Bio-Fuel Paper for COTMA 2023

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Kia ora, Teina koutou, teina tatoa, In the case I want to present this morning welcome to the story on biofuel.

I can see you all looking a bit bemused and thinking what the heck has biofuel got to do with running a heritage tramway. Well, it could have quite a bit if the scenario I am going to put to you, comes about.

The power for running our trams is generated somewhere and particularly in Australia, this is likely to be a coal fired power station - but bio-coal could be used as a direct replacement for fossil coal in these stations. Further, for those of us lucky enough to operate steam trams, bio-coal can also be a direct drop-in fuel for our boilers.

So, let's find out a bit more about this alternative fuel and why its use would be CO2 friendly.

Firstly, a little recap; Throughout history and before the present oil and gas age, energy from wood was a key enabler of human existence.

To survive in the agrarian era, people burned wood for warmth and cooking. In addition to use as a building material, wood remained the predominant global fuel for centuries.

The invention of the first modern steam engine, at the beginning of the 18th century, heralded the transformation from an agrarian to an industrial economy.

Steam engines could be powered by either wood or coal, but coal quickly became the preferred fuel and it enabled massive growth in the scale of industrialisation.

A half-ton of coal produced over twice as much energy as the same amount of wood and was cheaper to produce and, despite its bulk, easier to distribute.

Coal-fired steam locomotives dramatically reduced the time and cost of inland transportation, while steamships traversed the oceans. Machines powered by coal enabled breakthroughs in productivity while reducing physical toil.

With the dawn of the 20th century, environmental concerns and new technologies led to another energy shift away from coal to oil.

This breakthrough came with the discovery of underground oil sources, although the first oil had actually been discovered by the Chinese in 600BC and transported in pipelines made from bamboo.

However, the discovery of underground oil in Pennsylvania in 1859 and in Texas in 1901 set the stage for the modern era oil economy.

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Petroleum was far more adaptable and flexible than coal plus it reduced smoke pollution.

As a result, coal was largely discarded – apart from its use in large power stations, industrial boilers and steel making plants, where combustion and smoke could be more readily controlled.

With the technological breakthroughs of the 20th century, oil emerged as the preferred energy source. The key driver of this transformation was the exponential growth of the automobile after WW1, along with air and sea transportation around the same time.

Our wonderful automobiles and aeroplanes have proliferated ever since and we are totally reliant on them in the modern world. Until recently, we never gave much thought to burning fossil fuels to power them, or the resultant build-up of CO2 in the atmosphere. Allowing that buildup to continue though is rapidly proving a mistake. The time has come to make another energy shift away from fossil fuels and there are options on the table to help us do this.

In this paper I want to describe to you the biofuel way out and it is one where we have the source material and the technology to set it up very quickly.

There is no doubt that our future will almost exclusively be electrically powered. But electric power per-se is not an energy source. As I said previously this energy source has been largely provided by burning coal in power stations and this is still the predominate method globally – but those power stations will have to go or switch to burning a sustainable fuel if we are to avoid climate disaster.

We have been particularly blessed in N.Z. by having abundant renewable natural sources we have been able to tap into to produce electricity but this doesn't shelter us from what our neighbours in the rest of the world are doing.

We have pretty much exploited our natural resources for large-scale hydro development in NZ. Geothermal development probably has more upside and like the rest of the world we are adding wind farms and solar generation around the edges – but the wind doesn't always blow or the sun always shine so these methods can't be relied on for base load electricity generation.

The "holy grail" the world's top brains are working on, is fusion atomic energy but we are not getting any quick breakthroughs with that technology. So, that way out is still decades away and will no doubt require the building of massive infrastructure.

What are we going to do then meantime to supply our rapidly evolving all-electric future and abate climate change at the same time?

Well in NZ. we are again lucky having extensive commercial forests and suitable country to grow even more.

We haven't been very smart in how we use this resource, continuing our short-sightedness from over a century ago.

Our forefathers discovered the indigenous forests covering New Zealand contained some of the finest timber in the world and to exploit it they nearly stripped the land of these magnificent trees.

Maori folklore told that Tane the god of forests, would extract a heavy toll on us for doing so but that advice was ignored. It is not Tane but his mate Rangi the sky god who is now implementing this toll. Tremendous downpours with subsequent flooding, extreme temperatures and wild fires are practically an every-week event somewhere around the world now.

We are still doing something similar with our exotic forests creaming off the easy stuff in the form of logs and leaving all the branches, bark and slash in place on the forest floor. This too has come back to bite us in places like Tairawhiti (East Coast of the North Island) where massive flooding this year has washed this slash down onto the productive lower land causing untold damage, costing a fortune to remediate and years to do so.

If we had only got into this forestry waste earlier and recycled it into something useful…

So that brings us to the story of bio-coal.

Already a small proportion of this slash waste is used by the timber industry to generate electricity and heat to kiln-dry timber - and the process can easily be taken a stage further to the wider industry and power stations using fossil coal.

I can see you thinking what's the big deal here, surely when you burn this stuff you are putting more CO_2 into the atmosphere. Granted, but if we recycle the forests at the same time, the growing trees will reabsorb this CO_2 and we have a sustainable circular economy.

When trees grow, they absorb CO2 and lock it away in wood. If you chop down a tree and burn it you can't possibly emit more than was absorbed in the first place so the whole process is effectively carbon neutral – provided you replant the trees!

Burning fossil fuels on the other hand incrementally adds CO2 to the atmosphere and we are all becoming painfully aware of what this build-up is doing.

The method for producing bio-coal and bio-fuels has been known for some time and considerable research has gone on at SCION, the forestry research institute here in Rotorua, to find the most suitable methods to extract these products from our exotic forest wastes.

We should now rapidly commercialise this research and put this slash to good use.

Fonterra and Genesis Energy have got together to make a start on this.

Most Fonterra factories have large coal fired boilers to provide milk drying and process heat and Genesis operates the 1000MW Rankine cycle power station at Huntly. Bio-coal can be an immediate drop-in fuel for these existing boilers without adding any additional features.

There are many more industries in NZ operating large boilers (mostly coal fired) that could similarly meet new CO2 pollution regulations at minimal cost by switching to bio-coal.

Not to mention all the heritage users like ourselves whose boilers can't easily be converted from coal burning. Bio-coal simply slots in to existing fire grates.

Coming back to the Huntly Power station for a minute. This is a vital piece of our power generating infrastructure but is presently only brought into operation at peak power times so as to produce no more CO2 from fossil coal than necessary.

As our transport industry rapidly electrifies these times are going to become more frequent as we simply haven't got sufficient generating alternatives. New renewable source geothermal generation is being developed but with the exponential electricity demand in the timeframe ahead, I doubt if it is going to be enough. I see Huntly in the medium

term, not as a necessary evil as it would be on fossil coal but a full-time base load station running on bio-coal from our own forests.

Genesis has already carried out a trial using imported bio-coal from Canada in one of the boilers at Huntly and the unit operated very successfully with only a minor reduction in performance as against fossil coal.

We also have carried out a joint bio-coal trial at MOTAT using SCION produced bio-coal in our steam tram 100. The SCION briquettes were made from torrefied waste bark and the slide shows what they look like.

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We found the briquettes burnt really cleanly and generated less ash and we didn't all smell like gas works employees at the end of the day. The experiment was very successful despite the briquettes not being fully torrefied and a little crumbly and dusty. When this is remedied, I am sure we will have an excellent alternative to fossil coal and get similar consumption rates.

Unfortunately, the SCION process hasn't been commercialised yet so full-time use of this fuel at MOTAT is still several years away. MOTAT is exposed to public scrutiny so I hope their sentiment doesn't ban us from burning fossil coal meantime in our heritage boilers.

Let's have a look at a few other facts before we get into what wood torrefaction is and the manufacture of bio-fuels.

Nationwide, NZ industry presently burns over a million tonnes of fossil coal every year, creating more than two million tonnes of additional greenhouse gas emissions. That coal use can be replaced permanently by switching to solid bio-coal. A dedicated forest estate roughly the size of Wellington City would be sufficient to ensure the supply of renewable biomass feedstock for all NZs needs

On a regional basis, Gisborne would be the logical place to establish a bio-coal plant, being adjacent to our largest commercial forest area.

A plant here processing 120,000 green tonnes of wood residues could produce 50,000 tonnes of torrefied wood briquettes / annum and reduce NZ's greenhouse gas emissions by around 100,000 tonnes / annum.

A torrefied wood plant of this size, using off-the-shelf and locally made technology, would cost around NZ $50M and could be up and running in two to three years. Overall, such a plant would create at least 50 jobs locally, plus around 30 extra jobs collecting and delivering the residues and add $14 million to the regions and country's GDP. Those presently mining coal could be redeployed if they chose.

Compared to roading infrastructure projects, the cost is moderate and would reduce the country's present dependence on fossil fuels and consequently our greenhouse gas emissions. If we are to implement steps to a more sustainable future, we need to get serious with this option.

A movement to replace coal with biomass is unlikely to happen by itself though. New Zealand needs leadership at a national level and a national commitment to greenhouse gas reduction.

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Untreated forestry and mill residues can and do fuel boilers but their low bulk density, high moisture and low energy content in comparison to coal means they cannot directly replace coal in most existing boilers but by torrefying the residue we can overcome these problems.

Basically, torrefaction is the process of heating biomass to temperatures of up to 300 degrees C in the absence of oxygen.

In the torrefaction process, heat and pressure can transform wood waste into high-energy, high-density bio-coal that can be used as a direct drop-in fossil-coal replacement. It is a bit like speeding up natures process for making coal from biomass that grew aeons ago and where subsequent underground burial supplied the pressure needed.

When woody biomass is torrefied, bound water is removed, which increases the energy density and makes it less likely to reabsorb water. The wood cell walls are weakened, making it easier to reduce to a powder and then compress into dense pellets or briquettes. These approximate the energy density found in fossil coal.

For comparison, energy content per unit weight for untreated biomass is 5 – 7000 Btu/lb

when torrefied

8.5 – 10,500 Btu/lb

compared to coal

11,000 Btu /lb

The on-screen diagram shows schematically the steps in the torrefaction process. You will note the production of torgas during the heating part of the process and this gas can be burnt to supply the drying energy, so generally no external source is needed.

SCION have been researching the best way to torrefy NZ grown timbers for a number of years now and have the bio-coal process ready to upscale to commercial plants.

If you take wood waste a stage further by a process called pyrolysis it is possible to extract liquid fuels as well. But this requires a much more complicated plant with refining facilities.

Again, pyrolysis is carried out in the absence of oxygen but at 500 – 600 deg. C instead of 200 – 300deg.C as in torrefaction.

At this higher temperature liquid bio-oils, ethanol and other organic tars are driven off wood leaving a char residue – pretty much pure carbon which is a valuable resource for the steel making industry and carbon electrodes for electric furnaces. NZ Steel has recently invested in new electric furnaces that could benefit from this material.

Air NZ is very interested in blending bio-fuels with their jet fuel to lessen their carbon foot print so may invest actively in this too. They have carried out several blended fuel trials to date.

Long distance jet flights will be liquid fuelled for many years yet as conventional electric motors can't come anywhere near the power

output, for the same weight as a jet motor but if the bulk of that liquid burnt in the jet motor can be bio-fuel we are moving towards carbon neutral in the sky as well.

Governments in Norway and Sweden have mandated the use of biofuels in their air transport operations and other European countries are setting up similar mandates. Our government hasn't moved in this direction yet.

The future for the marine sector is similarly linked to liquid biofuels. At present, more than 99 percent of ships use liquid fossil fuels and over 97 percent of ships "on order" to replace the current fleet will also require a liquid fuel. We will have to replace "like-for-like" (liquid fossil fuel for liquid renewable fuel) to have a significant impact on these emissions within the next 30 years. Batteries and hydrogen could power up a small proportion of new ships but by and large, liquid biofuels will be the only alternative for a sustainable marine fleet in the foreseeable future.

Waste wood pyrolysis might be a good use for the recently moth-balled Marsden Point oil refinery with its pipeline direct to Auckland Airport. Repurposing could be viable and a good use for slash from the large Northland forests. The logs from which, are already transported right next door to the Marsden Point wharves for export.

The Germans exploited the pyrolysis process using both coal and wood during WW2 when they no longer had access to oil fields. Allied bombing of these plants became a prime objective and lack of liquid fuels was a major reason for the collapse of their mechanised war machine.

The point I am making, there is nothing really new about these technologies and with modern updates and control systems they could be easily implemented. The only thing I can see stopping us from getting started is our will to embrace change and our love for the status quo – namely fossil fuelled vehicles.

A decade ago, the debate on decarbonization started in earnest. Other than talkfests, not a great deal has happened since then. Now we have a way to do more than talk – Bio-fuels are a no brainer really and a relatively easy solution to implement.

Closer to home, my personal interest in bio-coal stems from a desire to keep our wonderful old steam tram 100 running into the future. This desire is shared by many others in the heritage railway and ship fraternity where prized loco's and boats will become cold museum pieces if fossil coal is legislated out.

In NZ think Mainline steam, Glenbrook, Steam Inc, the Earnslaw, William C Daldy, Wai Marie and many others.

Biofuel is an in-depth subject and I have briefly skimmed over it but if I have got you thinking about change that's a step in the right direction.

Nga mihi, and thank you for listening to my pitch for a bio-fuel future.