International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 1, January-2019

A PRACTICAL SOLUTION FOR REVERSING CLIMATE CHANGE

John M. Dobbs[1], Ronald L. Huston[2]

[1]*President, Ryalside Institute,*
[2]*Department of Materials and Mechanical Engineering, University of Cincinnati,*

Abstract – This paper presents a means for reducing carbon dioxide in the atmosphere by reducing decaying vegetation in the forests and eliminating forest fires. The basis for this process is the conversion of vegetation to charcoal by pyrolysis – heating in the absence of oxygen. The process can be self-sustaining by using the gaseous pyrolysis products to fuel the entire operation.

Index forms – Atmospheric carbon dioxide reduction, Charcoal, Forest fire containment, Forest waste disposal

I. Introduction

This paper is a correction, follow-up expansion, and extension of an earlier paper by the authors on reversing global warming[1].

In 2017 wildfire in the United States costs at least $85 billion, 2018 is not finished at this writing but it is far worse. For a decade wildfire in the US has cost more than $2 billion per year[2]. Many tens of millions of dollars are being spent (with inadequate results) burning ladder fuel (small trees, bushes, vines, and forest litter) to prevent it from fueling wildfire. Our objective is to develop procedures and equipment to dispose of ladder fuel flamelessly. The equipment will immediately improve present fire prevention with an *economically positive* outcome.

Initially our equipment will be in a pilot phase made to uncover and eliminate unforeseen negative consequences.

We estimate that our process will cost less than $75 per acre – substantially less than what is presently spent on average.

The pyrolysis process is free of seasonal constraints and produces, (except carbon dioxide,) no air pollution.

The program evolves from cutting firebreaks to thinning forests. When the forests are thinned every 10 years, the fires will become events of the past. Moreover, since they can be tightly circumscribed surface fires can be safely burned when needed for forest health.

Our technology can be sold throughout the regions containing large forests. We estimate that carbon can be removed from the Earth's atmosphere profitably at $50/tonne. By sequestering carbon, "zero carbon gasoline" could be sold for an extra cost of five cents per gallon. We believe that the general public would pay this premium knowing it would help solve the climate change problem.

It is important to note that this is not a mitigating technology as are wind and solar power,it lowers atmospheric CO_2. Over time we can reverse climate change by taking atmospheric CO_2 back to what it was before the Industrial Revolution. Moreover, this process will allow the fossil fuel industry and its culture to make a gradual, nondisruptive, transition to the post-fossil fuel era.

There are strong reasons to be concerned that, at the current CO_2emission rates, global climate will become unstable and radically change the planet's environment and ecology. We cannot afford to wait until it is too late to reverse the trend.

Most of the people on Earth are dependent on burning fossil fuels. It is clear that we are not going to stop now or soon. The movement to reduce fossil fuel burning has, to date, done very little to make things better. Moreover, poor people make up the vast majority of the world's population, are dependent upon fossil fuel consumption for survival.

II. Business Proposal

We will develop a practical, economically efficient, way to reduce atmospheric carbon dioxide. The procedure is based on known ecological facts and well-established principles of physics and chemistry.

The largest sources of atmospheric CO_2 are rotting forest litter and forest fires. Indeed, they contribute 6.7 times more CO_2 into the atmosphere than human activity[3].

With no change in the present consumption of fossil fuels, if we reduce the natural emission of CO_2 by 26% for 20 years, we will return the atmospheric levels to 300 ppm[4]. After that, a 15% reduction in natural emission will cancel the effect of burning fossil fuels.

The science is well-established. The issue is not whether the technology will work, but how to implement the process. The missing piece is a pyrolizer specifically designed for this application. Our next steps are to produce a specific design, then construct and test the prototype.

This will require investment capital. But providing seed money should be attractive to an investor looking to start a highly profitable company in a rapidly growing industry.

III. Analysis

Making biomass into charcoal takes carbon out of the natural carbon cycle's return path. Since charcoal doesn't support wildfire, there is a synergism with the need to prevent forest fires which has been a multimillion-dollar (unsuccessful) effort for decades. We can start the program as a profit-making business without dealing with the political and scientific complexity of climate change.

Present fire prevention consists of people going into the forest with chainsaws and heavy equipment to dispose of (burn) ladder fuel. If conditions are right it can be burned in place, but far more often it must be taken out of the forest for disposal. With pyrolysis, it can be disposed of in place without open fire and in all seasons.

Another problem with climate change is that snow melts much earlier and tends to run off rather than soak into the ground. Adding charcoal to the forest soil will make it significantly more water absorbent. This will be another way forest fires will be reduced.

We will convert ladder fuel to charcoal using our light pyrolyzing equipment. We will leave the charcoal in the forest.

By cutting the firebreaks throughout the forest, fires will either be eliminated or under control. Thinning the forest every 10 years will completely eliminate catastrophic fires.

Until now suitable equipment to perform the foregoing tasks has not yet been developed. The vision of converting ladder fuel into charcoal has not yet been significantly envisioned by the forestry world.

We are now in the process of sharing this vision with foresters and addressing all their concerns and objections.

IV. Historical Perspective

When Europeans first came to North America, they found park-like forests of large trees interspersed with grassy areas. In the East, there were thousands of white pines large enough to make masts, for the British Navy, 5 feet in diameter at the base and 120 feet tall. Early travelers to the West also found park-like forests. For centuries, the indigenous people had burned off the underbrush to benefit their farms and the wild grazing animals they harvested[5]. The extent of grassy areas in the 16^{th}-century forests can be inferred from the fact that bison ranged over an area the corners of which were Georgia, New England, Yukon, and California. On average, any given section was burned every 10 years. Our idea of an American primeval forest is a stable ecology of which man and fire were very much a part.

Agriculture and forest clear cutting were not seen as having an effect upon the overall forest ecology. Indeed, the settlers seemed to envision North America as a very large unoccupied space.

Now North America forests are fire-prone and less productive because they are choked with ladder fuel. This is the natural (unmanaged) state of forests; fires caused by lightning are too rare to make them safe from crown fires.

In the last quarter of the 19^{th} century and the first three-quarters of the 20^{th} century, forest fires were extinguished immediately. This led to disastrous crown fires. Now foresters allow surface fires to burn but wildfires are still a huge and growing problem.

V. Marketing the Use of Pyrolysis for Converting CO_2 Dispersement into Charcoal

In 2005, the USDA stated that the 15 western states there were 67 million acres of forest which were expected to need mechanical treatment before reintroduction of fire[6]. In 2005, there was not enough money available to do this. Since then drought throughout the West has made things worse.

We will provide that "mechanical treatment" at low cost. The USDA would like to carry out prescribed burns as the Indians did but the forests are too dry. We solve this problem with a flameless substitute and small, safe, prescribed burns, when needed, for forest health. In the South and West, thinning the forests will more than pay for itself by reducing firefighting costs. It will also improve biodiversity, make better environments for wildlife, and provide the opportunity to start many profitable businesses with well-paying, internally trained, local jobs both in manufacturing and in the forests. The money will come from money saved from firefighting and prevention.

In the North East where wildfire is not a problem thinning will make the forests more productive and more pleasant as well as improve biodiversity and wildlife habitats. Payment will come from owners wanting to improve their land or people and organizations concerned with better forests on public land and climate change.

This fire prevention program will provide data and experience for reversing climate change.

To start we will assemble suitable equipment then cut fire breaks around settlements in the urban-wildland interface with teams of people and light machines (chippers and pyrolizers) moving through the forest. Initially, we will sell our equipment and/or services to individuals and communities then work up to selling them to bigger organizations like the states and the Forestry Service.

Pyrolysis is heating biomass above 350°C with limited oxygen. Generally, it produces charcoal (biochar) which can be left in the forest, liquid hydrocarbon molecules (bio-oil) which can be used as industrial feedstock, water, and gases (biogas or syngas and carbon dioxide).The biogas can be used to fuel all the machinery thus eliminating the cost and environment damage of fuel trucks and the cost of fuel.

VI. Estimating Labor Costs and Profits

As a hypothetical operation which can be replicated as our operation grows, consider a team of 5 chippers moving (at 5 mph) through a forest. This will clear 12.5 acres per hour. Each chipper will be manned by an operator and leave bags of chips on the ground. An ATV towing trailer will pick up these bags. The chipper carries a replaceable assembly holding compressed fuel gas, and biochar, which is delivered, along with empty bags, by an ATV towing a trailer. These trailers and chippers must have mechanisms which help move heavy loads so that the people never exert more than appropriate force. The pickup and delivery function will require 5 people.

The pyrolizer will be operated by 3 people. 2 people will maintain the equipment and 3 people with chainsaws will cut and lop trees that are too big to convert to chips but must be removed to make an effective firebreak. (The branches of these trees will be chipped.) The team members will work 4-ten hour days and camp in the forest 3 nights a week. There will be 2 people to provide meals and move the camp each day. The whole operation will move at about 2 miles per day. The syngas will power everything except the chainsaws.

Five chippers, one pyrolizer system, and 20 people will process 12.5 acres per hour. If this staff makes $24 per hour in wages and benefits, this comes to $480 an hour for the group or $38.40 per acre. The cost of food and transporting people and supplies to and from the site will increase this a little.

Yet to be estimated are the cost of capital equipment, selling our services, and managing the entire operation. Capital costs will be less than is presently spent because gasoline is not carried into the forest or biomass out. A conservative(but educated) guess is that the cost of the whole operation will start at $75 per acre – as the program matures this cost will drop. The price charged to clear an acre will vary from place to place depending on local conditions.

The corresponding numbers for clearing the ladder fuel using presently available techniques are from $35 to $1000 per acre. The low end of this range is using prescribed burns which can only be done under ideal conditions. In the fiscal year 2001, the Departments of Interior and Agriculture treated 2 million acres across the nation at an average cost of $200 per acre. We do not have any open flame so we don't need to guard against fire, we do not take small wood out of the forest which is expensive and damaging to the forest floor. Our process can be carried out in all seasons, so it provides steady year-round jobs. In the beginning, we will work in the areas where the most profit can be made and use this money to expand operations.

When we are thinning 7 million acres a year, we will make a profit charging $100 per acre and have a $700 million business, requiring 1400 chippers and 280 pyrolizer systems, providing 6000 jobs in the field and a, yet to be determined, number of manufacturing and service jobs. There are 236 million acres of forest in the Western United States. When we show that our forest management is beneficial in multiple ways, and reverses climate change, the business will grow rapidly. Other businesses will come in to compete with us. This will be beneficial for the climate change problem and there is plenty of business to go around.

VII. Estimating the Cost of Carbon Sequestration

Cutting firebreaks will determine the actual cost of carbon sequestration, but we can estimate it now: on average, an acre of forest removes and stores 6.6 tonnes of carbon from the atmosphere each year. Left undisturbed each acre accumulates roughly 33 tons of carbon in 10 years – 11 tonnes stored in large tree growth, roots, and stumps and 22 tonnes stored in the ladder fuel, which can be chipped[7]. If 30% of this chipped biomass is left on the ground to cover the charcoal and prevent erosion, biomass containing 15.4 tonnes of carbon will be harvested per acre. Using relative yields of 70%, 0, 30%, (biochar, bio-oil, biogas), charcoal containing 10.8 tonnes of carbon, and syngas containing 4.6 tonnes of carbon will be produced.

The added growth of large trees (11 tonnes) and the 10.8 tonnes of carbon we take out of circulation as charcoal will remove 21.8 tonnes of carbon from the atmosphere for each acre of forest managed. This works out to a labor cost of about $2.20 per tonne if we include the new large tree growth and $4.40 a tonne if we don't. These numbers are preliminary but it's clear that the cost of sequestering carbon using this approach is modest. When we harvest carbon in isolated places the cost of transportation will rise and the equipment for rough terrain will be more complicated. Carbon capture and sequestration for $22/tonne seems to be a very conservative estimate. The early program (funded by fire prevention) will establish this number.

Since we are sequestering 70% of the returning carbon in each acre managed, we need to manage 21.4% of the Earth's forests to divert 15% of the naturally returning CO_2. If we consider the improved productivity of the forest, we need only manage 10%. It may be enough to manage only the fire-prone forests of the world. Therefore, we solve the world's forest fire problem while solving the climate change problem.

A related problem is that warmer winters have allowed pine bark beetles to kill huge tracts of Western forests. These dead trees should be cut down and the infested wood and slash pyrolyzed to kill the beetles and prevent the trees from contributing CO_2 to the air. This should be done as soon as funding to do it can be obtained.

VIII. The Next Projects

The foregoing sections provide a general description of the program. The next steps are:

1. Find funding to support a small team to carry out steps 2 through 8.
2. Write a market requirements specification for all the equipment with accessories.
3. Write an engineering specification for the pyrolizer system. Forest density varies from place to place, so the biomass harvested per day will vary a great deal. We are studying a design made up of one or more pyrolizer modules connected to a control module making a system which can vary in capacity over a wide range. Since the system will be used in all seasons, it will need a dedicated drying phase.
4. Choose or assemble on paper, the most suitable harvesting, and chipping system.
5. Carry out a cost analysis of capital, engineering, and labor for the program[8].
6. Study the economics and players in the fire prevention industry.
7. Develop a business plan to go from the start to positive cash flow.
8. Find sufficient capital to get to positive cash flow.
9. With this money put together staff and develop the fire prevention business.
10. Gather data relevant to reversing climate change.
11. With production data and costs, approach the fossil fuel companies for support for carbon sequestration[9].

IX. A List of the Usual Objections, With Our Responses

1. Such a business will ruin the world's forest. ---- Wild forests are ecosystems made up of diverse plants and animals interacting with each other. In America, before 1492 man had been a keystone species for thousands of years. This will put man back in that position, improve forest productivity, as well as plant and animal diversity. Note – when our program is fully in place even with no change in fossil fuel consumption, it will only affect 22% of the world's carbon cycle in the near term and less than 10% in the long-term. Only 15% of the world's forests will be affected.
2. This is geoengineering which is dangerous to the environment. ---- This is a minor change in what has been done to prevent forest fires for decades and a small, benign, change in a large natural process. It scales smoothly from small to very large. We will proceed carefully to find and correct any negative consequences.
3. This will cost too much. ---- Rather than costing too much it will save money. In the initial stages, it will reduce the money spent on wildfire, and provide a much-needed class of jobs. In the later stages, it will provide a cost-effective antidote to global warming and will save far more than it costs. The money that will be spent will provide year-round jobs rather than pay for short-term emergency work and such things as large airplanes spraying fire retardant chemicals.
4. This will interfere with food production. ---- This has nothing to do with food production. Any land,that has light and water and isn't constantly mowed, will rapidly become choked with small trees, bushes, and vines. (In New England, there is the choking problem but, because of ample rain, there is little wildfire.) It is this land that we will use to sequester carbon.
5. This is such an obvious idea if it really worked it would have been done by now. ---- Obvious ideas often go for years without being implemented. Consider cars with front-wheel drive and transverse engines pioneered by the Morris Mini in 1959. Fifty years later it was universal for small cars and extended quite far into larger cars. The moldboard plow was invented in China before 200 BC and adopted in Europe in 900 AD. There are many other examples of obvious ideas which took years to implement.

6. There is not enough energy in the ladder fuel to fuel cutting and pyrolyzing it. ---- This is almost obviously not true, but the actual engineering calculation is complex and multidisciplinary. The input data would be the gasoline consumption of commercial chippers and towing vehicles, the gasoline equivalent of biogas, the efficiency of the pyrolizer and the density of biomass in the forest. Intuitively the enormous amounts of energy released by wildfire give us an idea of how much energy is available. We believe there is far more energy than is needed. It may turn out that we will need to ship syngas or bio-oil out of the forest and sell it. If this is not practical it may be necessary to flare syngas in the forest.
7. The pyrolizer cannot be made. ---- There is a great deal of prior art. Our requirements are different from the requirements for commercially available machines in that we process very wet biomass, move on a regular basis, and need to be small enough to do minimal damage to the forest floor. The numbers are so positive that a machine can certainly be developed.

IX. End Notes

[1] J. McG. Dobbs and R. L. Huston, "Reversing Global Warming – A New and Practical Engineering Solution", *International Research Journal of Engineering Science Technology and Innovation* (IRJESTI), Vol. 3, No. 6, 2014, pp 178-183.

[2] T. Ingalsbee, *Getting Burned: A Taxpayer's Guide to Wildfire Suppression Costs*, Firefighters United for Safety, Ethics, & Ecology (FUSEE), August 2010.

[3] The CO_2 deposits due to plant respiration is 60 Gtons per year (a Gton is 10^9 tons) whereas that due to fossil fuel burning and industrial processes is only 9 Gtons per year – a ratio of 6.7 to 1.

[4] The amount of CO_2 that must be removed to reduce atmospheric levels from 400 ppm to 300 ppm is a total mass of the atmosphere; 5,500,000 Gtons, (Lide, David R. Handbook of Chemistry and Physics CRC, 1996:14-7) multiplied by 100 ppm (or divided by 10,000). This is 550 Gtons of CO_2 or 149.6 Gtons of carbon. To remove this carbon in 20 years, without changing fossil fuel consumption, we must remove 7.5 Gtons per year more than the 9.9 Gtons being emitted from burning fossil fuel, or 17.4 Gtons/year.

[5] Gerald W. Williams, *References on the American Indian use of Fire in Ecosystems* (USDA June 12, 2003); Charles Mann, 1491 (the Atlantic Monthly, March 2002); William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (Hill & Wang, 1983); *Fire Uses From the Past*, Fire Management today – Volume 64 – No.3 – 2004.

[6] R. Rummer et al. "A Strategic Assessment of Forest Biomass and Fuel Reduction Treatment in the Western States", US Department of Agriculture, 2005.

[7] Vaclav Smil, *Energy in Nature and Society* (The MIT Press 2007) p75. These numbers are rather general. We will refind them for our situation. A dog-hair thicket is more productive when it is young before the saplings start crowding each other. This may make a significant improvement in Vaclav Smil's numbers.

[8] To develop this system will need guidance from members of the forestry community. We can develop a process which provides more of the desired benefits of surface fires but with complete safety and control. This can only be done with the interest and involvement of knowledgeable foresters. We are beginning to get this input now.

[9] Suppose the US fossil fuel industry paid $50 a ton to sequester carbon. This would make carbon sequestration all over the world profitable and would change the cost of gasoline, here only a little, the effect of coal and gas premiums on the price of electricity is much more complicated but still modest.

X. Author's Qualification

John Dobbshas a bachelor's degree in mechanical engineering and a Ph.D. in physics. He practiced particle physics and taught at a university for seven years before going into industry, where he did physics, electrical engineering, mechanical engineering, software engineering, and systems engineering, and managed teams doing all those things. He has also done general management as a CEO, division manager, and company founder.

He has managed research and development groups in medical imaging, semiconductor capital equipment, laboratory instruments and machines for biotechnology. His products, (dedicated computers, and computer-controlled machines) have generated many tens of millions of dollars in sales. He has published 19 peer-reviewed papers, has 31 patents issued and 1 in process.

He is the founder of The Ryalside Institute (website: ryalside.org) a nonprofit organization dedicated to solving environmentally significant problems. Ronald Huston is a member of the Institute.

Ronald L. Huston is a professor emeritus of mechanics and a distinguished research professor in the Department of Mechanical and Materials Engineering at the University of Cincinnati, Cincinnati, Ohio. He is also a Herman Schneider Chair Professor.

Dr. Huston has been a member of the faculty of the University of Cincinnati since 1962. During his tenure, he was the head of the Department of Engineering Analysis, an interim head of Chemical and Materials Engineering, the director of the Institute for Applied Interdisciplinary Research, and acting Senior Vice President and Provost. He has also served as a secondary faculty member in the Department of Biomedical Engineering and as an adjunct professor for Orthopedic Surgery Research.

From 1979 to 1980, Dr. Huston was the division director of Civil and Mechanical Engineering for the National Science Foundation. In 1978, he was a visiting professor in applied mechanics at Stanford University.

Dr. Huston has authored more than 150 journal articles, 150 conference papers, 5 books, and 75 book reviews. He has served as a technical editor of *Applied Mechanics Reviews*, as an associate editor of the *Journal of Applied Mechanics*, and as a book review editor of the *International Journal of Industrial Engineering*.