generating baseload power for the power grid. https://www.nap.edu/resource/25259/Negative%20Emissions%20Technologies.pdf

[20] See "Providing decent living with minimum energy: A global scenario" from Global Environmental Change, November 2020, HERE



It is a tall order to ask for the US policymakers, under any administration, to implement a carbon tax. A look to the UK, Denmark, the Netherlands, Japan, or a number of other countries can provide guidance on other policy mechanisms that allow utilities to blend pellets with coal or switch to 100% pellets.

In the US, co-firing pellets with coal at a ratio that contributes to the carbon reduction mandates is the most likely scenario for compliance.   The cost per MWh for generation by co-firing pellets depends on the co-firing ratio (and of course the cost of the pellet fuel). On page 17 of this paper is a link to a FutureMetrics dashboard that allows the user to experiment with different co-firing ratios and see what the estimated incremental cost is.

How Existing US Coal Power Stations can be Part of the Transition

This white paper has shown that a simplistic view of wind, solar, and energy storage as an easy pathway to decarbonization does not capture the real challenges of supplying sufficient and reliable renewable power.

A proven, low cost, and ready to deploy solution is to substitute sustainably sourced biomass solid fuel[21] for coal. FutureMetrics and many others have documented the efficacy of this strategy.

Globally in 2020 about 43,730,000 MWh's of baseload electricity will be produced by wood pellets[22]. The comparison with battery capacity of about 2,272 MWh's in the US in the year 2023 is meaningless.

Every tonne of coal that is replaced by wood pellets lowers net CO_2 emissions by at about 85% in most locations[23] and each tonne of pellet fuel contains about 4.8 MWh's of renewable energy.

When (not if!) the US creates policy that will support this well-proven strategy, there are a number of coal stations in the US that could benefit from co-firing or, in selected locations[24], conversion to 100% renewable carbohydrate-based fuel instead of hydrocarbon-based fuels mined from the earth.

This existing fleet could continue to supply on-demand power to balance the grid as wind and solar generation increases. The carbon intensity of the power would be proportionally lowered as the ratio of pellets to coal is increased. That on-demand reduced carbon intensity generation can contribute to goals for lower CO_2 per MWh of electricity while transitioning to that day out in the future when solar, wind, and grid-level battery storage are sufficient. It also provides a known market for coal and a predictable gradual glidepath as coal is phased out. At the end of the glidepath a limited number coal stations using 100% pellet fuel will be ready to supply on-demand 100% renewable power as needed.

Again, this is not a novel idea. Both the Drax and Lynemouth stations in the UK run on 100% pellets today with a total capacity to generate about 3,000 MWs.

The chart on the next page shows the age distribution of all 529 of the US coal power generating units (some power plants have more than one coal fired unit).

There are 41 units that are less than 15 years old. There are at least three decades of life left in these newer high efficiency units representing about 22,000 MWs of capacity.

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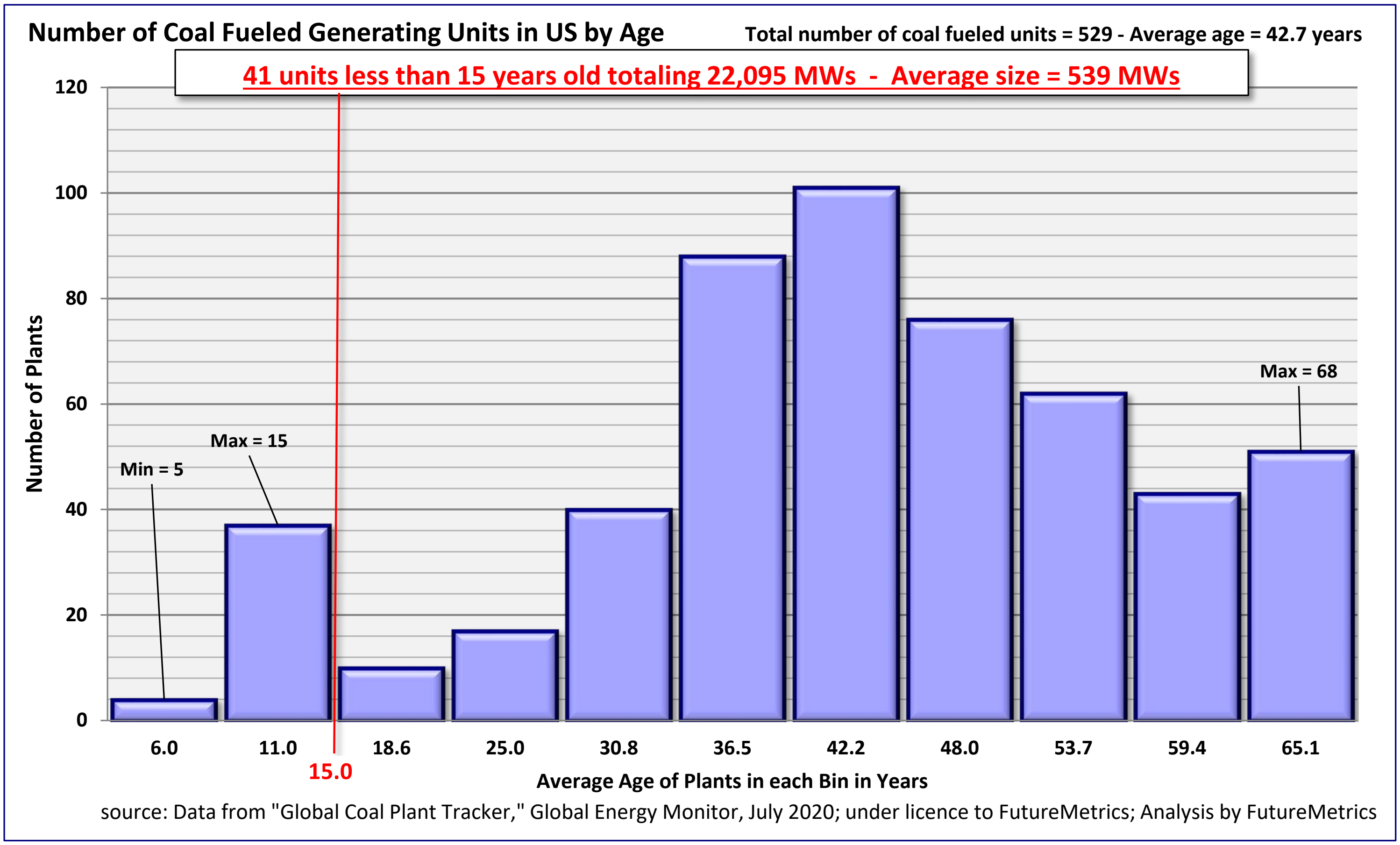
[21] Currently this is primarily wood pellets. But in the future biomass solid fuel suitable for large pulverized coal power units may also be produced from other suitable woody and agricultural biomass residues. In some locations, dedicated short cycle energy crops may also provide a low carbon fuel source.

[22] Based on 24 million tonnes of pellets being consumed, an average power plant efficiency of 40%, and with an average power station capacity factor of 80%.

[23] See the free FutureMetrics CO_2 footprint dashboard [HERE].

[24] There are some regions in the US where coal powered units are located in an area with an abundance of low-grade woody biomass that is sustainably available and well suited for conversion into pellets. These are locations that do not have good logistics solutions for pellet export and thus are not currently considered viable for industrial wood pellet production.

If some of these units are used rather than be closed in favor of lower cost (but carbon emitting) natural gas, they can contribute to a lowering of carbon emissions in the power sector and avoid the real costs to ratepayers of stranded assets. The cost of the modifications necessary to replace some of the coal with pellets are 0% to 25% the cost of building a new combined cycle natural gas plant depending on the ratio of pellets to coal from 5% up to 100%.



The map on the next page shows the locations of the 41 newer units. Some are in areas with an abundance of otherwise non-merchantable by-products from forestry operations. The map on page 15 shows a closer view of an area in the first map and has an overlay of the relative density of merchantable woody biomass (as a heat map).

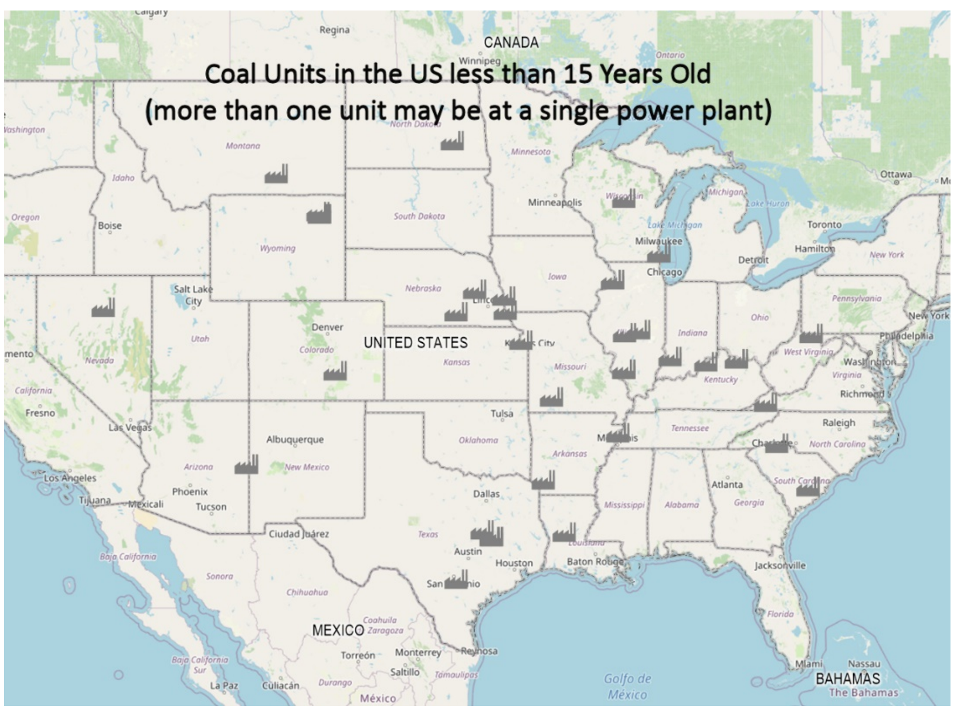
The major US pellet producers/exporters take advantage of the abundance of sustainable renewing feedstock in the southeast US region. But those producers have to export the pellets via ship, so the production facilities are relatively near the coast and deep-water ports.

Some of those areas of higher density suitable and sustainable pellet production feedstock are too far from ports and/or have no rail or barge options for economically moving the pellet fuel to an export terminal. In other words, there are areas around existing relatively new coal power stations in parts of the US that are capable of producing perpetually renewing biomass based solid fuel for power generation but are currently underutilized. One of those areas, West Virginia, would welcome the many jobs associated with forestry operations and a new fuel production industry as coal mining in the region declines.

If the concentration of available sustainable wood is close enough to the power station and is high enough, there is no need to make pellets first. Pellets are a way to maximize the energy density in a cubic meter of volume to minimize the cost to transport the energy they contain to the power plant. If transport distances are short enough within the wood supply region to the power plant and there is sufficient sustainable supply within that supply radius, a processing plant can be located directly next to the power station. Waste heat from the power station can be used for drying the wood and then it only has to be milled to the small particle size that the pulverized fuel system[25] needs for combustion. Pulverized fuel systems are typical in almost 100% of the large-scale utility power boilers in coal generating units.

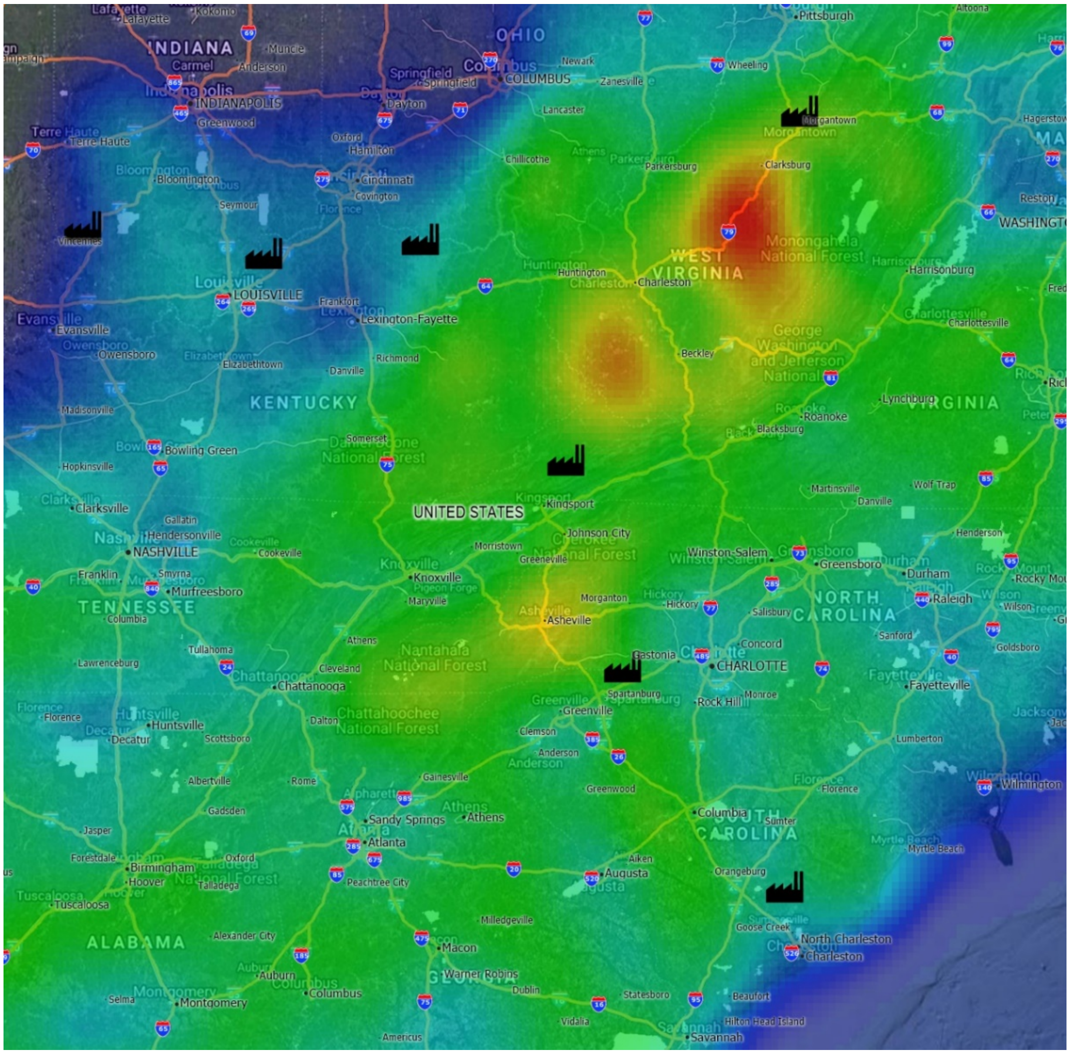
Under that scenario, without an investment in full sized pellet factory needed, without the operating costs associated with densifying milled dried wood into pellets, and without transport costs for moving pellets to a power plant, the cost of that sustainable fuel will be significantly lower than pellet fuel from farther away.

If the UK can make the substitution of coal with pellet fuel work economically with pellets from the US and western Canada, the US should have an easier and less costly experience with upgraded biomass based fuel from literally just down the road. Plus, the supply chain carbon footprint of the pellets will be significantly lower yielding reductions in CO_2 emissions versus coal of more than 90%.



A Google maps version is HERE where you can zoom in on a satellite image of any individual station.

[25] https://en.wikipedia.org/wiki/Pulverized_coal-fired_boiler



Source of map data: USDA, November 2020; Analysis by FutureMetrics

<u>What is the Cost?</u>

There is no question that currently the cost per unit of energy (gigajoule per metric tonne or BTU per pound) for coal is less than it is for wood pellets. But in those jurisdictions that are using pellets for power production (primarily western Europe, the UK, Japan, and South Korea) there is policy in place that compensates the generator for the higher cost of pellet fuel and/or allows them to avoid costs associated with CO_2 pollution.

A combination of policy instruments is used in those countries to compensate the utilities. Feed-in-tariffs (FiT), contracts for difference (CfD), and carbon pricing are common.

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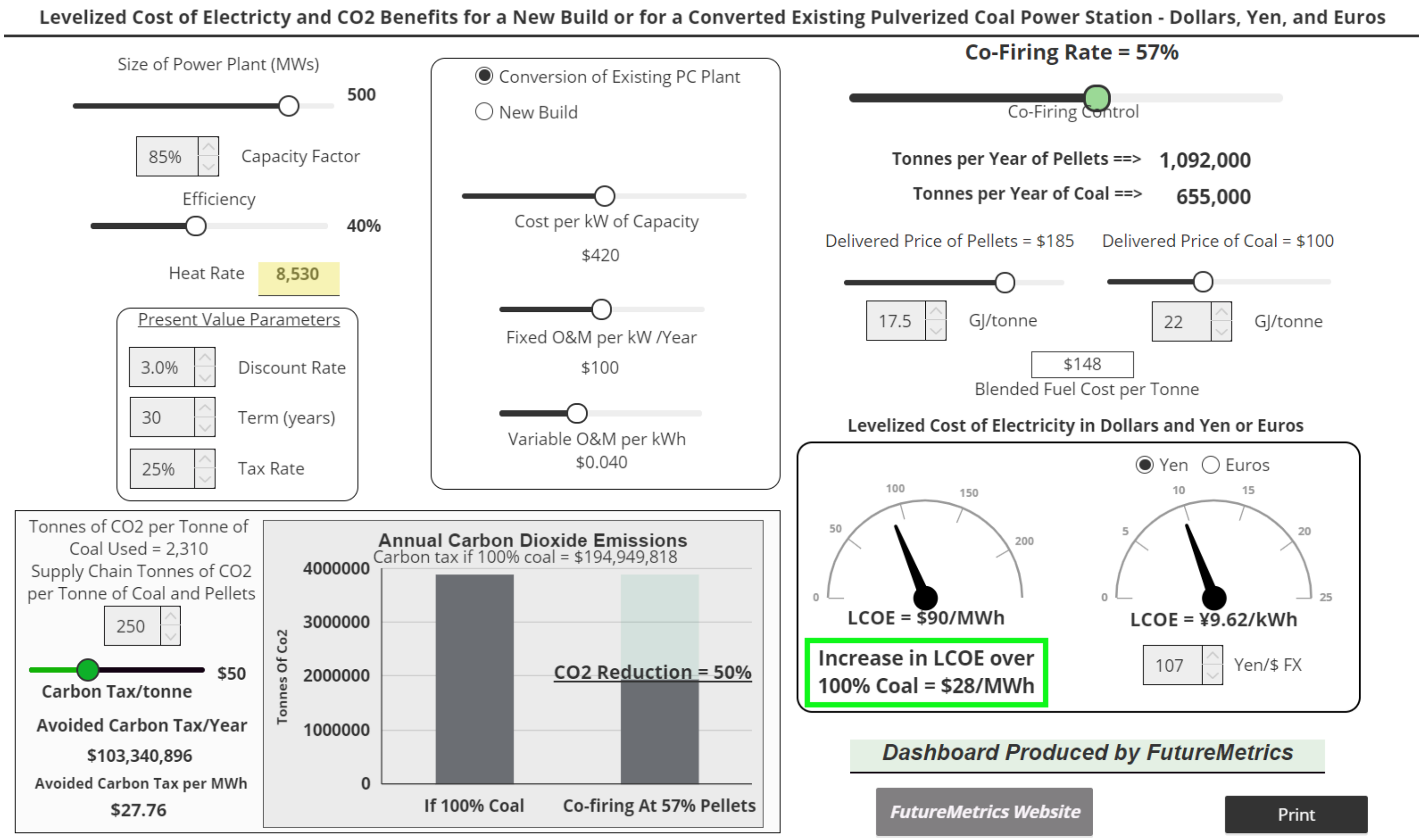
The image below[26] shows that if a 500 MW coal station is modified to co-fire pellets, based on the other assumptions in the dashboard including a co-firing ratio sufficient to lower the units CO_2 emissions by 50%, the increase in the levelized cost of generation versus 100% coal is about $28/MWh or less than three cents per kWh.



The increase in the levelized cost of electricity (LCOE[27]) versus using 100% coal has to be fully offset by whatever policy instrument is in place. If it were a carbon tax, as the dashboard shows in the far left bottom corner, the generator would be paying about $50 per metric tonne of CO_2 equivalent emitted, the use of pellets at a ratio of 57% pellets and 43% coal would make the generator's avoided carbon tax cost to equal the incremental increase in LCOE and thus the generator will prefer to co-fire. If the delivered cost of the pellet fuel is lower than shown in the dashboard due to the proximity of the pellet production facility and there is no need for ocean shipping, then the breakeven point will be reached with a lower increase in LCOE and thus a lower carbon tax would be needed.

The reader is invited to use the dashboard to experiment with different combinations of inputs including co-firing at lower or higher rates, or at a significantly lower delivered "pellet" price as a proxy for the scenario

[26] From the free FutureMetrics dashboard HERE.
[27] https://en.wikipedia.org/wiki/Levelized_cost_of_energy

described above in which the densification into pellets component of the conversion from wood to fuel suitable for a pulverized fuel unit is eliminated, or when the pellet plant is relatively near the power plant, or all of the above and more.

In the example above, if a carbon tax is used, the tax revenue based on the 655,000 tonnes per year of coal still being used, will pay for programs described in the earlier section of this white paper discussing equitable policy.

Conclusion – Can the Biden Administration Succeed on Environmental Protection

The change in administration in the US is expected to bring real leadership on climate issues. That leadership will define policy goals. Will the US senate stand in the way?

At the time of the writing of this paper it is not known which party will have the majority in the US senate.

But as this paper has shown, it should not matter. The consequences of climate change are causing even the actuaries, who base their forecasts on real data and rigorous probabilistic analysis, to raise a big red flag. It is difficult to imagine that most policymakers can continue to deny the link between CO_2 emissions and global warming. Time will tell.

What this white paper has offered is at least one small part of the solution that has winners on all sides.

If US policy supports a co-firing strategy, there is no shortage of winners:

- The **environmental benefits** are immediate and quantifiable. To lower carbon emissions by 10% requires a ratio of pellets to coal of about 11.24% pellets and 88.76% coal[28]. This takes almost no investment in modifications to the power station. For the lignite burning plants in Texas it can happen overnight.
- The **power generation assets** that are fueled with pulverized coal gain a significant new value as the only pathway that allows low cost renewable co-firing. At a co-firing rate that results in a 10% CO_2 reduction, the increase in the cost of generation is estimated to be less than one penny per kilowatt-hour.
- The **coal producers** have a secure long-term market for their product with a certainty for demand over the next decade or longer. Co-firing is not possible with natural gas turbines.
- The **pellet producers** have a new and gradually increasing market also with known demand. Many underutilized industrial working forests, such as those in West Virginia, are not in optimal locations for the existing pellet export market. Those locations, and new locations released from wood chip demand by the declining pulp and paper industry, can be responsibly developed to produce renewable refined solid fuel that is 100% compatible with existing pulverized coal plant fuel systems. US pellet manufacturers have already invested more than $1.7 billion in facilities in states like Mississippi, Alabama, Arkansas, Texas, Georgia, and the Carolinas for the export markets. Many

[28] This will vary slightly based on different energy contents of coal and pellets.

thousands of jobs are associated with this existing capacity. New capacity for a US market would replicate that history.

- And **US workers** benefit from a carbon mitigation solution that not only maintains jobs but increases the demand for labor. Natural gas plants require very little labor in the fuel supply chain relative to coal and pellets. Wind and solar power plants require no labor for the fuel supply.

Business-as-usual (BAU) in the case of CO_2 emissions will result in unimaginable negative changes to the world that we and the rest of living things have evolved in. To change that trajectory in time to prevent catastrophic outcomes, effective and meaningful policy has to make change happen in the near term.

Policy is needed because changing is more costly than business-as-usual.

A world powered by wind turbines and solar farms is possible. But not without massive investments in generation capacity and major investment and advances in battery technology. It will likely happen but most likely not in the next decade or more.

Sustainably using the natural solar energy collectors (growing trees and other plants) that convert that energy into carbohydrates and other organic molecules that can be used for many purposes, including energy production, is a solution that is already deployed in some places.

The incoming Biden administration is expected to engage in sensible carbon reduction strategic planning.

They should take a serious look at the ideas in this white paper as they formulae their version of the Clean Power Plan.