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From: [redacted]
Sent: Thursday, 14 November 2019 9:14 PM
To: Climate
Subject: Input for WA climate policy
Attachments: Poster 2019 August 22 GIF.gif

West Australian Department of Water and Environment Regulation, Issues paper
Response to Issues Paper request for public submissions.

Thank you for the opportunity for public response to this WA State Labor Govt initiative.
The broad ranging new approach I will be presenting touches on nearly of the areas raised by the Issues Paper because the new approach is indeed quite broad and multi-faceted, and yet well integrated. It is the result of some 15 years of research, inventing, prototyping and private discussions with experts from the various fields involved; climate science, mechanical engineering, agriculture and soil science. I have deliberately avoided publication to avoid compromising future intellectual property which may be necessary for implementation.
Conscious of the public nature of responses to the Issues Paper (while keeping my name and contact details confidential at this stage please) I have been careful to ensure that in this response to the Issues Paper there are no patent-able aspects of the technology disclosed, as patenting is often needed for successful development, even if R & D and licencing of IP is done by government or semi-government organisations, as I would prefer. Organisations such as CSIRO need to cover their costs as much as possible. Having a responsible government in control of the low cost dissemination of the technology, including to less wealthy countries is essential for actual reversal of climate change, ie restoring the climate. Climate change is a global problem and reversing it is not possible without widespread implementation. Fortunately the relatively "low tech" technology is very scalable and geographically adaptable and therefore suitable for developing countries. It has many useful synergies and benefits with food production, non skilled and skilled employment, etc, important for rich and poor countries.
Having a multinational corporation commercialise the technology would usually imply that the IP is kept to them selves, for maximising their own profits for the duration of the patents. However there is insufficient time for this usual business approach. The latest modelling done by scientists for the IPCC show that recent more accurate computer modelling that takes into account all the green house gases, and is informed by the recent deterioration in climate, especially in the Northern hemisphere, (some phenomena earlier than expected by decades), indicates that some climate tipping points are already happening. We clearly need a much much better strategy with enabling technologies, and to act quickly. I am keen to begin discussions with WA as soon as possible, as I will be pursuing other avenues if WA is not able to be involved. The climate crisis is urgent.

All the sections of the Issues Paper that are relevant to some extent, as will become apparent on a detailed reading of the material below and reflection, but a few comments may be appropriate at this stage.
1. Transforming energy generation
- This is the key focus of the new strategy and enabling technologies, eventually replacing fossil fuel energy in all sectors (except air transport), not just with low but still positive CO2 emissions, but significantly negative CO2 emissions (about 35% negative). See top right panel of the overview poster for how other climate change mechanisms are also addressed to varying extents.

2. Industry innovation
- In addition to direct benefits agriculture ("stage 1" in the poster), there several new manufacturing industries for both CO2 negative fuel production units, various transport vehicles - starting with farm

equipment, then rail, marine, heavy road, then light road transport. Smelting of iron with minimal adaption of present blast furnaces, yet with near zero CO2 emissions avoids the very slow and costly construction of "next generation" blast furnaces using hydrogen, ("stage 4" of the overview poster).

3. Future mobility
- As mentioned above, transport is one of the best initial markets. Transport fuels/energy has higher economic value than stationary electricity (petrol ~$1 / kg, cf coal ~10c/kg). See comments below about the uncertain scope for electrification of transport.

4. Regional prosperity
- The agricultural focus is very clear in "stage 1" of the overview poster, and would prosper the regional towns which are the hubs for the combined production of the fuel and soil enhancer (for farmers who don't want to "Do It Yourself"). The general expansion of sustainable agriculture, and increased arable land, would have a great boost in new regional employment and prosperity.

5. Waste reduction
- As indicated in the central green panel of the overview poster, the new strategy has very diverse inputs, (unlike other bio-energy systems), which include many wastes (but not all, eg not PVC). Another major biomass waste could be the dry vegetation removed instead of burnt as part of necessary bush-fire risk reduction. Instead of hazard reduction burns (which are becoming more difficult in drier hotter climates nowadays) the more expensive collection of dry undergrowth (on public and private land) would be economically viable when this biomass is readily converted into a transport fuel and soil enhancer.

6. Safe and healthy communities
- Increasing vegetation in local communities is something everyone can participate in. Local councils could collect dried vegetation (except roots), which is readily processed into a transport fuel (for council vehicles etc) and soil enhancer for local council gardens etc. Everyone being able to make a genuine, visible difference would be very good for communities. A new optimism associated with their new industry doing great global good would assist the psychology of communities. In the long term, if successful with global implementation, having a restored climate would be extremely beneficial to communities.

7. Water security
- Enhancing soil's absorption and retention water in agriculture, enables less artificial nitrogen and phosphate fertilisers, (since they are absorbed more, retained more), with less resulting run-off into natural water systems, with less toxic algae blooms (together with other measures). Reclamation of saline soils and soils degraded by mining and over-farming would also have a helpful impact on water security. Native reforestation assists the local water cycle (local evaporation and local dew-fall). Wide-scale reforestation on coastal strips where the onshore winds are favourable, may progressively bring rainfall inland. Western Australia is ideally sited for this - see overview poster bottom left corner, and top right corner under "water vapour".

8. Liveable towns and cities
- See above for prosperity of regional centres. Cities would probably have the extra role of being manufacturing centres for the technologies.

9. Resilient infrastructure and businesses
- The general benefits of increased manufacturing and expanded agriculture would have other secondary benefits to other enterprises.

10. Protecting biodiversity

- As is noted in the green panel of the overview panel, since the fuel production and soil enhancer is so tolerant of all and every plant biomass, one can avoid mono-cultures favoured by some agribusiness, and use native species diversity. One can cultivate diverse adapted drought and disease resistant native plants, especially perennial species. Past attempts with five year harvest cycles of widely spaced mallee would have been more successful is able to compete in the high value transport fuel market, rather than burning the whole branches to fire steam turbines in stationary electric power stations.

11. Strengthening adaptive capacity - With greater economic capacity and prosperity the ability to cope with the current stresses of climate change, while the decades long process of restoration of climate is in progress, will facilitate the other means of adapting to a harsher climate - until it is restored.

New Strategy and Enabling Technologies.

What is most needed environmentally and economically can be expressed in the following "wish list", below.

The challenges are enormous, but there is a newly invented answer that could be developed in West Australia and exported around the world.

A wish list for the very best strategy and technology for addressing climate change includes:

1. Negative CO2 emissions that are intrinsically part of an energy system in its cheapest form - not just low but still positive CO2 emissions energy, not additional cost negative emissions energy such as biomass energy with carbon capture and storage BE + CCS, not various unrealistic atmospheric CO2 capture technologies unrelated to primary energy generation, but significantly negative CO2 emissions energy that even on full life cycle analysis still has usefully negative CO2 emissions energy. In this way an absolute reduction of atmospheric CO2 occurs at no additional cost, and thus could be considered to be free.

2. Clear cost competitiveness with fossil fuels is commercially important, and even with the many generally worthwhile low CO2 emissions renewables. This competition includes shale oil ("tight oil" having enough supply for present prices to persist through the climatically critical next few decades), and non conventional gas (fracking etc) in transport and electricity respectively. Cost competitiveness without tax payer subsidy is preferable politically.

3. Non reliance on electrification of transport is wise, given that on full life cycle analysis present electric vehicles are far from CO2 neutral, even when they use low (but still positive) CO2 energy on LCA, given manufacturing of batteries, often use of neodymium magnets, recycling etc. The scalability and appropriateness of just commuter transport at global scale is very dubious, let alone heavy transport; road, rail and marine. Even if "green hydrogen" for electric transport becomes cost competitive it is not CO2 negative, and the expensive catalysts for hydrogen fuel cells (platinum etc) limit scalability.

4. Synergistically addressing the other climate change mechanisms such as the greenhouse gases related to synthetic fertiliser manufacture and use in modern agriculture (nitrous oxide N2O), and reducing some of the methane associated with agriculture, and assisting with reforestation/new-forestation, would all be very useful additional benefits.

5. Scalability of many other proposals limit their potential, but having a strategy and enabling technology which increases scalability potential with implementation is advantageous. In addition one would prefer a broad tolerant flexible pathway/strategy with multiple inputs and business plans, towards which most ordinary people can practically contribute, further assisting scalability as well helping some of the social and psychological problems associated with the worsening climate situation and public awareness of the magnitude of the problems.

6. Appropriateness of "solutions" for both rich and developing nations is needed to address a collective, global problem. A relatively "low tech" solution may indeed be the best solution.

This is indeed a challenging wish list, but there may be an important new strategy and enabling technology that meets all these targets. The attached 4MB gif file outlines a solution which could be developed and exported around the world. I have demonstrated proof of concept of the key new mechanical engineering

aspects, other new aspects are clear to competent engineers. Much of the other knowledge is well understood by specialists, just not assembled into an integrated whole. The recent work on biochar in soil by Simon Jeffrey, 2017, also by Prof Lukas Van Zweiten (NSW Dept' Primary Industries), may not yet be appreciated by all in this field. As an inventor I understand the importance of intellectual property usually being necessary for successful development and commercialisation, and so have not publicised the new strategy and enabling technologies. However would be keen to discuss it with you and seek your advice and work with WA.

The only similar competition in negative CO2 emissions energy is biomass combustion with carbon capture and storage, BE + CCS, but this is always more expensive than plain BE without CCS. Furthermore BE+CCS is competing in the already crowded electricity market, not the higher value transport market which the new strategy addresses most readily. Additionally, BE+CCS faces scalability problems given that relevant plant biomass is somewhat limited.

In contrast the new strategy significantly increases new plant biomass with many synergies in agriculture as explained in the attached overview poster. Additional advantages are these include addressing the other greenhouse gases methane and nitrous oxide etc to varying extents, assisting sustainable agriculture and reforestation.

The Intergovernmental Panel on Climate Change, IPCC, has long wanted a negative CO2 emissions energy system that replaces fossil fuels, and with increasing urgency recently. Arguably this new approach is exactly what they are wanting, but really new ideas find it difficult to find a serious hearing.

Looking forward to more detailed discussions very soon if the WA government wants to get involved,

Yours sincerely,

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Energy, Food & Water Security, Financial Profitability, & *Reversal* of Climate Change

Via a significantly ***negative*** CO_2 emissions liquid fuel, "Slow Pyrolysis Oil", in its non-upgraded hence cheap form, and its co-product "Biochar". When both are commercialised together, with the proposed business plans, the fuel is able to compete on price with fossil fuels in stationary electric power generation (recycling present thermal power station assets), and especially in transport, (except air) though this requires a new flexi-fuel automotive engine - see below right. Biochar greatly assists agriculture & has many helpful climate synergies. In order to address all major fossil fuel uses, "Biochar-Coke,Hot-Forged-with-Holes", is a CO_2 neutral, cost competitive, direct substitute for coke in iron smelting.

Overview

This holistic integrated technology centres on a scientifically well understood, but in the past neglected liquid fuel, "Slow Pyrolysis Oil", manufactured with similar amounts of co-product "Biochar", a sequesterable carbon powder, hence fuel production overall has significantly negative CO_2 emissions. A better known product "*Fast* Pyrolysis Oil" has negligible Biochar, (hence is CO_2 neutral), but makes more oil. See research & development on Fast Pyrolysis Oil by the International Energy Agency "Task 34", summarised by the Pyrolysis Network, at www.PyNe.co.uk, also US Govt' Dept' of Energy, Bio Energy Technology Office, DOE BETO.

Biochar was included for the first time as a promising *negative emission* ***technology*** in the IPCC special report of 8th Oct 2018. *Negative emission* ***energy*** is even more important because it replaces fossil fuel as well as having negative CO_2 emissions, not merely zero CO_2 emission.

The IPCC has also recently stressed (2019) the importance of greatly improved land and agricultural management. This strategy enables a lot of leverage for these improvements

Neither fast nor slow pyrolysis oil has been successfully commercialized in automotive transport because of the prohibitively high cost of upgrading to automotive quality diesel. Nor has even non-upgraded pyrolysis oil been able to fully compete with low cost thermal coal in stationary electric energy generation, although it can be easily co-fired with fossils fuels, (but needs government subsidies etc). For example the "Oilon" company of Finland has commercially available pyrolysis oil burners to retrofit to steam turbine electric power stations.

Nevertheless Slow Pyrolysis Oil is relatively easily made, (easier and cheaper than Fast Pyrolysis Oil). It is more scalable, and more economically feasible than all other biofuels since it uses the whole plant (except roots) of maximally diverse, cheaper, less dry, less dense plant biomass such as grasses, leaves, algae, many wastes, as well as more expensive, already well utilised woody biomass (the latter being preferred by Fast Pyrolysis).

When fully developed the scalability of this one pathway would be sufficient to fully replace nearly all fossil fuels because of biochar's several synergies in growing more plant biomass on existing farmland and increasing useful land, resulting in even more fuel and biochar. Non upgraded Slow Pyrolysis Oil can progressively replace fossil fuels in stages:

Stage 1, Transport; **A.** Initially farm vehicles,
B. General transport, especially heavy transport, trucks, rail, marine - but not aviation (energy/mass density of fuel)

Stage 2, Electric power,

Stage 3, Industrial scale heating (most), but probably not domestic gas,

Stage 4, Metallurgical coke - used in smelting iron and some other metals, about 7% of all fossil fuel use.

The order of these stages is variable depending on economic opportunity, e.g. metallurgical coke could be commercialized first.

Replacing almost all fossil fuels with significantly *negative* CO_2 emissions energy, in 4 stages

Stage 1. Transport. Non upgraded hence cheap Slow Pyrolysis Oil competes on price most easily in higher value transport fuel markets, compared to the lower value already crowded electricity markets. This is only possible with a new genuinely flexi-fuel automotive engine, with high mechanical performance, energy efficiency, able to use Slow Pyrolysis Oil in it cheap, potentially plentiful form (n.b. not a diesel engine). (See bottom right panel of poster.)

1. A. Farm vehicles are probably the best initial niche market due to multiple synergies & cost benefits, with return on investment for a typical farmer within the first year:

1. Cheap do-it-yourself fuel replacing expensive diesel.
2. Co-product Biochar when used appropriately usually increases yields by about 20%, especially in warm climates, & gives greater relative benefit when starting with all too common poorer soils.
3. Less artificial fertilizer - cost savings & less harmful runoff.
4. Drought proofing soil.
5. Reclaiming degraded land.

Costs are competitive with farmers transporting their air dried farm waste (straw, prunings) to a do-it-yourself pyrolysis facility for large farms. For groups of smaller farmers a facility can be located at their usual rural grain hub- the farmers receive back their share of biochar to enrich their soil with many long acting productivity & other commercial benefits.

Co-product biochar's soil improvement properties have been controversial until about 2017, when it was finally determined that most relative benefits are from poor soils, and in warm climates, (not cold climates), and after soil biota adapt to give secondary benefits in nitrogen fertiliser fixation and build up of root derived soil carbon - after about 8 years of in-field aging of biochar. When the initial plant matter for pyrolysis is rich in nitrogen nutrients (eg poultry litter) there is an additional short term boost from biochar enriched with nutrient, but the structural improvements of soil persist long term.

Too much low nutrient biochar at a single application can absorb and deplete existing soil nutrient, but still acts as a longer term reserve. Drought-proofing soil by layering water absorbent biochar just under the seed at time of sowing is optimal and conserves water and nutrient, reducing nutrient run-off/leaching and enabling less artificial fertiliser (cost savings of about 50%) without compromising yield.

There is about double the soil organic carbon thus formed compared to traditional return of farm waste direct to the soil. In addition "Biota Enhanced Biochar" can target the needs of a farmer's particular soil.

Leaving some straw as mulch protects soil and biota from excessive heat & evaporation. At least two, preferably three tonnes per hectare of retained straw for mulch is optimal. This is usually possible for non-irrigated dryland grain farmers except in severe drought conditions - in which some fields could have hay crops rather than grain crops.

Other agricultural industries usually have ample plant waste to cover fuel needs & build soil with biochar over about 12 years to optimal levels, generally about 10 tonnes per hectare to the topsoil.

Stage 1.B. Transport - heavy road transport, rail, marine, commuter. Slow Pyrolysis Oil in transport is more feasible than past attempts to commercialise biodiesel or lingo-cellulosic ethanol, since slow pyrolysis uses cheaper more scalable plant feedstock inputs, many forms of waste, and "Energy Crops" – non-food plants grown purely for fuel and biochar, and use the whole plant (except roots), ideally hardy drought resistant native perennial grasses, shrubs, mallee, etc., rapidly grown on land not suitable for food, assisted by the soil enhancement and land reclamation benefits of biochar. Diverse native perennial plants don't require high quality land nor much water, using previously very low economic value land.

Non upgraded slow pyrolysis oil is suitable for heavy road transport, trucks, mining vehicles, rail, & marine engines (if using the new engine). Fuel distribution in these markets is easier than with light commuter transport since fuel outlet networks can be less widespread with long haul heavy transport. Distribution infrastructure may best start large then go small, i.e. marine, rail, heavy transport, & finally commuter vehicles.

Being genuinely flexi-fuel avoids many disruptive technology problems.

Slow Pyrolysis Oil can be blended optionally with 5 to 10% ethanol, to help with shelf life, energy content & reduces viscosity. This is both economically & environmentally sustainable, as with "E10" gasoline.

Further improvements to Slow Pyrolysis Oil & Biochar co-production, both for large farms (or farm collectives), or larger scale Energy Crops, with design patent applications, awaiting the right time & financial support.

Stage 2. Electricity. At a later stage of scaling up of energy crops, Slow Pyrolysis Oil could compete on price with current low cost coal & gas, (& other low but not-negative CO_2 emissions renewables). This can recycle the asset of aging steam turbine stationary electric power plants (presently using fossil fuels). The main expense is plant biomass feedstock from energy crops as described above, but can also include native wild disease resistant prolific algae which use the whole plant not just oil rich portion. Locating an Algae-Photo-Bio--Reactor adjacent to a Slow Pyrolyis Oil and Biochar facility is helpful.

Stage 3. Industrial scale heating can generally use slow pyrolysis oil if is it cost competitive with natural gas. This would probably not occur till energy crops are scaled up over some decades. Domestic gas for cooking and washing presently uses fossil fuel natural gas, and in the future may best be served with bio-methane (if costs can be reduced considerably). Alternatively, domestic heating can be supplied by electricity generated by renewables, preferably CO_2 negative emissions energy, i.e. the present strategy.

Stage 4. "Hot Forged Biochar Coke" is a cost competitive, direct substitute for solid large chunks of metallurgical coke in present technology blast furnaces. Modern furnaces are already near the limit of Pulverised Coal Injection, (there is a similar limit for Pulverised Biochar Injection).

Reversing Climate Change – Multi-Pronged Strategy

Eight of the nine main climate change mechanisms are addressed to varying extents, safely and quickly reversing adverse climate change - if implemented in a timely manner:

1. Carbon dioxide – absolute reduction via significantly negative CO_2 emissions from stationary & automotive engines & industrial heating. Photosynthesis produces CO_2 negative plant biomass. Of the initial plant biomass carbon; 30% is converted to CO_2 neutral emission fuel, 35% is semi-sequestered as biochar, & 35% is CO_2 neutral emissions that are emitted in the fuel production process.

• Synergy of biochar as soil enhancer amplifies total photosynthesis further reducing CO_2.

• Reclaiming land via biochar (food and energy crops) amplifies reduction of CO_2, nitrous oxide and methane.

2. Methane – relative reduction via select "natural" biomass sources being diverted to Biochar and Slow Pyrolysis Oil production.

• Biochar in soil further adsorbs methane release from anaerobic decay of organic matter in soil.

• Biochar enhanced with appropriate native methanotrophic bacteria further reduce methane emissions from soil.

3. "Black carbon" are the fine atmospheric particles of smoke and soot from incomplete combustion, internal combustion diesels comprise about 20% of all black carbon.

Relative reduction via the longer, more complete, cleaner burn of external combustion in the new automotive engines.

4. Nitrous Oxide, (N_2O) - relative reduction via lower temperature external combustion at about 1100ºC, well below the temperature for formation of "thermal NO_x" (c.1600ºC), c.f. internal combustion about 2000ºC. This indirectly reduces N_2O in the complex biological & non biological equilibrium of the nitrogen oxides.

• Less black carbon (see above) also reduces the formation of N_2O from the nitrogen oxides.

•The uses of biochar in agriculture enables lower usage of artificial nitrogen containing fertilisers, (ammonium phosphates, urea) with less N_2O emissions and environmentally unhelpful fertilizer run-off and leaching.

• Further reduction of N_2O gas is via biochar in soil adsorbing N_2O gas from soil, released from both artificial and natural nitrogen sources, and helpfully retaining it as a soil nutrient.

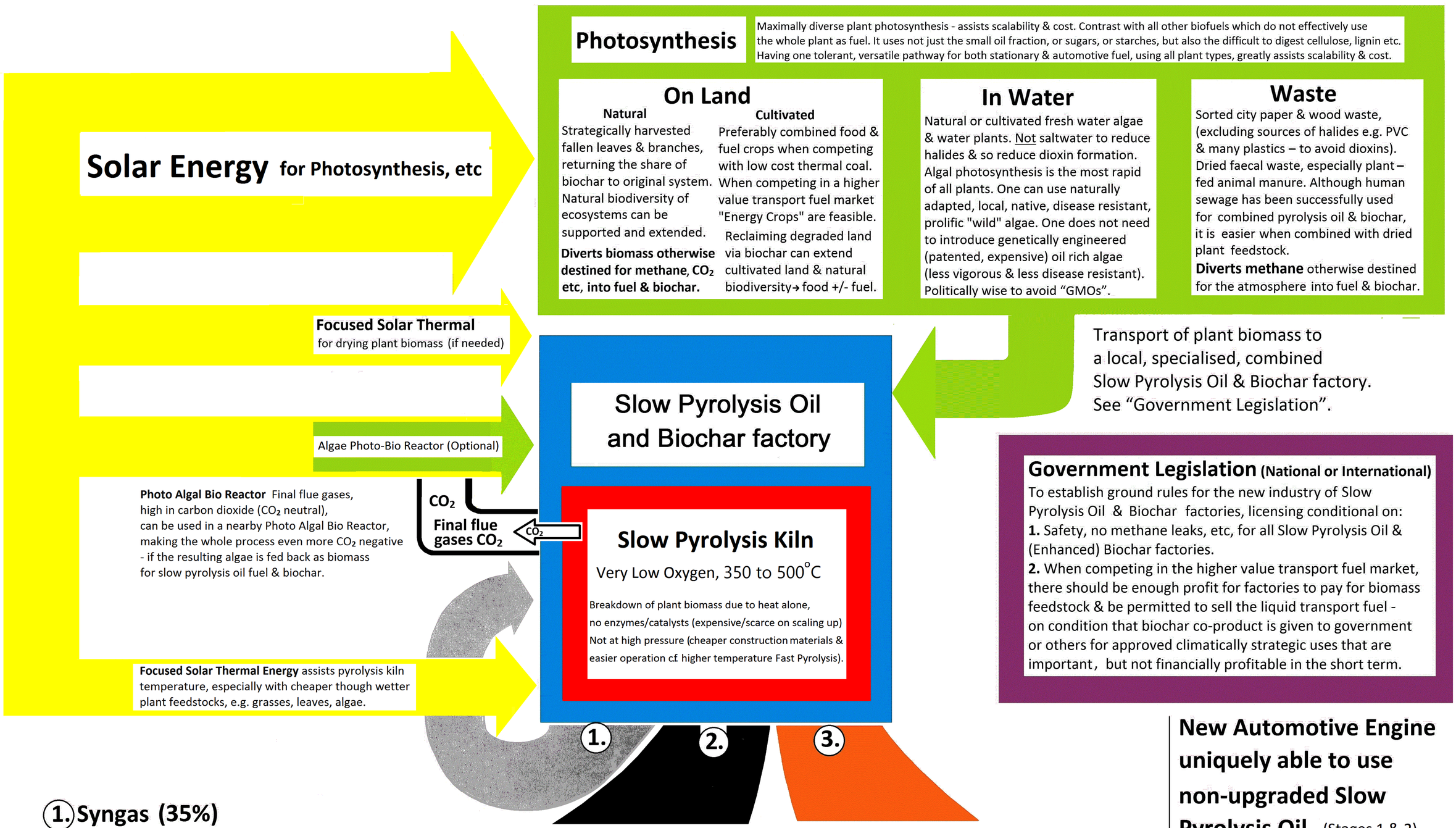
5. Water Vapour is a Green House Gas of relatively low potency, very variable concentration, but relatively high concentration.
Relative reduction via large scale agriculture and native reforestation is assisted by low cost biochar (see "government legislation"). Increased vegetation encourages the local daily water cycle, which helps stabilise water vapour at a larger scale.
• Biochar enhanced soil retains water and delays evaporation, in a non-equilibrium system this reduces net water vapour.
• Vegetation usually improves whiter light cloud coverage which is usually climatically helpful, associated with less extreme weather.

6. Tropospheric Ozone - relative reduction of this minor Green House Gas is via reducing black carbon which catalyses O_3 formation at low altitude. Higher stratospheric ozone has an important role in shielding higher energy UV light.

7. Reforestation – involves increasing soil carbon sinks, and long lived large plants including root system carbon.
•Reforestation has helpful weather and climate effects independent of and in addition to Green House Gas effects, e.g via the small local water cycle encouraging light clouds, and bringing rain inland from the large ocean based water cycle.

8. Reflectivity, albedo ("whiteness") - relative reductions, via increased vegetation and net photosynthesis storing solar energy chemically as carbohydrates rather than radiant energy.
• Relative reduction via reduced black carbon deposited on mountain ice and snow (a small effect),
• If the new strategy is successful, albedo may be restored via reversing climate change which is melting floating reflective ice in polar regions, especially north pole/arctic. The increasingly rapid loss of polar ice, complicated by increased fires (black carbon, methane) burning in thawed and drying out permafrost.
N.B. In agriculture, biochar should be placed during sowing in a layer or band a few cm deeper than the seed to give optimal crop yields, and also assist albedo. Ideally biochar should not be placed on the soil surface unless there is near constant leaf coverage of soil.

(9. Hydrofluorocarbons – already reducing since the Montreal Protocol implemented in 1989.)



1. Syngas (35%)

35% of initial dry plant biomass, with slow pyrolysis heating (very low O_2 , ~500ºC) forms pyrolysis gas (smoke) which on rapid condensing leaves some gas "Syngas", which includes some combustibles; methane carbon monoxide, small organic molecules, hydrogen.

Also present are significant amounts of already fully combusted carbon dioxide. Syngas gas is burnt outside the chamber containing the biomass, heating the chamber and biomass to the required ~500ºC temperature.

There is potential for different types of combustion.

Fully combusted CO_2 can be optionally transferred to an algae photo bioreactor, situated nearby, to make more biomass, and increasing the net negative CO_2 emissions of the system.

2. Biochar (35%)

Slow pyrolysis biochar is about 35% of initial dry plant biomass, about 90% quite stable carbon, semi-sequesterable in soil, with proven added value as a soil enhancer. It absorbs, retains slowly releases nutrient and water - ideal for native soil biota and plants. This is why, if used properly biochar usually increase crop yields by 20% for grain crops in *warm* climate, although details are complex, see appendix, and work by Simon Jeffry et al., 2017. The 30 to 35% of long term, carbon retention in soil with biochar is much better than the 12% to 15% retention with current farm practice. "Enhanced biochar" with added fertilizer (synthetic or natural eg manure / sewerage), and/or native biota, further boosts crop yield. Biochar always has "structural" benefit to soil health (increases with in-field ageing and biota changes). Nutrient rich biochar (eg made from poultry litter) has a shorter term benefit. Placing a layer or band of biochar a few cm below the seed at the time of planting is strategic.

3. Non-upgraded Slow Pyrolysis Oil (30%)

Automotive power plants (Stages 1)
Stationary power plants - electricity (Stage 2)
Industrial heating (Stage 3)

Slow Pyrolysis Oil is a carbohydrate-tar / water emulsion (about 25% water), as viscous as thick sump oil, acidic (about pH2, similar to vinegar) and with only about 42% of energy on combustion as the same mass of hydrocarbon fuel.

It can't be refined using the usual cheap methods of petroleum distillation and cracking. Without prohibitively expensive, unscalable chemical upgrading, or pointless high dilution with >75% of other good fuels, it is entirely unsuitable for automotive diesels. At best it is suitable for slow, ultra-high compression, heavy stationary diesels attempting to compete in the low value electricity market, but not automotive engines.

However it is suitable for simple non-explosive combustion, being burnt in furnaces to raise steam for steam turbines.

Unfortunately steam turbines are not suitable for the rapid & highly variable loads of modern automotive engines. It could be used in other types of automotive steam engines, but only if able to compete on performance and efficiency with internal combustion engines. This is normally considered impossible by mechanical engineers, though a small flaw in their usual logic means there is a solution, see next column.

New Automotive Engine uniquely able to use non-upgraded Slow Pyrolysis Oil (Stages 1 & 2)

The automotive engine under development performs very well, and with all the innovations planned would excel in terms of; mechanical performance, excellent torque at all speeds, acceleration under a variable load, energy efficiency, good power to weight ratio, exceptionally low vibration, etc. There are no exotic, expensive, potentially scarce materials (on scaling up) in manufacture, and only standard mechanical engineering techniques are required.

Slow Pyrolysis Oil can be blended with a sustainable 5% to 10% of 2nd or 3rd generation ethanol, (cf 10% ethanol blend in gasoline at present). Ethanol lowers viscosity, increases energy content, and increases shelf life (the latter also helped by small amount of surfactant). Compared to typical internal combustion engines there are much lower than usual NO_X emissions, & "black carbon" (smoke, soot) emissions.

The engine is genuinely "flexi-fuel", e.g. L.P.G. reducing disruption in fuel distribution in initial phases while Slow Pyrolysis Oil production is scaled up. It is probably best to start with farm vehicles, then rail, heavy road, or marine, as there are less complex fuel distribution networks required compared to the many small outlets of light road transport fuel networks.

Stationary electric power stations (stage 3), would also benefit from the new engine - when current steam turbines are retired - lower capital cost, more energy efficient & durable. The new engine manufacturers may choose to sell only to power generators committed to using Slow Pyrolysis Oil- to help *reverse* climate change.

E. Smith, revised Aug 2019

Climatically Strategic Large Scale Use of Low Cost or "Free" Biochar to *Reverse* Climate Change

Government and Approved Not-For-Profit Groups

See "Government Legislation" for details on "free Biochar".

"Free biochar" for climatically strategic purposes that are not financially profitable in the short to medium term. Biochar used to promote reforestation and reclamation of degraded soils in:

1. Margins of enlarging deserts, to halt desertification, especially where there is good potential for re-vegetation.

2. Reclaiming degraded land which will take a long time to restore even with biochar enhanced soil - too long for a reasonable financial return of investment, e.g. over farmed or saline soil from poor irrigation.

3. Arid coastal strips with dry inland regions, where new coastal vegetation would progressively bring rain inland, assisted by usual weather patterns with wind coming from the West, e.g. Western Australia. Note that this uses the large water cycle with ocean evaporation and weather patterns, not the small local water cycle using local evaporation from soil, plants & inland waterways with daily dew fall, as was mentioned in Reversing Climate Change Multi-Pronged Strategy, points 5 & 7.ii, top right panel.

Farming and Forestry

Commercial agriculture would usually be able to generate their own Biochar (possibly enhanced) as part of the deal to make Slow Pyrolysis Oil competitive with thermal coal and natural gas. ("Stage 1 & 2").

The deal could require Biochar being used in climatically strategic manner, i.e. optimal concentrations, and black biochar not being left on sun exposed soil, but ploughed in at optimal depth.

Hot-Forged Fenestrated Biochar-Coke

Some biochar may be specially processed as Hot-Forged Biochar-Coke with holes (fenestrations), as a cost competitive direct replacement for metallurgical coke in smelting iron and some other metals. Australian patent granted, but lapsed, but further ideas ready for likely patenting when opportunity is right.

The highest purity carbon Biochar may be best used as Biochar-Coke instead of in agriculture. Impurities such ash often serve as helpful nutrients in agricultural biochar, in contrast to coke. The much higher price for "Designer Biochar-Coke" could financially support the maximum overall biochar production - for optimal climatic benefit.