Coal to Oil, CO_2 Emission Free at the Point of Production, then Carbon Fiber and Advanced Materials

Precis: A new and transformational technology styled "Wave Liquefaction™" (WL) has emerged that will be the basis for converting coal and natural gas into synthetic oil, carbon fiber, petrochemicals and other materials. The initial step in the process uses only electricity to power microwave generators that, in turn, create non-thermal plasmas that power the reactors. The product created is a thick, heavy hydrocarbon liquid that becomes feedstock for making myriad oil, chemical and carbon products to meet current and future market demands. The WL process itself is emissions free, creating no CO_2 and using no water.

There are two holy grails in coal conversion. One is to create a process from which multiple products can be manufactured, a coal refinery if you will. The second is to create a cost-effective process that is not only efficient but free of emissions, including CO_2 emissions. WL qualifies in both arenas.

Ultimately, WL is a unique expression of the benefits of electrification. Electricity is the cleanest, most efficient form of energy at its point of use. It is the only source of energy input that WL uses; resulting in a range of coal-derived high-impact products that we need now and for as far as the eye can see. WL produced oil and advanced materials will continue the beneficial, industrial evolution of the human community, meaning more people living longer and living better. Modest funding for further development of WL to scale is needed, but the process deployed at scale will use already existing technology with no additional "new inventions" needed.

The decline of coal use for electricity generation in the US is well documented. Over the past decade, the deadly combination of the EPA's 2009 CO_2 Endangerment Findings; the technological breakthroughs of fracturing shale to produce natural gas and tight oil; and the prodigious amounts of imprudently borrowed money (over $200 billion and associated massive debt) for 'fracking" led to natural gas prices below cost causing a precipitous decrease in coal consumption in the US. Since 2010, many tens of thousands of workers in the coal supply chain have lost their well-paying jobs due to these multiplicative impacts and the decline of the industry. Communities have been virtually decimated through drastically reduced tax revenues, outmigration, unemployment, drug use, crime and the general socioeconomic malaise that inevitably accompanies the loss of hope.

Yet, the US still has a coal endowment of over <u>250 Billion</u> tons and the infrastructure to support the mining, production and transport of well over one billion tons per year. Leaving these resources as stranded assets makes neither economic nor social sense. WL offers the opportunity to revitalize these communities, restore a vibrant quality of life and strengthen the backbone of the US economy.

The disruptive and transformative WL technology will not only enable coal and natural gas conversion at scale but also provide expanded access to the World's largest market - oil. WL

will enable a resurgence of coal in the United States through conversion to synthetic oil, petrochemicals, carbon fiber and other materials. Initially conceived in a USDOE laboratory, WL is an entirely new way of using electricity to liquefy coal and natural gas with no CO_2 emissions or water consumption. Electricity is the only driver of this environmentally responsible, economically attractive coal conversion technology. Instantaneous conversion takes place in a microwave powered, low-temperature non-thermal plasma reactor.

WL is beneficial electricity in action. With about 2/3rds of the feedstock energy from coal and the rest from natural gas, WL is expected to be economically competitive at oil prices of $35-40/b. The EIA projected oil price in 2030 is $87/b. With no significant resource depletion, as well as minimal annual capital expenditures, synthetic oil production using WL could easily provide new demand for hundreds of million tons of coal per year at the initial cost of only $200M per plant producing 10,000 barrels a day. Indeed, with this modest capex, low operating cost and dramatically reduced emissions, there is the real potential for substantial growth in new coal demand to over one billion tons/y as the technology becomes widely established. Importantly, by getting hydrogen from natural gas, the heavy hydrocarbon liquids from WL can be upgraded to virtually any gravity, thereby ensuring the United States has a steady supply of heavy oils to meet refining requirements without the need to import millions of b/d of heavy grades or requiring highly expensive, and perhaps infeasible, retrofits by current US refiners. WL reactors can be "turned on or off" immediately with no need for the costly and time-consuming startups or shutdowns characteristic of oil wells. To be sure, the currently struggling US shale industry will come back -- but at a lower level of tight oil production. Nevertheless, the demand for liquid fuels and particularly heavier grades of oil will continue to expand and WL will provide the means to meet that expansion and to complement light, tight oil. WL will sustainably put tens of thousands of men and women back to work, revitalize communities devastated by coal's decline, and ensure US energy independence, security and dominance well into the next Century.

The H Quest companies have exclusive access to WL technology through licenses and their own patents and pending patents. An associated company, NewERA Carbon, has the option to earn an exclusive license to develop WL for commercial and industrial scale applications involving coal together with natural gas. The benefits of this unique process are profound and will be far-reaching.

The US holds almost 25% of the world's proved coal reserves, and their BTU value exceeds the Nation's oil and natural gas reserves combined. For over a century coal was the cornerstone of electricity in America. Coal production for electricity generation peaked at one billion tons in 2008 with well over 50% market share of power output. But the decline in coal consumption has been precipitous and now the EIA forecasts that in 2020, only 563 million tons of coal will be used to account for just 26% of electricity generation in the US. Further, Moody's forecasts that by 2030, coal-based electricity will comprise only 11% of generation and the resulting coal use will reach just 250 million tons. For the last decade, coal plant retirements have been the order of the day. In November, for example, two of America's largest coal plants closed permanently-- Arizona's 2.25 GW Navajo Generating Station and

Pennsylvania's 2.7 GW Bruce Mansfield unit. In 2020, even more coal plants will be shuttered including Kentucky's Paradise plant operated by TVA. The revitalization of the coal industry would positively reverberate throughout American society.

WL will create a new, massive market for coal, replacing the losses in the electricity market and restoring the central role of our very underutilized coal fleet. Initially, production facilities can be located at coal power plants as a value enhancing base load customer in a market environment where many remaining coal plants are now being used for peaking purposes. Similarly, since source fuels are 2/3rds coal and 1/3 natural gas, WL will also present a new market for gas -- a welcome addition to an industry that is also struggling economically. Gas fields are often where the coal plants are (e.g. West Virginia). Converting coal and gas to oil will open a new economic door for those states and communities that have been dramatically impacted by the decline of coal and the low price of gas.

The impact of the coronavirus has induced massive loss of oil demand while supply has surged due to the Saudi- Russian price war. Consequently, it has been easy to lose perspective on the role oil plays and will continue to play in every society. Hyperbolic articles declaring "The End of the Oil Era" become the order of the day as wishful thinking by special interest groups ignores the fundamental realities of global energy consumption. Liquid fuels account for approximately 94% of modern worldwide transportation--- automobiles, tractors, trucks, airplanes, ships, on and on. Liquid fuel demand was 100 million b/d in 2019 and by 2025 will reach over 105 million. The short-term perspectives of the media and the financial markets belie this fundamental fact, but Demography always wins in the end. More than 80 million people will be added to the global population this year-- upwards of a quarter million today alone or a new Philadelphia every week. By 2025, the World's population will have increased by over 400 million -- if these people were a country, it would be the third-largest nation on earth. Covid 19 and the price war notwithstanding, oil demand will resurge and continue to increase for decades to come. The International Energy Agency (IEA) recently affirmed its projection that peak oil demand is nowhere in sight. Fatih Birol, Executive Director of the IEA, put the situation in perspective; "American business consultants using Zoom will not compensate for 150 million new urban residents in India and Africa traveling, working in factories and buying products transported by trucks."

Thus, significantly increased demand is not an issue - it is a given. The major question is supply. Where will it come from? Virtually all major producing countries, from Saudi Arabia to Russia to Norway to Brazil to Mexico are facing depletion rates that Exxon estimates may be as much as 7% on a worldwide basis. For those who doubt the relevance of this data point, keep in mind that over the last five years about 2/3rds of all incremental global oil production has come from US tight oil (shale). Oil production from horizontal wells in the US ended last year at around 8.1 million b/d-- an increase of 800,000 b/d compared with 2018. Even more importantly, future global supply over the next five years has also been projected to be dominated by US shale. The following statement by the International Energy Agency (IEA) near the end of 2019 demonstrates the crucial role US tight oil has been assumed to play over the next two decades: "U.S. tight crude oil production is seen rising to 11 million b/d in 2035 from 6 million b/d in 2018. The share of oil production by the Organization of the

Petroleum Exporting Countries plus Russia is seen falling to 47% for much of the next decade, a level not seen since the 1980s.." (IEA, 2019)

Now, however, the model of ever-increasing growth that characterized US tight oil production is gone. Bill Thomas, CEO of EOG Resources, has stated: "U.S. oil production is in severe decline and it could take years for domestic production to turn around". Bankruptcy of dozens of companies is occurring and could continue to occur at the extremely low prices characterizing the second quarter of 2020. Shale Profile, a leading industry website, forecasts a 3.2 million b/d production decline in the remaining 8 months of 2020 and nearly 4 million b/d in just 12 months. Spot prices for WTI oil averaged $17 a barrel in April and would have to more than triple to give stability to the market. The industry itself has said it cannot survive without substantially higher oil prices. The fracking industry faces a mountain of debt-- as much as $200 billion. Company executives are pleading for a lifeline to preserve the industry. In a frequently cited essay on oilprice.com, Dan Doyle, President of Reliance Well Services, called for President Trump to take these two steps — (1) fix a national oil price at $62/b and (2) provide capital for US refiners to retool their facilities so they can use the light oil that predominantly comes from US shale.

Virtually all new tight oil production has been dominated by high gravity (light) oil which does not meet all the needs of US refiners who also require significant amounts of heavier grades. This surplus of lighter oil must be exported while heavier oil must be imported. In fact, about 97% of all oil imported into the United States in 2018 (7.5Mb/d) was API gravity 40 degrees or less. Jennifer Rowland, analyst with Edward Jones, stated the issue clearly: "That's a big structural problem that's not going to go away anytime soon. We've got this mismatch in the country. We've got refineries that want heavy oil and producers that make light oil." A massive retrofit of US refining facilities is highly unlikely to occur without dramatic increases in the price of oil. Consequently, more and more imports are on the horizon in coming years unless the United States gains new access to heavier oils. WL can produce oil at virtually any gravity and thereby serve as a partner to tight oil production, providing the full spectrum of oil needed by US refineries. This is the true path to American energy independence.

Most shale companies have negative cash flows. These companies have historically relied on bond markets to finance their operations. With this financial avenue now severely constrained -- capex is dropping of a cliff and severe production declines will follow. Thousands of oil workers are being terminated, rigs are being laid down by the dozens, fracking crews are being recalled, hundreds of wells are being shut in, budgets are being drastically reduced and exploration is now the rarity rather than the norm. Shutting in wells will have serious long-term consequences for future production. As Bjarne Schieldrop of Nordic Bank SEB has warned: "Damage today implies less production tomorrow". Even modest damage to wells will have a dramatically cumulative effect.

Given the high rate of natural decline of tight oil fields, coupled with the temporary and permanent damage to the industry by the "virus" and price war, it is increasingly unlikely that the optimistic projections of tight oil accounting for over 11 million b/d of US production will be met. And even if it were, the predominance of light oil production would necessitate the

continued importation of millions of barrels of heavy oil every day. The vaunted goal of "energy independence" of the United States would be shattered-- or not. Waiting in the wings is the real master energy resource of America - coal - the fuel that built the country and the fuel that will ensure its dominance as a global energy power.

Wave Liquefaction: The Sustainable Pathway

The primary focus here is on the oil market because it approaches $2 trillion per year. But Carbon Fiber is a promising long-term market that through education and experience will evolve over time from current levels to a serious player in the automotive and construction industries, displacing steel and aluminum based on its extraordinary strength, light weight and the future low production costs of WL technology. The market will move in the lower cost direction and coal demand in the carbon fiber market could rival demand to convert coal to oil in coming decades. Certainly, the coal resource is there.

WL's use of electricity as 100% of the external energy input produces no emissions at all, including no CO_2, and it uses no water. As such, as an electricity customer with no emissions, the EPA has no jurisdiction under the *Clean Air Act* and the *Endangerment Findings* do not apply to WL operations as they do to power plants. Further, all this can be accomplished at a financial cost far less than any previous coal conversion processes and well below the cost of both conventional and tight oil production. Finally, a crucially important, WL reactors are safe.

WL is an entirely new way of liquefying coal using only electricity as the driving force. WL was first conceived at the DOE's Pacific Northwest National Laboratory for production of jet fuel from coal. The concept of using low temperature thermal plasma to modify coal was discovered in 2011 in a PNNL investigation funded by the Defense Advanced Research Projects Agency (DARPA). Subsequently, H Quest took on funding and expanded the program to test many coals in the laboratory. H Quest holds an exclusive license to the technology, including its own patents and pending patents. The associated company, NewERA Carbon, has the option to earn an exclusive license to

develop WL for commercial and industrial scale applications involving coal together with natural gas. The projected benefits of this unique process are profound and will be far-reaching:

<u>Technical/Environmental Achievements:</u>

- **Electricity is the only 'driver' or supplier of external energy.**
- **No emissions from WL reactors, including no CO_2**
- **No flaring-- tight oil production has led to unprecedented flaring of natural gas. In fact, the volume flared in Texas in 2018 was greater than residential gas demand in the entire state.**
- **No water consumption (water is actually produced, the amount depending on coal type)**
- **Continuous, rapid processing (<1 sec. residence time in the reactor)**
- **Post reactor, products are 'by design'.**
- **Amenable to virtually all types of bituminous and sub-bituminous coal (e.g., Illinois, Appalachian, PRB)**

<u>Socioeconomic Benefits:</u>

- **Low capital requirements ($20-25k/b/d)**
- **Competitive at oil $35-40/b (The EIA projected oil price in 2030 is $87/b)**
- **Profitable at small scales (1-10 kb/d)**
- **Tight oil has decline rate of over 60% in the first year. WL has virtually no depletion concern given the size of the US coal resource base.**
- **With *de minimus* depletion WL avoids the billions of dollars tight oil wells require just to <u>maintain</u> production let alone increase output.**
- **Can provide customized oils with API < 40 to meet needs of US refiners for heavier oil**
- **Heavier oil through WL will greatly reduce the need for imports from such countries as Venezuela and Iran.**
- **Modest size of WL reactors requires minimal land use**
- **Assures true American energy dominance into the next Century and beyond. For all practical purposes, in perpetuity.**

Consider:

(1) As the next several decades unfold, global population growth and economic expansion will continue to grow demand for liquid fuels by over 1 Mb/d/y: "there is no peak demand on the horizon" according to the IEA. Literally billions of people will enter the middle class across the world. The transportation sector will drive more than half of liquid fuels demand and trucks alone will consume 30 Mb/d by 2050. Petrochemical demand will add 7 Mb/d. Few people recognize that a 100x growth in the number of electric vehicles to 400 million on the roads by 2040 would displace only 5% of global oil demand. Oil is here to stay.

Nevertheless, on the side of caution, it is instructive to keep in mind that some projections indicate the possibility of a lower range of oil demand over the next several decades. The IEA sustainable development scenario, for example, projects oil demand to be only 67 million barrels a day by 2040 and Barclays recently published a scenario indicating the lower bound of demand would be 69 million barrels a day over the same time frame. It is important to note that even in these low-range cases WL would be both profitable and necessary because of its financial and environmental benefits. Importantly, WL succeeds even in a 69 MB/d demand environment because it is at the lower end of the cost curve globally except perhaps for Saudi Arabia and Russia. And even in those countries a decline rate approaching 7% makes their ability to maintain even their current level of production problematic. In other words, in virtually any reasonable scenario from high demand to low demand WL presents one of the strongest cases to meet the global need for oil.

(2) Tight oil from US shale has met over 65% of global liquid fuel demand growth for the past 5 years and will be the primary source of supply for years to come. But the decline rate of US tight oil wells is relentless and accelerating. For example, Goldman Sachs estimated that in 2016 about 1 Mb/d of new production was needed to replace declines in US tight oil wells. But by 2020 the required new production is about 2.7 Mb/d and growing. This decline rate creates a treadmill that essentially results in an overall US production plateau of

a little more than 14 Mb/d by 2024 even with EIA's optimistic forecast. Production will stagnate at that level until it begins a slow decline about 2040.

(3) A parallel problem relates to the ever increasing "gas to oil ratio" (GOR) of tight oil wells. The rapid output decline of these wells is widely recognized but the decline is more severe for oil than for gas as the wells age. Higher GORs are typically accompanied by falling oil production and there is clear evidence that the GOR in the America's top producing oil field - the Permian- is becoming increasingly gassy over time. For instance, Eugene Kim, Director of Gas Research at Wood – MacKenzie, has found that in the Permian's Wolfcamp A&B bench drilling, oil cuts have started to decline. Average Midland and Delaware basin oil cuts have fallen nearly 10% over the last five years, with more dramatic cuts seen in sub-plays like the Northern Reeves in the Delaware and the Midland basin's Southern Fairway. Average Wolfcamp A&B oil cuts have dropped below 65%, driven by aging tight-oil wells hitting their bubble points. As US tight oil production plateaus and wells become more "gassy", the ferocious worldwide demand for liquid fuels will collide with constrained supply, and establish WL conversion of coal to oil as the world's most important energy resource.

(4) Moreover, while the supply of tight oil has burgeoned in the last decade the physical characteristics of tight oil mean it is not suited for the production of diesel fuel. Light, tight oil is becoming dominant in US production but does not meet the needs of domestic or foreign refiners seeking to produce diesel. For example, in 2015 oil with the gravity lower than 40 API accounted for about half of US production. By 2019, this heavier oil accounted for only 42% of US production while lighter oils above 40 API accounted for 58%. In terms of numbers lighter oils have increased from 4.5 Mb/d barrels per day to 7 Mb/d. This trend toward lighter tight oil production is projected to continue (and increase) for the foreseeable future. The emerging shortage of heavier grade oil will become more apparent as the demand for diesel fuel grows globally, i.e. developing Asia/Africa. In fact, the issue has already arisen as the price of heavy oil has been escalating worldwide relative to lighter oils. With its "bespoke" attributes, WL will meet the need for heavier grade oil to reduce US dependence on imports while expanding exports of lighter grades. Note that the

US is far from independent regarding oil and is currently forced to import over 6 Mb/d to meet refining needs of heavier oils. Converting coal to reduce the importation of these heavier oils, while expanding the exportation of domestically produced light oil, will usher in a new age of prosperity for the United States.

(5) At commercial scale, a WL plant with an estimated capital cost of $200 M will produce 10,000 barrels of coal-derived oil every day on a cost basis at the low end of the cost curve. Just 100 WL plants would produce one million barrels of bespoke oil per day, increase coal demand by over 112 million t/yr , and natural gas demand by upwards of 1,000 bcf / year. New demand for electricity would reach 100 million MWh with the accompanying potential of additional demand for 44 million t/y of coal. These actions would create many thousands of jobs in the largely rural areas and small towns greatly suffering by coal's production decline. But this is only the cutting edge of the ultimate possibilities of WL.

In reality, the potential supply of oil from coal using WL is virtually unlimited. The EIA estimates that in 2019, the United States imported about 6.8 Mb/d of crude oil. With over 250 billion tons of coal as feedstock, the US clearly has the potential to displace all of these imports through WL. This would require about 680 WL reactors processing a total of 760 million tons of coal per year for oil production and also require as much as 300 million tons per year to meet new electricity demand—for a total of over one billion tons of new coal demand. It has already been demonstrated that the US has the infrastructure to support the mining, production and transport of well over one billion tons per year. Importantly, the demand for natural gas would also significantly increase by over 6,000 BCF per year---three times the production of West Virginia.

The Future of WL in a World Dependent on Oil

Population growth and economic expansion mean oil demand will remain strong and steady for decades to come. Conventional oil production is increasingly expensive as the low hanging fruit has already been picked and operations migrate to more difficult environments (e.g. deepwater and the

Arctic). Tight oil in the US has staved off the need for heroic conventional production. But even in the optimistic projections of the EIA resource, tight oil will reach a plateau by 2024 and demand will violently collide with supply due to resource depletion and high capex costs. In essence, both conventional and tight oil production have demonstrated they are not the pathway to American energy independence. Meanwhile, the US has 25% of the world's coal and virtually all those reserves are amenable to conversion to customized liquid fuels through Wave Liquefaction™. The projected cost of WL at $35-40 /b is especially meaningful in a world where, based on Rystad analyses, the North American offshore shelf has average breakeven price of $49 a barrel, deepwater has a $58 breakeven price, and Russia onshore has a $59 a barrel breakeven. Thus, EIA projects $82/b oil in just five years.

Remembering, the WL environmental process is superior in that it produces virtually no GHG emissions and uses no water. But people are part of the environment also and the drastic decline of coal consumption in the US has devastated communities, institutions and families. WL provides the opportunity to produce liquid fuels inexpensively, meet the needs of refiners, have basically no environmental impact and also put many tens of thousands of people back to work in well paying jobs. Finally, the dramatic positive impact of WL on US national security cannot be overstated. This transformative technology will assure US energy dominance well into the next Century and, for all practical purposes, in perpetuity.

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