Biochar Network New Zealand’s Response to CCC Consultation Questions

Are you here to tell us your one big thing?

If you're here because you have one big thing to tell us, you can do that here. If this is all you want to provide by way of your submission, that's fine by us. We will consider all the submissions we receive.

Your one big thing:

Our one big thing is to promote biochar as a reliable, long lived, negative emissions technology which has natural and historic synergies with existing climate efforts and delivers myriad co-benefits for New Zealand.

The CCC advice does not appear to have factored biochar into its climate policy strategy. Leaving out biochar’s contribution, in spite of its GHG mitigation potential for NZ being at megatonnes CO_2e scale using proven science and technologies, is disappointing.

The CCC evidence documents do touch on the climate benefits and risks of biochar production, but do not fully consider the direct and indirect benefits from biochar use for a New Zealand context. There are myriad opportunities to be pursued in those gaps.

There are also significant longevity risks in only sequestering carbon within biological systems. Biochar mitigates this risk.

BNNZ’s submission therefore highlights the opportunities where New Zealand can invest to its advantage, and to enjoy the co-benefits that biochar brings to quality of environment and life for the people of New Zealand, and our trading partners.

We are here to help

Biochar Network New Zealand (BNNZ) thanks the Climate Change Commission (CCC) for their effort put into producing its advice and evidence, and for the opportunity to provide feedback to consider for improving on this important work.

BNNZ exists to support the production and use of biochar to improve our social, economic and ecological environments by providing information, education, connections and opportunities within the New Zealand context[1].

Carbon markets are rapidly evolving around the world, driven by societal risks associated with climate change and business opportunities connected with addressing these risks. Global and government driven initiatives have been developed, however it should be noted that the 'formal[2]' sector has historically focused on emissions trading[3]. The New Zealand Emissions Trading Scheme[4] is an early example of efforts to address NZ climate change responsibilities.

Other carbon market initiatives have progressed ahead of international agreement, government policy or government support. Biochar is being supported by new carbon market initiatives coming from industry, NGO's and entrepreneurs. These markets are at various stages of evolution but NZ has yet to 'catch this bus'.

Major international companies are working with the voluntary carbon market sector to offset their carbon footprint via biochar carbon sequestration. Examples of this progress are detailed in the BNNZ supplementary submission.

BNNZ is confident that the current costs of biochar production have been covered by the CCC advice at a high level. This submission prompts the CCC to recognise the wider benefits and opportunities that biochar presents for New Zealand, and its place as an enabler for a successful climate transition. This submission also touches on the ancient use of ngārehu (charcoal) by Māori in their whenua. We suggest that recognising and honouring this indigenous knowledge, and those who have been kaitiaki of it, can help enhance the Crown-Māori relationship.

Risks and implications of biological sequestration

BNNZ notes that the Commission's advice describes a sequestration strategy which seeks to use biological means to remove atmospheric carbon in the first instance, and from there to maintain a new equilibrium where increased carbon

1 For more information on BNNZ, its mission and activities and a full reference list, please refer to the supplementary document that accompanies this submission.

2 'Formal' in this context refers to international or government supported initiatives.
3 https://en.wikipedia.org/wiki/Emissions_trading
4 https://en.wikipedia.org/wiki/New_Zealand_Emissions_Trading_Scheme

stocks are maintained within biological systems, rather than the atmosphere.

An ongoing reliance on biologically sequestered carbon stocks comes with management complexities and governance risks to maintaining that equilibrium, especially when considering the impact that even small changes in temperature and climate can have on ecosystems at community, regional, national and even international levels.

Prior to the industrial era, natural long-term storage of fossil carbon via geosequestration was relatively secure as recalcitrant carbon in the form of coal, or immobilised carbon in oil and gas deposits. Our consumption of fossil fuels along with land use change, particularly deforestation and tillage-based cropping, has created an accumulation of atmospheric carbon which is a debt that must be recouped by increasing both the quantity and longevity of recalcitrant carbon stores to avert catastrophic climate change. The atmospheric debt is the principal that must be repaid; emissions reductions are just limiting further borrowing.

A challenge for New Zealand is efficiently and reliably sequestering carbon in ways that provide net enhancement to ecosystems and climate, and at the same time providing societal and economic benefits. A further challenge is how to do this with long-lived solutions which are resilient to climate and resource management changes, and not so complex or capital intensive as to deter investment and implementation.

Without further sequestration via chemical or geological processes, there is a risk that the equilibrium for carbon sequestered in biological systems may be reduced in future, with part of the carbon stocks lost to the atmosphere through fire or biological decay. However, if we introduce biochar to the toolset, we can future-proof the outcome by pyrolysing biomass and turning it into a product that resists decay, enhances biological carbon deposition and can be safely stored in productive soils and enduring infrastructure.

Impact and Co-benefits of Biochar Production and Use

BNNZ is concerned that the CCC may not have had sufficient evidence to fully consider the benefits, costs and risks of using biochar in New Zealand versus other GHG abatement tools. BNNZ is also concerned that the CCC advice does not mention biochar as an abatement tool.

Given underutilised biomass resources available now, biochar could be used to directly sequester more than 1%+ of New Zealand's GHG emissions annually. Through various applications of biochar there is a scientific basis for proposing that biochar could help reduce requirements for emissions intensive inputs and reduce GHG efflux, increasing biochar's impact to a combined gross 6%+ reduction in New Zealand's GHG emissions. With more biomass from additional forests and ongoing R&D, biochar has even greater potential going forward. The CCC evidence report does consider some narrow cost considerations and risks of biochar, but does not display sufficient evidence or focus to fully consider the systemic place for, or co-benefits of biochar use for New Zealand.

BNNZ sees biochar as a complementary tool to biological systems where it can make positive impacts. These are some of the many areas where the cascading services of biochar increase its value beyond carbon removal and sequestration:

- Forestry – additional revenue streams, increased seedling survival rates, benefits during growth periods when thinning and pruning and providing options for end of life management of trees, harvest waste, site remediation and waterborne debris risks. Soil borne disease mitigation such as Kauri dieback /phytophthora and other pathogens.
- Soil – applications of biochar will be cumulative, increasing the quantity of recalcitrant soil carbon, and with careful land management can provide negative priming effects which serve to increase overall soil carbon[5]. Numerous additional benefits in soil structure, aeration, water retention, fertility and reduced fertiliser requirements, improved operating models and further reductions in GHG emissions from N production and use are all documented outcomes of biochar in agricultural and horticultural contexts.
- Livestock – biochar applications in feed and bedding support nutrient cycling, odour reduction, animal health, leading to increases in growth, productivity and economic returns and reducing methane emissions from ruminants by over 10%.
- Freshwater – biochar supports soil aggregate stability and retains nutrients in the root zone, leading to reduced leaching from soils, serves as a sponge for nutrients and filter for contaminants such as cadmium from phosphate application, helping to keep wetlands and rivers clean.
- Wastewater – biochar provides a substrate for biological remediation and retains nutrients. Enhanced methane recovery from AD systems. Urban and

[5] Blanco-Canqui, H, Laird, DA, Heaton, EA, Rathke, S, Acharya, BS. Soil carbon increased by twice the amount of biochar carbon applied after 6 years: Field evidence of negative priming. GCB Bioenergy. 2020; 12: 240– 251. https://doi.org/10.1111/gcbb.12665

highway stormwater remediation and recycling.

- Solid waste – biochar production diverts excess organic matter from landfill, preventing anaerobic decomposition and the release of methane, as well as further sequestering biomass carbon in a stable form.
- Basic technology and engineering – biochar is a stable carbon replacement for rock aggregates and sands in construction materials (concrete, brick, plaster and other composite materials).
- Hightech engineering– biochar is suitable feedstock for myriad exotic materials applications including polymers, 3D printing, filtration, battery and supercapacitor manufacturing.

BNNZ encourages the CCC to also consider the work of biochar researchers in New Zealand and overseas who provide more detailed descriptions of the benefits from biochar use. We have included a reference list at the end of this submission as a starting point, and also include supplementary documentation.

Current status of biochar in New Zealand

Despite both its clear value in atmospheric carbon removal and its myriad co-benefits, biochar is a very early stage industry in New Zealand, and has struggled to gain funding and recognition in this country. A holistic approach is required so that we can situate biochar production within the economic landscape relative to other uses of biomass, and application in terms of its solutions to environmental problems.

Biochar has been used by Māori in New Zealand for over 700 years and represents fundamentally indigenous knowledge(Calvelo Pereira et al.2014). Biochar production and use can be mobile and operationally flexible, providing opportunity for community, hapu, iwi and regional scale enterprise and development.

Although no large-scale dedicated commercial production is yet operational, biochar is already being unwittingly produced in New Zealand by government bodies and the private sector through boilers which convert biomass to energy and, due to incomplete combustion, yield a high carbon boiler ash. Through the initiatives of BNNZ members, some of this material is finding economic applications around NZ and increasing soil carbon levels.

BNNZ and our network currently support small to medium scale producers and users across the country, but we need policy and funding assistance to raise the profile of biochar applications in New Zealand and gain critical mass for greater scale and wider benefit. Our estimates indicate the available direct carbon sequestration potential from an integrated biochar programme at the national scale to be well above 5 MT CO_2e annually and this could be increased further with production incentives and growing additional biomass specifically for biochar production. This estimate does not include displacement or substitution of fossil fuels by biomass energy derived from pyrolysis, nor does it account for emissions reductions through decreased fertiliser use, lower methane emissions from use of biochar in stockfeed and lower N efflux following application to productive soils.

Where to invest?

BNNZ strongly advocates for the expanded production and application of biochar as one of New Zealand's best options for carbon drawdown due to its myriad co-benefits. Placing the appropriate market signals in the form of policy and targets will provide the crucial initial incentives for investment and development of both technology and logistics to scale up and simplify adoption of biochar solutions.

It has made economic sense for early movers in New Zealand to use biochar in the absence of climate considerations. Some of their stories appear in our supplementary document. Our goal is to further reinforce the economic case, aided by a national recognition of biochar's additional services to ecosystems and climate.

Please refer to our supplementary document for more detail about BNNZ, our mission and membership, New Zealand case studies, further references to relevant literature.

Our six big issues

Our six big issues - the pace of change

Big issues question 1. Do you agree that the emissions budgets we have proposed would put Aotearoa on course to meet the 2050 emissions targets?

Disagree

We have concerns about the assumptions of the NDC and its suitability for actually limiting warming to 1.5 degrees C. We refer to the submission by Lawyers for Climate Action NZ on this subject, and note that the emissions targets need to be based on a more rigorous limit. Therefore, the budgets are inadequate.

Our six big issues - future generations

Big issues question 2. Do you agree we have struck a fair balance between requiring the current generation to take action, and leaving future generations to do more work to meet the 2050 target and beyond?

Neutral

BNNZ is not taking a position on the ethical implications of the current versus future loading of actions required, but instead advocating for more work in drawdown commencing immediately in order to set a better example.

Our six big issues - our contribution

Big issues 3. Do you agree with the changes we have suggested to make the NDC compatible with the 1.5°C goal?

Neutral

BNNZ relies on the scientific consensus and precautionary principle, which indicates that a goal of 1.5 degrees is probably not achievable on our present emissions trajectory, and therefore a far greater degree of active sequestration measures will be required.

Our six big issues - role and type of forests

Big issues 4. Do you agree with our approach to meet the 2050 target that prioritises growing new native forests to provide a long-term store of carbon?

Agree

BNNZ supports a shift to permanent forestry as a long-term storage strategy, but we also believe there needs to be a consideration of permanent, managed productive landscapes incorporating tree cover and crops. This can be a mix of natives and exotics, with yields including food, fibre, medicinals, and biomass on a sustainable basis.

Long-term planning around biomass supply is important, with potential needs for biomass for bioeconomy industries, fuels, and biochar. These uses may compete for limited biomass supply, though biochars made from processing residues can be a co-product from bioeconomy, bioenergy and biofuel industries. Although new plantings to supply biomass do not need to be radiata pine, establishing increased biomass supply requires planning many years in advance of emerging needs.

Our six big issues - policy priorities to reduce emissions

Big issues 5. What are the most urgent policy interventions needed to help meet our emissions budgets? (Select all that apply)

All of the following are applicable policy interventions: Action to address barriers + Pricing to influence investments and choices + Investment to spur innovation and system transformation

BNNZ proposes the following policy interventions to help with New Zealand's climate effort.

The highest impact and/or high leverage actions for biochar in New Zealand include:

1. High impact applications:

   a. Pyrolysis as a proven, climate positive use for end of life stands of pine trees with many co-benefits. Radiata pine forestry *kicks the can down the road* on sequestration for a maximum of 80-100 years, much less if forestry products are harvested. Biochar is cumulative, and buys us hundreds to thousands of years.

   b. Promotion of biochar as an animal feed additive for livestock health, increased production and reduced enteric methane emissions. Robust studies to determine and optimise potential benefits to livestock farming in the New Zealand context.

2. High impact, quick win areas for public-private cooperation:

   a. Connecting BNNZ members with sources of high carbon boiler ash biochar from the biomass boilers funded as part of the Decarbonisation of The State Sector programme.

   b. Establishment of industry standards and legal protection for those wishing to market products as "biochar" in New Zealand, to enhance and protect credibility of biochar, and protect end users from risks such as the use of contaminated biomass feedstocks or poor practices which could result in a net addition of GHGs to atmosphere instead of the opposite.

   c. Establishing national and regional models for possible biochar production and uptake. Include forecast of climate and economic impacts of biochar production and use (including reducing needs for other inputs) based on CCC and Government biomass availability projections, current knowledge of good practice production and an agreed set of assumptions.

   d. Establishing a brokering framework and contract structures for coordination of supply and demand for biomass.

   e. Combining current shelterbelt and riparian planting initiatives with short rotation coppice forestry to sustainably yield biomass feedstock for pyrolysis.

   f. Wilding pine management via biochar production.

3. High leverage government moves:

   a. Increasing New Zealand's landfill levy, especially for organics, to incentivise alternative use of resources.

   b. Funding research on the economic benefits of biochar from commercial forestry residues.

   c. Investing in techno-economic and market analysis to develop multiple roles for biochar in the New Zealand context.

   d. Developing a pathway for biochar inclusion as a negative emission technology within the New Zealand national emissions budgets and the ETS. Or (better) developing and/or leveraging existing voluntary carbon markets that place a more realistic price on emissions outside the ETS framework.

   e. Funding and enabling investment support for biochar projects, especially in settings where biomass is diverted as a waste product that would otherwise be burnt or decompose in situ, and as a source of energy that could displace or substitute for fossil fuels.

BNNZ strongly advocates investing in biochar's potential for GHG sequestration and emissions reduction in New Zealand by providing funding for, and collaboration with BNNZ to:

- Identify and further investigate the highest potential (value first, then volume) biochar applications in a New Zealand context, and barriers to adoption.
- Identify and investigate the economics of biochar production options and their most suitable applications for regional contexts.
- Invest in research and publicise case studies and findings of the following, in the New Zealand context:
    - Optimum biochar feed supplementation levels for representative ruminant livestock groups and feeding regimes in New Zealand pastoral production, with view to reducing methane emissions, maximising animal health and production and preventing leaching of nutrients from animal manures.
    - Emissions from decaying organic matter (such as effluent ponds, landfills or composting operations) with vs without biochar added.
    - High value applications from biochar use such as reduced input requirements, increased output or quality for operations before vs after biochar use.
    - Guidelines for biochar deployment in NZ including:
        - practicalities of application.
        - operational parameters and pyrolysis design.
        - operational health and safety.
        - ease of use of pyrolysis equipment.
- Identify and summarise sources, volumes and effects of current disposal methods for problematic biomass in New Zealand such as wilding pines, willows from stream clearing, agricultural residues, municipal solid waste, sewage sludge, and construction scrap, and assess options and economics for climate positive use.
- Run trials in identified key industries and build a network of early adopters, case studies and extension measures, building on principles of homophily (Quade, 2010).
- Establish an ETS innovation fund which lowers or dismantles barriers to market participation by non-incumbent technologies and small-scale GHG sequestration initiatives.

BNNZ strongly advocates for the following interventions to address barriers to biochar adoption:

- A pathway is required for biochar to be recognised under the New Zealand ETS so that New Zealand can benefit from its own biochar production. Without this, New Zealand biochar producers' carbon sequestration efforts would be forced to go unrecognised, or be sold on international voluntary carbon markets.
- biochar's strength is that it can be created and used in industrial, community or even back yard scale operations. However, for small and community scale producers the investment required to gain certification for voluntary or ETS markets is cost prohibitive. BNNZ suggests further work to bring down barriers to small scale participation.
- there are many indirect, climate positive benefits of biochar use. A practical means is required to account for these. For example, the reduction in fertiliser requirements for a farm due to biochar incorporation in soil does

not have an established attribution pathway, may remain difficult to quantify on a national basis, and may require additional guidance to be developed to recognise these actions for GHG accounting purposes.
- invest in research and application guidance for biochar use in various soils. There is too little funding for research on biochar use in New Zealand contexts and soils.
- Analysis models should recognise wellbeing in its widest sense, resilience and risk mitigation, and not be purely focused on financial performance as an end, but a means. Biochar use can enable savings in farm inputs, reduce nutrient leaching and help increase farm resilience, especially to drought. An economic analysis with a pure financial view may look at this biochar use case and show reduced spend as "lost" GDP, not recognise the risk reduction, and also ignore the positive environmental effects that result from biochar use. Both New Zealand's models and data should be fit for purpose.

BNNZ suggests the following interventions where pricing mechanisms are also required to address barriers:

- Significantly increase the waste minimisation landfill levy to disincentivise landfilling of organic resources;
- Signal increases, and begin to raise the floor and ceiling prices in the ETS auctions to approach the $240 estimated long term price;
- Consider a tax on carbon emissions;
- Reinvest proceeds from the ETS into feasibility for and investment in GHG mitigation and reversal initiatives; and
- Introduce a pricing mechanism (perhaps similar to the waste minimisation levy or forest commodity levy) to foster innovation for further sequestration of carbon forestry and beneficial use of stands which have been damaged or are approaching end of life, to be able to proactively manage these risks.

Our six big issues - technology and behaviour change

Big 6. Do you think our proposed emissions budgets and path to 2035 are both ambitious and achievable considering the potential for future behaviour and technology changes in the next 15 years?

Neutral

BNNZ prefers to focus on the advancement of biochar as a backstop or hedge against inevitable shifts in behaviour, technological disruptions, and other exogenous factors.

Detailed questions on the CCC advice

1. How we developed our advice

Consultation question

1. Do you support the principles we have used to guide our analysis?

Partially support

BNNZ fully supports Principles 1, 5, 6 and 7. BNNZ also considers that principle 7 is highly relevant to give biochar the proper consideration for a New Zealand context.

BNNZ supports Principle 2: decarbonising the economy, and prompts the CCC to expand its scope for decarbonising to consider and support credible carbon sequestration pathways via other avenues than forests, such as carbon sequestration via biological means on and in soil, in freshwater via algae and plants and similarly in oceans.

BNNZ supports creating options (Principle 3), but wishes to emphasise that, as much as possible, climate transition moves should be sensible to do, even before one factors in climate change considerations (i.e. a negative marginal abatement cost). For the many biochar customers in New Zealand, the benefits of biochar well exceed the cost and risk of using it, so it makes sense to them to adopt its use, even before considering its carbon sequestration function. BNNZ therefore suggests changing the wording from "cheaper" to "more economically valuable". This will likely require marketing support to assess and emphasise the value proposition for the co-benefits of carbon abatement for negative emission technologies such as biochar. This type of approach would be especially beneficial for biochar as a high leverage work stream that stimulates demand and builds critical mass so that further biochar uptake becomes a self-sustaining virtuous cycle.

BNNZ does support the principle of avoiding unnecessary costs (Principle 4), but encourages the CCC to strengthen its supporting wording to demonstrate the necessity of action. New Zealand's long term outlook for its society and our economy's heavy reliance on a stable climate cannot be overshadowed by nearsighted financial considerations of high-emitting business models. Also, New Zealand cannot let past assumptions about asset worth and depreciation stifle innovation and our climate response by fixing options based on current thinking, existing asset bases and outdated business models. In many cases, better options are available or possible and these should remain on the table.

2. Emissions budgets numbers

Consultation question

2. Do you support budget recommendation 1? Is there anything we should change and why?

	Too ambitious	**About right**	**Not ambitious enough**	**Don't know**
Emissions budget 1 (2022 – 2025)			Not ambitious enough	
Emissions budget 2 (2026-2030)			Not ambitious enough	
Emissions budget 3 (2031-2035)			Not ambitious enough	

None of the budgets are ambitious enough

The Commission's approach is not ambitious enough given the risks that are projected to arise from climate change. Even if we meet (or exceed) all targets, the carbon debt remains in the atmosphere and the current climate of just over 1 degree warming is already causing material hardship to our infrastructure and primary sectors.

3. Breakdown of emissions budgets

Consultation question

3. Do you support our proposed break down of emissions budgets between gross long-lived gases, biogenic methane and carbon removals from forestry? Is there anything we should change, and why?

	Too ambitious	About right	Not ambitious enough	Don't know
Gross long-lived gases			Not ambitious enough	
Biogenic methane			Not ambitious enough	
Forestry			Not ambitious enough	

Partially support, but not ambitious enough

See also our response to the previous question.

4. Limit on offshore mitigation for emissions budgets and circumstances justifying its use

Consultation question

4.Do you support budget recommendation 4? Is there anything we should change, and why?

We recommend that, given that emissions budgets must be met as far as possible through domestic action, for the purposes of meeting emissions budgets:

a. *The limit on offshore mitigation should be zero for the first three emissions budgets.*
b. *The only circumstances that at this stage would justify the use of offshore mitigation is as a last resort in exceptional circumstances beyond the Government's control, such as force majeure events, where domestic measures cannot compensate for emissions impacts.*

Partially support

New Zealand should get ahead of the curve, and have a safe buffer in the case of *force majeure*, rather than relying on mitigations from other countries. The limit on offshore mitigation should be zero for all budgets. As a relatively wealthy, developed and technologically advanced country with low population density and productive land, there is no reason why New Zealand shouldn't be able to more than meet its emissions obligations domestically. Our drawdown and storage commitments should be increased to provide the required buffer and act as insurance for exogenous shocks.

A key component of emissions mitigation technology development is the existence of financial incentives, particularly in the early stages when capital investment may be required. Voluntary carbon markets are demonstrating this capability internationally by putting a price on production of biochar, and New Zealand could become a destination for offsetting transactions instead of the reverse.

Enabling an enduring climate transition - intro

5. Cross-party support for emissions budget

Consultation question

5. Do you support enabling recommendation 1 on cross-party support for emissions budgets? Is there anything we should change and why?

We recommend the Minister for Climate Change seek cross-party support on emissions budgets. We note that the Minister must consult representatives of political parties on emissions budgets before they are notified but, in addition to this, the Minister should also seek to ensure that the emissions budgets are debated in the House of Representatives so that the positions of each political party are on the parliamentary record

Fully support

We also recommend that CCC should advise Government to agree on an ambitious cross-party ceiling recommendation now, and challenge successive governments to work to beat that recommendation.

6. Coordinate efforts to address climate change across Government

Consultation question

6. Do you support enabling recommendation 2 on coordinating efforts to address climate change across Government? Is there anything we should change and why?

Fully support

7. Genuine, Active and Enduring Partnerships with

Iwi/Maori

Consultation question

4.Do you support enabling recommendation 3? Is there anything we should change, and why?

Fully support

8. Central and local government working in partnership

Consultation question

8. Do you support enabling recommendation 4 on central and local government working in partnership? Is there anything we should change and why?

Partially support

The alignment work should also include waste legislation, especially increased waste levies via the Waste Minimisation Act 2008.

The CCC should also consider advising a phase out, and an eventual ban of landfilling of non-pyrolysed, organic material where appropriate, given considerations such as biomass contamination, volatilisation of contaminants and robust life cycle analysis where feedstocks would need to be dried before pyrolysis.

The Government, ACC, the New Zealand Superannuation Fund, Universities and other government entities and agencies should also continue to disinvest in emissions intensive businesses and pursue prosperity without necessarily growing, and within environmental holding capacity.

9. Ensuring inclusive and effective consultation, engagement and public participation

Consultation question

9. Do you support enabling recommendation 5 on establishing processes for incorporating the views of all New Zealanders? Is there anything we should change and why?

Fully support

10-11. Locking in net zero

Consultation questions

10. Do you support our approach to focus on decarbonising sources of long-lived gas emissions where possible? Is there anything we should change and why?

Partially support

BNNZ advocates for climate positive outcomes, i.e. a national negative emissions profile which comprises a combined reduction of greenhouse gas emissions and long-lived sequestration techniques, and democratising the techniques and technology where the economics are marginal so that individuals and communities can make discretionary contributions to the climate effort.

BNNZ supports a focus on decarbonising long lived gases where possible, including challenging incumbent business models where superior technologies and practices exist. New Zealand must do better than net zero to ensure a stable climate.

If the CCC seeks to continue to use biological carbon sequestration techniques, BNNZ challenges the CCC to consider other means for supporting innovation in biological carbon capture including in water bodies and in soil biology. BNNZ advocates for the use of long-lived negative emissions technologies such as biochar, where the marginal abatement cost is negative and society benefits from the many possible co-benefits of its use.

BNNZ notes the CCC advice describes a carbon sequestration strategy which primarily seeks to use biological means to sequester carbon, and maintain a new equilibrium where increased carbon stocks are maintained within biological systems, rather than the atmosphere.

BNNZ encourages the CCC to consider additional options for carbon sequestration other than solely relying on the carbon in living and biologically active biomass because of the tenuous nature of this mode of storage in the face of management changes or adverse events. Even small changes in temperature and climate can have far reaching effects on ecosystems at a community, regional, and even national. The amount of carbon that can be effectively stored in these ecosystems can change dramatically as a result, potentially turning from a sink into a source in extreme cases.

A challenge for New Zealand is efficiently and reliably sequestering carbon in a way that provides net enhancement to ecosystems and climate, and at the same time provides societal and economic benefits. A further challenge is how to do this with long-lived solutions which are resilient to climate and resource management changes.

Without further sequestration via proven chemical or geological processes, there is a risk that the equilibrium for carbon sequestered in biological systems may be reduced in future, with part of the carbon stocks lost to the atmosphere through fire or biological decay.

Biochar reduces this risk by using pyrolysis to thermochemically convert around half of the carbon in biomass to a recalcitrant form which is resistant to chemical and biological decay. This has the effect of increasing the longevity of these carbon sinks, from months or years for untreated biomass, to centuries or in some cases millenia for biochar. Treatment in this manner gives an effective increase of 3-4 orders of magnitude in sequestration lifecycle along with placing the physical storage medium out of harm's way. The IPCC provides good guidelines supporting biochar's ancient track record.

Biochar production is therefore a tool which further locks up biologically sequestered carbon, somewhat like a "reverse coal," but with energy, economic and ecosystem benefits. Applied well, biochar provides net benefits to society, economy, and ecosystems in addition to its climate credentials.

11. Do you support our approach to focus on growing new native forests to create a long-lived source of carbon removals? Is there anything we should change and why?

Partially support

BNNZ supports the use of native forests to capture carbon for ecosystem and biodiversity reasons on highly erodible, steep land.

Planning for future forests should provide for sustainable biomass harvesting of forest waste for biochar under normal forest management. This will allow biochar to be a value adding complementary option in any drawdown scenario which uses forestry.

BNNZ challenges the CCC to incentivise the horticultural and agricultural industries to consider how to create highly biologically diverse, high yielding, climate positive designed landscapes which can be accounted for in climate budgets and produce valuable animal, plant, biomass, and energy products. The economics of this is outlined in *Restoration Agriculture* by Mark Shepherd, and references his New Forest Farm, and practitioners can be found across the country under the general rubric of regenerative methods promoted by Quorum Sense. The recent work by O Tātou Ngāhere (Our Forest[6]) and profiled by PureAdvantage can also be referenced.

BNNZ notes that national capacity to replant has been identified as a constraint, and offers biochar as a means of reducing replanting, especially in areas where soil is marginal. Biochar seed balls are being used around the world in conjunction with drone forest planting.

To maximise seedling survival rates, BNNZ advocates for nursery growing media utilising compost which has been made with biochar and beneficial microbiology sourced from healthy local, native ecosystems. Biochar itself can provide a superior, climate positive growing media with properties similar to vermiculite.

12. Our path to 2035

Consultation question

12. Do you support the overall path that we have proposed to meet the first three budgets? Is there anything we should change and why?

Partially support

There are many individual ways that biochar could lower New Zealand's emissions. A partial listing:

- Biochar presents a complementary option to utilise the harvest residue from exotic forest biomass, native forest biomass, orchard prunings, wilding biomass management and other waste biomass as a carbon sink with many co-benefits.
- Biochar reducing methane release from cattle and sheep.
- Biochar can sequester up to 5+ MT CO_2e per year by pyrolising biomass on site in remote locations. Lower mass and remote production gives superior efficiency vs biomass to energy where biomass sources are remote, requiring long transport distances between biofuel sources and demand.
- Biochar can increase efficiency for fertiliser use - providing direct carbon drawdown and requiring less emissions from fertiliser use because biochar is long lived in soil. New Zealand potato and avocado growers have reported fertiliser requirements reducing by 50% after application of biochar.
- Reduced nitrification in effluent treatment.
- Biochar addition to soils creates a negative priming effect which can result in soil sequestration factors of 3X the amount of biochar used.
- Biogenic methane efflux from soils can be reduced by the application of biochar.

[6] https://www.facebook.com/allblackearth/posts/3569248739967132

- Capture of nutrients in biochar matrix and application to land.
- Increased speed of decomposition, value add nutrients.
- Farmers could turn their organic waste into biochar.
- Farmers can grow carbon crops such as short rotation coppice forestry specifically to make biochar, and this function can be stacked with increased shelter and riparian protection.
- Biochar is not downcycling - it is upcycling to a more valuable, circular economy product.
- Biochar can be used to capture nutrients and GHGs from food and green waste via worm farms, bokashi, traditional composting and black soldier fly operations.
- Capture of methane from decomposition of food, green waste and and providing conditions for metabolism of captured methane by methanotrophs.
- Nitrous oxide capture and reduced denitrification via microbiology.
- Fuel switching from coal to biomass offers opportunities to introduce boiler technologies that can co-produce biochar.
- Some older, inefficient boilers are producing biochar in a form known as high carbon boiler ash (HCBA). HCBA is already being applied as biochar in NZ and this case study is included in our supplementary document.
- Biochar application on pastoral and horticultural land can reduce GHG emissions, such as nitrous oxide and methane, and contribute to increased carbon storage in plants and soils through negative priming effects.
- Biochar can be used to process organic waste at landfill, and BNNZ concurs with its massive potential to reduce landfill emissions in New Zealand - why is this not included in CCC's emissions budget?
- The sequestration impacts of biochar production from orchard prunings was considered by the Biological Emissions Reference Group (BERG), but the beneficial effects of its use in soil or animals were not factored in by BERG, and remain un(der)estimated.
- BNNZ has low confidence in methane vaccines or inhibitors due to the variability of microbiology within animal rumen and the adaptive nature of microbiology across generations. BNNZ considers biochar a proven option with a lower risk profile compared to methane vaccines and inhibitors. Trialling, validating, and optimising the use of biochar as a feed additive to reduce methane production in the New Zealand farming context needs to be a priority.

13. An equitable, inclusive and well-planned climate transition

Consultation question

13. Do you support the package of recommendations and actions we have proposed to increase the likelihood of an equitable, inclusive and well-planned climate transition? Is there anything we should change, and why?

Partially support

BNNZ believes that biochar production and application technologies are ideally suited to community, hapu and iwi-led enterprises, and should form a key component of economic development in a just transition. Many of the attributes of biochar are a good fit:

- Biochar is an indigenous technology historically used by Māori in New Zealand.

- Biochar production as dispersed, community scale technology has relatively small start up costs of <$200k and can be profitable after a first year of operation, and can provide direct employment opportunities for 1 person per $200k investment and is complementary to other existing land uses.
- Due to a higher value to weight ratio of biochar versus unprocessed biomass, and portable production options, biochar has the potential to be economically viable in more remote locations than simply hauling biomass for process heat.
- Biochar produced by community enterprises can feed into local and regional food growing and environmental projects, giving the stakeholders the co-benefits of the cascading services provided.

14. Transport

Consultation question

14. Do you support the package of recommendations and actions for the transport sector? Is there anything we should change and why?

Neutral

BNNZ does not have specific policy recommendations in transport. We do note that biochar production capabilities could supply sustainable porous carbon materials for use in battery electrodes, supercapacitors, and fuel cells.

Bio-oils can be a co-product of industrial scale pyrolysis (particularly fast/flash pyrolysis and hydrothermal carbonisation). Bio-oils can be a precursor to a liquid fuels industry. Looking back to our industrial history on 'wood distillation' can provide important lessons on future opportunities.

15. Heat, industry and power

Consultation question

15. Do you support the package of recommendations and actions for the heat, industry and power sectors? Is there anything we should change and why?

Support some of the actions

BNNZ encourages decarbonisation of the industrial sector through the deployment of biomass for process heat using pyrolysis and gasification technology.

Establishing a widespread NZ industry for thermal transformation of biomass into carbon-rich solid forms, could provide regional employment and add value to a future integrated bioeconomy by providing a diverse range of potential products. Biomass could be converted into high-carbon materials such as activated carbon absorbents, battery materials (Cheng, Zeng, & Jiang, 2017; Gabhi, Kirk, & Jia, 2017; Huggins, Wang, Kearns, Jenkins, & Ren, 2014), and new construction materials (McDonald-Wharry, 2014; Werner, Schmidt, Gerten, Lucht, & Kammann, 2018). In many of these applications the carbon will be kept out of the atmosphere for decades and potentially much longer.

Facilities which convert biomass to heat, industrial chemicals, electricity, and/or fuel (wood boilers through to biofuel refineries) can be designed to produce biochar as a co-product allowing the overall process to potentially become carbon negative (Gaunt & Lehmann, 2008). Most biochar production processes also produce heat with scope to utilise this heat if a biochar processing facility can be co-located with users of heat.

Although not "biochar" in the sense of sequestering carbon long-term, biochar production technologies can manufacture charcoals for use as an alternative to fossil coal as a fuel and for industrial reduction processes such as steel making (Fortini & Fruehan, 2005) and manufacturing high purity silicon (Antal & Grønli, 2003). Switching to a sustainable biomass charcoal could reduce the coal CO_2 emissions from NZ's steel manufacturing and wood charcoals are also sought after for producing pure silicon. The use of charcoal as a fuel would reduce the fossil carbon released into the atmosphere by transport and electricity generation activities, aiding the goal of long-term carbon neutrality. This could potentially take the form of running diesel locomotives on char-water slurries (Patton, Steele, & Yu) or chars used as fuels to generate electricity in newer technologies such as solid carbon fuel cells (Huggins et al., 2014; Nunoura et al., 2007).

Example of existing commercial production opportunities: Large industrial scale multi-hearth technology (Herreshoff) has been operating in NZ for many years and could be trialed for production of biochar and industrial reductants from plantation forest residues. These production facilities also correspond with potentially suitable rail head infrastructure for efficient biomass transportation. Productivity and efficiency from this existing equipment would need to be assessed during trials but each multi-hearth could probably process 20-40 tonnes of biomass per hour without modification. Future commercial production could be assigned based on the periodic availability of any of the four operational furnaces.

16. Agriculture -

Consultation question

16. Do you support the package of recommendations and actions for the agriculture sector? Is there anything we should change and why?

Support some of the actions

BNNZ supports the proposed actions but strongly recommends introducing biochar into Agriculture under Action 11 b. Biochar's mitigation of climate change is fourfold – most importantly in the form of direct carbon sequestration, but also by reducing nutrient losses and lessening inputs, reducing soil emissions, and reducing enteric methane emissions as an additive to animal feed.

The cascading services of biochar in agricultural settings are recognised by many well-developed international agriculture producers and are being adopted enthusiastically in Europe and North America. However, the range of benefits are yet to be fully discovered in New Zealand. This may be a side effect of having to date been the most efficient meat, wool and dairy producers in the world, and in coasting on this success our primary sector has been slow to take up the growing international biochar movement.

Biochar adoption in New Zealand is therefore starting from a very low base but could grow far more quickly if the advantages were more widely understood. BNNZ advocates for increased field trials so that benefits can be seen and appreciated where it matters most.

The addition of biochars to cattle diets has shown promise in reducing enteric methane emissions, with international studies reporting significant reductions are possible (-10 to -22%), while also improving livestock growth rates and feed conversion efficiency (Man et al., 2021). Given the major challenge of reducing methane emissions from livestock in the NZ context, it is important that trials are conducted to determine and optimise methane reductions when biochars are used as stock feed additives in NZ farming systems.

17. Forestry

Consultation question

17. Do you support the package of recommendations and actions for the forestry sector? Is there anything we should change and why?

Support some of the actions

While BNNZ supports the planting of permanent native forests (above "A") two important points should be considered:

- First, there is finite suitable land area to plant natives and the higher carbon sequestration rates achieved with pines means, under the current ETS, commercial pine trees planted purely for carbon credit accumulation will be more profitable. Native plantings have many other positive attributes over pines and this needs to be recognised. The concern that large areas of pre-1990 forests will be cleared will be negated by the growing value of carbon credits which need to be applied against cleared areas.
- Second, BNNZ believes that it is not the area of exotic pine plantations that are planted that is important, but rather the management of plantations to produce a mix of timber and biochar from less valuable (in timber terms) parts of trees. This is why BNNZ strongly supports points "B" and "C."

We have already covered the problem of forestry "kicking the can down the road" for at best one hundred years. The questionable part of this one rotation strategy is in relying on one forestry cycle is with finite forestry growing land (which, if planted, will displace agricultural land and carry shorter and longer term effects on rural New Zealand communities) without reduced emissions or greater long term sequestration, this approach is not sustainable longer term.

The other major issue to consider is the risk of one or more adverse events turning large portions of this living carbon storage into an abrupt emissions liability. Drought, disease and pest outbreaks, extreme weather, and fire all threaten standing forest in the long term.

However...turning much of rotation forestry into biochar buys us hundreds to thousands of years. The recoverable quantities of forestry harvest residues, currently left to rot or burn in NZ's radiata forests, could be converted into biochar this would sequester several megatonnes worth of CO_2e per year. If growing and harvesting trees primarily for biochar production is prioritised and sufficient biochar production capacity established, then sequestering carbon at rates above 10 megatonnes of CO_2e per year is achievable.

As noted above under "Agriculture," it is conceivable that New Zealand's success in food and fibre production efficiency has created complacency and therefore an aversion to considering new paradigms such as biochar. Even with a tree- and pasture-growing climate that is one of the best in the world, New Zealand can do more to capitalise on the natural advantages of our environment to take carbon out of the atmosphere and sequester it within our soils ...with the huge bonus of improved water and nutrient holding capacity, and hence productivity.

Biochars can also be applied to forests to provide benefits to forest restoration. A meta-analysis on the limited studies on the effect of application of biochars to trees indicated an average of ~41% increase in tree biomass (Thomas & Gale, 2015). This is higher than the average benefits reported for biochar application to food crops (Jeffery, Verheijen, van der Velde, & Bastos, 2011). Lower tree mortality and large increases in radiata pine growth rates have been reported in a Spanish study where a high char ash (from burning wood and bark in a thermal power plant) was applied to a plantation forest. Although these benefits need to be studied in the NZ context, biochar application during forestation activity could have great potential for enhancing seedling survival, growth rates of trees and ultimately carbon uptake rates in new and replanted forests, whether they be native or exotic species.

18. Waste

Consultation question

18. Do you support the package of recommendations and actions for the waste sector? Is there anything we should change and why?

Support some of the actions

The Commission's organic waste reduction targets can aim much higher than 23% by 2030.

BNNZ is highly supportive of the proposals to reduce waste, and we advocate a dramatically higher waste minimisation levy to discourage the tipping of organic material. We refer to the numerous pathways listed above for biochar to help solve several facets of solid waste in New Zealand.

19. Multi-sector strategy

Consultation question

19. Do you support the package of recommendations and actions to create a multisector strategy, and is there anything we should change?

Support some of the actions

20. Rules for measuring progress

Consultation question

20. Do you agree with Budget recommendation 5 on the rules for measuring progress? Is there anything we should change any why?

Neutral

21-23. Our Nationally Determined Contribution (NDC)

Consultation question

21. Do you support our assessment of the country's NDC? Do you support our NDC Recommendation?

Partially support

BNNZ believes that strengthening the NDC will be required but we do not have a firm view on the timing or magnitude of this move. As stated numerous times in this submission, we advocate a far more ambitious approach to carbon removal and sequestration and believe that this approach supports the Commission's assessment.

22. **Do you support our recommendations on the form of the NDC?**

Support, not ambitious enough

23. **Do you support our recommendations on reporting on and meeting the NDC? Is there anything we should change, and why?**

Support

Refer also to the BNNZ response to Question 4.

24. Eventual reductions in biogenic methane

Consultation question

24. Do you support our assessment of the possible required reductions in biogenic methane emissions?

Somewhat support

What's the problem?
Methane is excreted by methanogenic microbes

Methanotrophs exist in rumen and eat methane, but don't eat it all because the methane turns to gas and is burped out.

Methane emissions from animal rumen is therefore seen as a GHG emissions problem.

Is the problem methanogenesis from in-rumen methanogens, or the fact that methane is emitted to the atmosphere?

Preventing Methanogenesis
The current New Zealand research focus on selective breeding of animals (and their gut microbiology), methane vaccines and inhibitors, which focus on reducing methanogenesis and the effect these measures may have on the in-rumen microbial communities.

We are lying if we say that science fully understands the complex dynamics of a single animal's gut.

An animal gut is a microscopic ecosystem. Methanogens are naturally occurring microbes, and over time have adapted in symbiosis with their hosts. Methanogens have adapted to in-rumen conditions with other members of the gut microbial food web. There are likely unintended consequences both in-rumen and in fields of using inhibitors and vaccines to prevent effectiveness of entire sectors of a microbial food web.

The CCC and government should carefully consider this with reference to the myriad examples of observed effects of removing key members of macro scale ecosystems.

Addressing Emissions
The NZAGRC also considered methane capture and breaking down methane from housed cattle and stored animal waste, and injecting it in the soil for oxidation by methanotrophs with unfavourable results.

Methanotrophs can do this much more effectively in-rumen when supported by biochar. Biochar increases the methane residence time in-rumen and acts as a substrate on which methanotrophs metabolise methane, increasing feed conversion efficiency and reducing methane emissions by 11-13%. Farmers in NZ such as Parengarenga Incorporation using biochar in animal feed enjoy this win-win-win for ecology, profitability and climate.

Considering the promising early results, BNNZ encourages the CCC and government to investigate the opportunities for this further.

Working with biology
A strategy could be taken to either try to prevent methanogens from doing what they have done for millenia, or seek to amplify the helpful existing natural relationships available.

BNNZ has low confidence in the long term efficacy of methane vaccines or inhibitors due to the variability of microbiology within animal rumen and the adaptive nature of microbiology across generations.

BNNZ considers biochar feed combined with methanotrophs a proven option with a lower risk profile compared to methane vaccines and inhibitors. Trialling, validating, and optimising the use of biochar as a feed additive supplemented by methanotrophs to reduce methane production in the New Zealand farming context needs to be a priority.

Getting the Question Right First, Then Drive the Answers
There appears to be a reluctance to consider other farming practices which could lower methane emissions. Given the importance placed on reducing NZ's methane emissions, it would be troubling if the priority for government policy and funding is placed on a 'silver bullet' solution, instead of investing in a range of proven and promising farming practices which can and do reduce methane emissions. In this context, BNNZ considers trialling, optimising and deploying the use of biochar as a feed additive in New Zealand farming systems to be a critical priority.

Again, this is an area which New Zealand can look to gain significant benefit from.

BNNZ Key References List

References for the BNNZ Submission to the Climate Change Commission, March 2021. Separate reference lists are provided with the supplementary document provided with the BNNZ submission.

This document is sorted into thematic areas for ease of reference.

CCC Evidence Base

Jones, J., & Camps, M. (2019). Estimating the environmental impact and economic cost of biochar [Comment to MPI]. Massey University.

Hedley, M. J., Camps-Arbestain, M., McLaren, S., Jones, J., & Chen, Q. (2020). A review of evidence for the potential role of biochar to reduce net GHG emissions from New Zealand agriculture [A report prepared for the New Zealand Ministry of Primary Industries and the New Zealand Agricultural Greenhouse Gas Research Centre]. MJ & CB Hedley Soil Science, Massey University.

Summary of Meta Analyses of Biochar Effects

https://www.youtube.com/watch?v=zf5rbSJ3lHo

Ancient Use of Biochar in NZ by Māori Gardeners
http://www.theprow.org.nz/māori/māori-horticultural-skills-and-their-soils/

"Detailed carbon chemistry in charcoals from pre-European Māori gardens of New Zealand as a
tool for understanding biochar stability in soils" - R . Calvelo Pereira et al, European Journal of Soil Science, January 2014, 65, 83–95

Biochar and nutrients

Ye, L., Camps-Arbestain, M., Shen, Q., Lehmann, J., Singh, B., Sabir, M.`(2019) Biochar effects on crop yields with and without fertilizer: A meta-analysis of field studies using separate controls Soil Use and Management https://doi.org/10.1111/sum.12546

Alba Llovet, Stefania Mattana, Juan Chin-Pampillo, Neus Otero, Raul Carrey, Claudio Mondini, Gabriel Gasco, Esther Marti, Rosanna Margalef, Josep Maria Alcaniz, Xavier Domene, Angela Ribas, (2021) Fresh biochar application provokes a reduction of nitrate which is unexplained by conventional mechanisms. Science of The total Environment, https://doi.org/10.1016/j.scitotenv.2020.142430

Biochar Impacts on Soil Organic Matter

Shen, Q., Suarez-Abelenda, M., Camps-Arbestain, M., Pereira, R. C., McNally, S. R., Kelliher, F. M. (2018) An investigation of organic matter quality and quantity in acid soils as influenced by soil type and land use Geoderma Vol. 328, Pages 44-55

Herath, H. M. S. K., Camps-Arbestain, M., Hedley, M. J., Kirschbaum, M. U. F., Wang, and Van Hale, R. (2014) Experimental evidence for sequestering C with biochar by avoidance of CO2 emissions from original feedstock and protection of native soil organic matter GCB Bioenergy, pages 1-15

Whitehead, D., Schipper, L. A., Pronger, J., Moinet, G. Y. K., Mudge, P. L., Pereira, R. C., Kirschbaum, M. U. F., McNally, S. R., Beare, M. H., Camps-Arbestain, M. (2018) Management practises to reduce losses or increase soil carbon stocks in temperate grazed grasslands: New Zealand a case study Agriculture, Ecosystems & Environment volume 265, pages 432-443

Biochar Classification

Camps-Arbestain, M., Amonette, J. E., Singh, B., Wang, T., Schmidt, H. P. (2015) A biochar classification system and associated test methods Biochar for Environmental Management Book Chapter 8 pages 165-191

Pyrolysis for Sequestration

Werner, C., Schmidt, H. P., Gerten, D., Lucht, W., Kammann, C. (2018) Biogeochemical potential of biomass pyrolysis systems for limiting global warming to 1.5oC IOP Science Environmental Research Letters vol. 13, no. 4

Fawzy, S., Osman, A.I., Yang, H. *et al.* Industrial biochar systems for atmospheric carbon removal: a review. *Environ Chem Lett* (2021). https://doi.org/10.1007/s10311-021-01210-1

Yang, Q., Zhou, H., Bartocci, P. *et al.* Prospective contributions of biomass pyrolysis to China's 2050 carbon reduction and renewable energy goals. *Nat Commun* **12,** 1698 (2021). https://doi.org/10.1038/s41467-021-21868-z

Decay of Biomass

Garrett, L. ; Davis, M. ; Oliver, G. NZ Ministry for the Environment/Ensis. (2006) Decomposition of coarse woody debris, and methods for determining decay rates

Biochar for Feed Supplement, Reducing Methanogenesis

Ka Yan Man, Ka Lai Chow, Yu Bon Man, Wing Yin Mo & Ming Hung Wong (2021) Use of biochar as feed supplements for animal farming, Critical Reviews in Environmental Science and Technology, 51:2, 187-217, DOI: 10.1080/10643389.2020.1721980

Leng, R. A., Preston, T. R., & Inthapanya, S. (2012). Biochar reduces enteric methane and improves growth and feed conversion in local "Yellow" cattle fed cassava root chips and fresh cassava foliage. Livestock Research for Rural Development, 24(199).

Saleem, A. M., Ribeiro, G. O., Jr, Yang, W. Z., Ran, T., Beauchemin, K. A., McGeough, E. J., McAllister, T. A. (2018). Effect of engineered biocarbon on rumen fermentation, microbial protein synthesis, and methane production in an artificial rumen (RUSITEC) fed a high forage diet1. Journal of Animal Science, 96(8), 3121-3130. doi: 10.1093/jas/sky204

Winders, T. M., Jolly-Breithaupt, M. L., Wilson, H. C., MacDonald, J. C., Erickson, G. E., Watson, A. K. (2019) Evaluation of the effects of biochar on diet digestibility and methane production from growing and finishing steers Department of Animal Science, University of Nebraska-Lincoln pages 775-783

Schmidt, H. P., Hagemann, N., Draper, K., Kammann, C. (2019) The use of biochar in animal feeding *DOI 10.7717/PeerJ.7373*

Joseph, S., Pow, D., Dawson, K., Mitchell, D. R. G., Rawal, A., Hook, J., Taherymoosavi, S., Van Zwieten, L., Rust, J., Donne, S., Munroe, P., Pace, B., Graber, E., Thomas, T., Nielsen, S., Ye, J., Lin, Y., Pan, G., Li, L., Solaiman, Z. M. (2015) Feeding Biochar to Cows: An Innovative Solution for Improving Soil Fertility and Farm Productivity Pedosphere

Biochars and Forestry

Jeffery, S., Verheijen, F. G. A., van der Velde, M., & Bastos, A. C. (2011). A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. Agriculture, Ecosystems & Environment, 144(1), 175-187. doi: http://dx.doi.org/10.1016/j.agee.2011.08.015

Thomas, S. C., & Gale, N. (2015). Biochar and forest restoration: a review and meta-analysis of tree growth responses. New Forests, 46(5-6), 931-946. doi: 10.1007/s11056-015-9491-7

Biochars and charcoals for heat, industry and power sectors

Antal, M. J., & Grønli, M. (2003). The art, science, and technology of charcoal production. Industrial & Engineering Chemistry Research, 42(8), 1619-1640. doi: 10.1021/ie0207919

Cheng, B.-H., Zeng, R. J., & Jiang, H. (2017). Recent developments of post-modification of biochar for electrochemical energy storage. Bioresource Technology, 246, 224-233. doi: https://doi.org/10.1016/j.biortech.2017.07.060

Fortini, O. M., & Fruehan, R. J. (2005). Rate of reduction of ore-carbon composites: Part II. Modeling of reduction in extended composites. Metallurgical and Materials Transactions B-Process Metallurgy and Materials Processing Science, 36(6), 709-717.

Gabhi, R. S., Kirk, D. W., & Jia, C. Q. (2017). Preliminary investigation of electrical conductivity of monolithic biochar. Carbon, 116, 435-442. doi: https://doi.org/10.1016/j.carbon.2017.01.069

Gaunt, J. L., & Lehmann, J. (2008). Energy Balance and Emissions Associated with Biochar Sequestration and Pyrolysis Bioenergy Production. Environmental Science & Technology, 42(11), 4152-4158. doi: 10.1021/es071361i

Huggins, T., Wang, H., Kearns, J., Jenkins, P., & Ren, Z. J. (2014). Biochar as a sustainable electrode material for electricity production in microbial fuel cells. Bioresource Technology, 157, 114-119. doi: https://doi.org/10.1016/j.biortech.2014.01.058

McDonald-Wharry, J. (2014). Biochars and carbonised biomass: a New Zealand perspective with a focus on chemistry Chemistry in New Zealand, 78(1), 28-32.

Nunoura, T., Dowaki, K., Fushimi, C., Allen, S., Mészáros, E., & Antal, M. J. (2007). Performance of a first-generation, aqueous-alkaline biocarbon fuel cell. Industrial & Engineering Chemistry Research, 46(3), 734-744. doi: 10.1021/ie061202s

Patton, R., Steele, P., & Yu, F. Coal vs. Charcoal-fueled Diesel Engines: A Review. Energy Sources Part a-Recovery Utilization and Environmental Effects, 32(4), 315-322. doi: 10.1080/15567030802612028

Werner, C., Schmidt, H.-P., Gerten, D., Lucht, W., & Kammann, C. (2018). Biogeochemical potential of biomass pyrolysis systems for limiting global warming to 1.5 C. Environmental Research Letters, 13(4), 044036.

Global Warming Potentials
https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Historic, In Part Superseded, NZ Commentary on Biochar Policy Considerations
Veronika Meduna, Motu (TBC) *New Offset Options for New Zealand*. Retrieved from:
https://www.motu.nz/assets/Documents/our-work/environment-and-resources/climate-change-mitigation/emissions-trading/Offset-options-for-NZ2.pdf

Quade, D (2010) *What are the Implications for Public Policy in New Zealand regarding Biochar as a Climate Change Mitigation Tool?* Masters Thesis. Available from
https://researcharchive.vuw.ac.nz/xmlui/handle/10063/1450

Principles for Adoption of Change
Centola, D (2021) *Change: How to Make Big Things Happen.* John Murray

BNNZ Submission to the Climate Change Commission

Supplementary Document

Table of Contents

Introduction

The Climate Change Commission's Advice to Government document sets up a framework of actions and targets to help the government legislate to reduce emissions of greenhouse gasses (GHG). This will enable it to meet its legal obligations under the Paris Agreement. The CCC document could also be seen as an acknowledgment of the need to take urgent action to reduce, or if we are honest enough, reverse the future effects of human induced climate change. In the long term, the goal of the Paris Agreement, to limit post-industrial global warming to 1.5 $^{\circ}$C by 2050, will not prevent major changes to global climate or knock on effects such as sea level rise with consequent major impacts to the biosphere and dislocation of global population.

Despite the 1997 Kyoto protocol and 2015 Paris agreement anthropomorphic greenhouse gas (GHG) emissions continue to increase at an accelerating rate with a 2% increase for 2018 (Fawzy et al, 2020). *In 2018, the world encountered 315 cases of natural disasters which are mainly related to the climate. Approximately 68.5 million people were affected, and economic losses amounted to $131.7 billion, of which storms, floods, wildfires and droughts accounted for approximately 93%. Economic losses attributed to wildfires in 2018 alone are almost equal to the collective losses from wildfires incurred over the past decade, which is quite alarming* (Fawzy et al, 2020).

Effectively the approach is business as usual but gradually reducing emissions to meet legal obligations. There appears to be an assumption that if the planet becomes carbon neutral by 2050, the greenhouse effects including increasing temperature will be mitigated and be controllable. However the scientific evidence suggests that the positive feedback effects from even small increases in global temperature, causing among other things, changing planetary albedo and driving atmospheric uptake of other greenhouse gases, (Dufresne J & Saint-Lu M) makes it probable that aiming to become carbon neutral but at a higher CO_2e concentration is extremely unlikely to prevent catastrophic change to the biosphere in the long term. Equally, there is a growing body of evidence that current mitigation strategies along with the future emission reduction commitments are not enough to meet the Paris agreement temperature goals, (Fawzy et al, 2020; IPCC, 2018). Therefore there is an urgent need for long term solutions for the stable sequestration of atmospheric CO_2 leading to a reduction in atmospheric concentration.

In order to meet New Zealand's GHG reduction targets the commission requires the planting and long term management of forestry and reestablishment of native forests as a carbon sink to mitigate current emissions deficits. This is the closest the commission gets to incorporating Negative Emission Technologies (NETs) into their strategy. The rapid deforestation of New Zealand following human colonisation gives a historically huge CO_2e emissions debt that could only be mitigated by the complete restoration of New Zealand forest cover. Planting forests in the future to mitigate concurrent emissions is an expediency that is only possible and meaningful by ignoring the historical actions and emissions that make replacement planting possible. The ethics of this are questionable at best. Other ways of long term sequestering of atmospheric carbon need to be actively supported and implemented.

The emissions debt that previous and current generations have accrued will not be reduced even when we reach net zero -- all we will have achieved is no further borrowing. If we are to decrease the principal owed, we must remove carbon from the atmosphere and store it outside the biological fast cycle. There are a limited number of methods to do this that do not entail risks of unintended consequences, or carry high energy and capital investment requirements. Biochar is one of these methods, and as such deserves far greater focus for its potential roles in ensuring a safer climate future for New Zealand.

Biochar Basics

Biochar is charcoal formed from the pyrolysis (heating in a low oxygen environment) of organic matter, from wood, agricultural products/waste or other biologically derived material. Biochar's proponents regard its production to be of particular interest in sequestering atmospheric carbon due to its ease of production from most organic feedstocks and its relative chemical stability when added to soil. *Soil organic carbon (OC) represents the largest C reservoir of the biosphere-atmosphere system and even small changes of the soil OC pools can substantially influence the global C balance and therefore global climate. Recent evidence suggests that black C (BC) from biomass burning constitutes a significant pool of OC in soils* (Cheng et al, 2008).

Estimates of the lifespan of biochar (BC) in soils can be one to 3 orders of magnitude higher than that of non-charred organic matter. *Assuming a Q_{10} of 3.4 as estimated above, the half-life of BC at a site with 10°C MAT may be as high as 925 years. Due to systematic overestimation of long-term BC decay by short-term incubations* [Lehmann, 2007b], *the true half-life of BC is most likely greater than calculated here. This agrees well with the C-14 ages of BC which have been reported to lie in the hundreds to thousands of years* (Cheng et al, 2008).

Biochar has been added to soils for many centuries as a soil amendment. It has been shown to act as a fertiliser due to nutrients held in the precursor biomass, enhance physio-chemical properties – water holding capacity, organic matter content, reduce bulk density, and increase nutrient retention. Biochar can substantially increase crop production in low fertility and degraded soils though this is not always significant in fertile soils (El-Naggar et al, 2019). It has been shown to reduce GHG emissions (nitrous oxide (N_2O) and methane (CH_4)) from soils (Vijayaraghavan, 2019).

Raw biochar is frequently mixed with organic matter – compost, manure, fertilisers, sewage etc (co-composting) to prime it with nutrients. This has been shown to lower emissions of GHG during the composting process (Vijayaraghavan, 2019) and biochar-compost mix can significantly improve the fertility of sandy soil compared to the addition of compost alone (El-Naggar et al, 2019).

Addition of biochar is generally considered to increase soil microorganism numbers and variety. *Indeed, not only higher biological activity, but also higher reproduction rates and greater bacterial species richness and diversity can be found in BC-containing soils* (Cheng et al, 2008). However this is not always the case and further research is required to understand all the factors involved (El-Naggar et al, 2019).

The addition of biochar to soil offers the largest maximum mitigation potential among agricultural pathways, but unlike most other NCS (natural climate solutions) *options, it has* *not been well demonstrated beyond research settings. Hence trade-offs, cost, and feasibility of large scale implementation of biochar are poorly understood* (Griscom et al, 2017). While biochar is usually added to agricultural soils and Griscom et al, 2017 note the potential trade off/conflict for land for forest planting to mitigate emissions versus land for food/fibre production. There is no reason (apart from transport and application costs) why biochar cannot be sequestered in non-agricultural land such as permanent and plantation forest soils. It has also been shown to increase tree growth rate, particularly in the establishment phase (Thomas and Gale, 2015). This could multiply the potential NET value for this type of land use.

Civil infrastructure projects can also provide long term storage of biochar. Biochar added to asphalt has been shown to increase viscosity and deformation resistance and decrease susceptibility to aging (Kumar et al, 2018; Fawzy et al, 2021). Added to cement composites it can enhance internal curing, improving durability and improve mechanical properties such as compressive strength ductility and general toughness (Fawzy et al, 2021).

Biochar added to feedstock has been shown to increase the yield, size and quality of chicken eggs, decrease the rate of egg cracking, reduce pathogenic gut bacteria and increase feed conversion ratio (FCR) (Man et al, 2021). *In general, pigs' growth performance and immunity are promoted by adding 0.3% to 3% biochar to the daily diet* (Man et al, 2021) with improved faecal microflora composition and decreases in the counts of pathogenic coliform and salmonella species. Biochar included in the feed of farmed fish can significantly increase weight gain, specific growth rate, feed conversion ratio, and survival rate (Man et al, 2021).

Mitigation of CH4 emissions in ruminants is seen as a key combatant to climate change as it accounts for 28% of global anthropogenic CH4 emissions (Saleem et al, 2021). Biochar included in feed has been shown to reduce methane emissions, both *in vitro* (Saleem et al, 2021) and *in vivo* (Leng et al, 2012). Biochar addition also increased live weight gain (Leng et al, 2012) and increased FCR (Man et al, 2021)

In Europe, including Germany, Austria and Switzerland, 90% of the produced biochar is used in animal husbandry, mainly in cattle and poultry farming and used as a feed additive (Man et al, 2021).

Biochar can also be used for soil or waste water remediation. Biochar adsorption can lock up heavy metals and pesticides preventing their uptake by plants growing in the soil (He et al 2019; Guo et al 2020). It has been used to absorb nutrients (nitrate and phosphate), heavy metals and pesticides from waste waters (Xiang et al, 2020). *Equally, biochar has been widely reported to reduce nutrient leaching in agricultural systems* (Gao and DeLuca, 2016).

Biochar is clearly not a panacea that will bring increased yields to all agricultural crops, in any type of soil, using any application method or rate. However, we do know that there are agricultural applications in all climate zones in which biochar can offer great ecological and economic added value. This does not only mean increasing yields, but also counteracting the loss of humus in the soil, preventing nitrate leaching and improving water storage capacity and thus resistance to drought. The use of biochar in urban trees has proven to be an effective means of counteracting increasing climate-related stress. The question is no longer whether biochar functions as a soil conditioner, but where and how it has the greatest effect and where its use makes the most economic sense.

Beyond this, more and more applications of biochar are emerging outside agriculture. (Bier et al, 2020)

Effects of Feedstock and Production Conditions on Biochar Properties and Stability

Through photosynthesis plants and some microorganisms capture atmospheric CO_2 and convert it, along with many other elements, into biomass which includes complex polymers – sugars, starches, cellulose, hemicellulose, and lignin. The biomass can be characterised by Proximate Analysis, which divides by heating into 4 fractions, (1) volatile matter – the vapour resulting from heating (2) fixed carbon, the char fraction that remains after de-volatilization (3) moisture and (4) ash content – the inorganic (solid) fraction remaining after complete oxidation of biomass. Ultimate analysis is determination and quantification, in weight percentage, of carbon, hydrogen, nitrogen, sulphur and oxygen within biomass material (Fawzy et al, 2021).

Biochar is a complex product that can show markedly different properties, affected by many parameters including feedstock type, process temperature, heating rate, residence time, particle size and reactor type.

In general, biomass with a high inorganic fraction, such as manures and bio-solids, yields biochar with low surface area and porosity, high cation exchange capacity and pH, high nutrient availability (Ippolito et al. 2020), and high solid fraction yield which is mainly due to the catalytic effect of the inorganic fraction in the parent material. However, such feedstocks produce biochar with lower carbon content and stability (Fawzy et al, 2021). Crop derived biochar decomposed faster than wood derived biochar (Wang et al, 2016).

The high lignin content and low inorganic mineral fraction in woody material are the main contributors to carbon stability in the resulting biochar (Leng and Huang 2018). For carbon sequestration applications, wood-based biochar exhibits the highest carbon removal and stability potential (Ippolito et al. 2020).

The impact of temperature is well documented in the literature. Biochar yield is negatively correlated with temperature; that is at higher processing temperatures a decrease in biochar yield is realized. Furthermore, in terms of physical and structural properties, temperature is positively correlated with surface area, porosity, bulk density and mechanical strength (Fawzy et al, 2021). Higher temperatures also result in the reduction of oxygen containing functional groups which lowers the cation exchange capacity but tends to increase hydrophilicity and water holding capacity. Higher temperatures increases the amount of fused aromatic carbon structures with higher stability. This creates a trade-off between biochar yield and long-term stability (Fawzy et al, 2021). The reduction in reactive functional groups from increased temperatures and residence times removes more of the labile, decomposable fraction of the biochar leaving a higher percentage of recalcitrant material.

Soil micro-organisms have been reported to be more likely to decompose water-soluble organic matter in biochar and to release more CO_2 in response to a higher biochar application rate (Zhang et al, 2020). Biochar processed at higher temperatures is more recalcitrant and is less likely to be degraded by soil organisms over time. Biochar with higher pyrolysis temperatures (501–600 °C) has the potential to reduce soil GHG emissions. (Zhang et al, 2020). Increasing pyrolysis temperature decreased decomposition rate though the effect plateaued at around 375 °C (Wang et al, 2016).

Fawzy et al, (2021) note; *At lower heating rates, the degradation of the biomass is minimized during the secondary decomposition phase, which favours biochar production. Many studies reported the impact of low heating rates on enhanced biochar yield; Zeng et al. investigated the pyrolytic behaviour of beech wood under a temperature range of 600–2000 °C and heating rate range of 5–450 °C s−1. Under all temperatures, a lower heating rate resulted in a higher biochar yield* (Zeng et al. 2015).

A meta-analysis of 24 studies suggests on average biochar consists of 3% labile and 97% recalcitrant material. As the labile fraction is relatively rapidly decomposed in soil, studies that last less than six months give a much higher decomposition rate than studies that last over a year. *Despite the major content of aromatic C, the results of short-term studies mainly represent the decomposition of the non- or less-condensed fraction of biochar* (Wang et al, 2016). The experimental duration is one of the most important factors affecting calculated biochar decomposition rates in soils. The Mean Residence Time for biochar calculated by the studies varied between less than three years to 891 years with an average of 107 (Wang et al, 2016).

Monolithic biochar degradation parameters, such as the oft quoted mean residence time of 1000-10,000 y should be abandoned in favor of an understanding of biochar as a heterogeneous material. A portion of biochar is lost with C half-lives on orders of years to decades. After this the residual and more chemically recalcitrant component of biochar, such as that found in as charcoal in ancient soils or detected as BC-soot in sediments, may have residence times of thousands to millions of years (Zimmerman and Gao, 2013).

The decisive factor associated with the ability of biochar to mitigate climate change is its carbon stability. Furthermore, it is important to note that biochar needs to be effectively applied to potential carbon reservoirs for long-term storage to qualify as a carbon removal strategy (Fawzy et al, 2021).

International carbon markets and biochar

Carbon markets are rapidly evolving around the world, driven by societal risks associated with climate change and business opportunities connected with addressing these risks. Global and government driven initiatives have been developed but it should be noted that the 'formal' sector has historically focused on emissions trading. The New Zealand Emissions Trading Scheme is an early example of efforts to address NZ climate change responsibilities.

Other carbon market initiatives have progressed ahead of international agreement, government policy or government support. Biochar is being supported by new carbon market initiatives coming from industry, NGO's and entrepreneurs. These markets are at various stages of evolution but NZ has yet to 'catch this bus.'

Biochar proponents in NZ and Australia have begun to reach out to new international voluntary carbon markets. Australian biochar industry advocates have successfully completed the first trades (see Microsoft & Puro reports below).

Major international companies are working with the voluntary carbon market sector to offset their carbon footprint via biochar carbon sequestration. Examples of this include,

Shopify https://www.shopify.my/about/environment/sustainability-fund/biomass

Microsoft
https://www.northwestgeorgianews.com/associated_press/usbi-applauds-biochar-funding-from-microsoft-s-1-billion-climate-innovation-fund/article_9497e73f-6dc8-58c7-9568-d39460b25815.html

Stripe https://stripe.com/blog/first-negative-emissions-purchases

BNNZ proposes that,

1. The current review of the NZ ETS considers and accommodates a future where biochar carbon sequestration is recognised, accepted and potentially incorporated in any ETS changes.
2. Policy initiatives and resources (R&D funding) allow and facilitate the establishment of a NZ based biochar carbon market that can accommodate the support of small scale biochar producers.

Voluntary carbon markets

Below is a description of some of the more high profile companies that have evolved in the voluntary carbon market space around the world, and that have a focus on the future of biochar.

Puro

"*Puro.earth focuses solely on verified net-negative technologies that can remove carbon at an industrial scale and store it for a minimum of 50 years. Our innovation is harmonizing different methods of* CO_2 removal and turning them into digital tradable assets called CO2 Removal Certificates (CORCs)."

"Biochar: A very stable, solid form of carbon that can endure in soil for thousands of years, making it an ideal technology for scalable carbon removal.

Puro White Paper: https://puro.earth/publications/

Reversing climate change with Puro CO2 removal marketplace (2019)
"*Examples of the very long-term, stable CO2 Removal methods are mineralization to carbonates, biochar with high content of fixed carbon, geo-storages and wooden buildings.*"

Puro have participated in the first biochar carbon trades in Australia,

Verra

Verra's Voluntary Carbon Standard (VCS) "*Program is the world's most widely used voluntary GHG program. Over 1,600 certified VCS projects have collectively reduced or removed more than 500 million tonnes of carbon and other GHG emissions from the atmosphere.*"

Verra is currently developing a biochar methodology which will be completed in 2021

Verra to Undertake Development of a VCS Biochar Methodology to Unlock its Potential to Mitigate Climate Change

(Dec.2020 press release below).

https://en.wikipedia.org/wiki/Verified_Carbon_Standard

Carbonfuture

"As of January 2020, we have actually created the first fully documented and verified biochar based carbon sinks which fulfil the quality criteria needed to become a commercially viable financing instrument."

Pacific Biochar lands first U.S. biochar carbon sink credits on carbonfuture's platform

Stripe

Stripe made their first *negative emissions purchases* in 2020 and have worked with CarbonPlan on their reporting on this process (referencing biochar). They have now opened the door to a continuous process that can include the direct purchase of biochar-based carbon sequestration:

"Applications for @stripe's Spring 2021 carbon removal purchases are now open: https://t.co/Je3XszREw5

We accept applicants globally. If you'd like to apply, follow the instructions here. Due by March 21st. We're excited to learn more about what you're building!"

https://www.siliconrepublic.com/companies/stripe-climate-removal-purchase-tool-globally

CarbonPlan

"CarbonPlan analyzes carbon removal projects and programs because we believe these activities will play an important role in addressing the climate crisis. In 2020, we began building a publicly accessible database of carbon dioxide removal project reports. The purpose of this database is to help engender a culture of openness, transparency, and accountability for those participating in the field of carbon removal.

We previously summarized our insights from analyzing 24 proposals submitted in response to Stripe's first carbon removal purchase. We are now releasing a major update to our database, adding analysis of 161 proposals submitted in response to Microsoft's 2021 carbon removal purchase. We also took this opportunity to redesign the web interface for improved performance and usability.

Ekos

A NZ-based company that sells carbon offsets, currently based on forestry establishment.

https://ekos.co.nz/

The rapid proliferation of international carbon markets and their support of biochar is an indication of their confidence in biochar as a climate change solution.

Case Studies: New Zealand and Abroad

Many consider that biochar is costly and not economically viable for large scale adoption., and that it needs to rely on a certain level of Carbon Credits to be viable. This is the case in some circumstances but definitely not all. Most of the successful business models are operating overseas (Examples 5 and 6 below), but there are NZ companies, e.g. Soil Conditioning Products Ltd profitably selling large volumes, 3000 plus t/year, of NZ produced biochar (Example 1 below).

1) A NZ example of large scale use of Biochar February 2021

Soil Conditioner Products Ltd (Soilpro) is a company based at Mangatawhiri recycling products that were destined for landfill for soil conditioning, including high carbon boiler ash (HCBA) biochar. Last year Soilpro sold over 3000 tonnes of HCBA biochar into agriculture systems such as vegetable production, Kiwi fruit production and arable farming. Other markets are sports fields, home gardens and for filtering out water contaminants. There is year on year increasing demand.

For example, ST Growers at Pukekohe produce potatoes and onions on over 600 ha and have been using HCBA biochar for over 5 years. They have found reduced soil sediment runoff, less irrigation needed, lower rates of chemical fertilisers required by up to 50%, and increased product quality as reported by corporate customers.

This HCBA biochar is likely to be representative of bi-products from many boilers around NZ and has been extensively analysed both in NZ and Australia as well as been the focus of a Scion Research project all of which prove it to be a quality product. Further to this, assessment against ANZBIG code of practice and other climate positive standards (e.g. Puro.earth) are expected.

Further commercial information from these businesses supporting the potential for carbon drawdown and climate change mitigation can be obtained by contacting Miles Pope (ph: 0274935659 *email:miles@soilpro.co.nz*), Jason Thomas (phone: 021786111 email: *jason@stgrowers.co.nz*) and Jay Masters

2) Parengarenga Incorporation

Parengarenga is an iwi owned and run organisation in the Far North that transforms its waste forest slash into cattle meat and dollars via biochar. The biochar cost over $4.55/kg to produce, and Parengarenga still enjoyed over 500% direct ROI from additional weight gain by day 81 for the mob fed supplementary biochar versus a control mob in similar conditions. Additionally, the biochar-fed cattle enjoyed had zero worms detected, and therefore significantly lower drenching bills versus the control.

Parengarenga is also enjoying the better pasture and animal health that the biochar supplementary feed and biochar enriched manure has allowed.

Parengarenga Incorporation now provides ongoing employment for biochar production workers, and has plans to scale up production to provide biochar to the Far North market.

Parengarenga is also keeping production records to in time for their sequestration for recognition in carbon markets

Environmental gains anticipated for Northland BioChar research

3) Biochar & turfing

https://www.drivingthegreen.golf/dtg-blog/biochar-how-golf-courses-can-mimic-natural-grasslands-to-save-30-in-water-consumption

Benefits observed for the turfing industry include:

- 30-40% increase in volumetric soil moisture content % when using 15% biochar amendment (by weight) in a USGA spec sand
- >40% increase in turfgrass root depth
- Reduction in the leaching of Nitrate (up to 78% reduction measured)
- Increase in turfgrass clipping yield
- Increase in turfgrass disease resistance
- 90% reduction in Localized Dry Spot occurrence
- Reduction in earthworm casting on the surface
- Enhanced color and uniformity (DGCI)
- 30% conservative reduction in input requirements.

4) Hot Lime Labs

Hot Lime Labs is developing technology to recover clean CO2 from biomass energy systems and supply it to large commercial greenhouses growing vegetables and flowers - a huge global market. The industry is currently dependent on fossil fuels for heating and as a source of clean CO2. The latter being an indispensable ingredient for greenhouse growing at that scale, responsible for 15-30% of total yields.

By providing access to clean, low-cost CO2 from a renewable source, HLL technology can catalyze the industry to transition to renewable energy. See www.hotlimelabs.co.nz and TVNZ report.

Hot Lime Labs is developing a version of their system where clean CO2 can be recovered from a char-maker. This would enable the conversion of local forestry waste into three useful products: Heat (for greenhouses) , CO2 (for greenhouses) and biochar (for dairy industry). Extracting multiple value streams from a waste product allows HLL to produce biochar at very low costs (est. $300/ton) for up to 200t p.a per hectare of greenhouses served. This biochar would then go on to generate value as a wastewater treatment and then as carbon sequestration through voluntary markets.

This integration could allow biochar production > 200kt p.a. with existing NZ greenhouses. This material would go on to create value all around NZ regions serving forestry, horticulture and dairy while sequestering > 400ktp.a of CO2eq.

Hot Lime Labs is conducting R&D into its production of biochar and working on developing a wastewater treatment system for the dairy industry (dairy shed and drying plant effluent) and are planning to set-up a demonstration facility in 2021, likely in the Taupo area.

5) CarbonScape

Deep tech company CarbonScape, based in Marlborough, NZ and has developed technology to convert biochar to exotic carbon-based nanomaterials. CarbonScape is at technology readiness level (TRL) 6 with view to commercialising its highly efficient, patented process. The process produces premium quality graphite, equivalent in performance to synthetic graphite for lithium-ion battery applications, increasing the value of the biochar by over 500%. 2020 annual consumption of graphite for lithium-ion batteries was 650,000 tonnes with analysts Benchmark Minerals forecasting growth to 13.5 million tonnes PA by 2040. The World Bank puts market growth in graphite at over 500% by 2050.

6) Solutions for urban problems e.g. Stockholm project (& Minnesota)

Stockholm Biochar Project *Bloomfield Cities Mar 30, 2017*

Stockholm, Sweden celebrated the opening of an innovative new biochar facility that will work wonders in the city's effort to fight climate change. A first-of-its-kind project, the facility turns plant waste from parks and homes — everything from grass clippings to trees and limbs — into carbon-capturing charcoal that residents can then use in their window boxes and gardens to promote plant growth. Through its production, it will even create enough energy to provide heat and hot water for more than 80 apartments in the city.

The facility is the first of five planned as part of the *Stockholm Biochar Project,* a Bloomberg Philanthropies' *Mayors Challenge* winning entry from 2014. Together, the five plants are expected to produce 7,000 tons of biochar over the next three years — sequestering enough carbon to take the equivalent of 3,500 cars off Stockholm's streets. *More details for cities interested in replicating Stockholm's program are here.*

Inspired by Stockholm's success, a U.S. city goes big on biochar *July 25, 2019*

Biochar is nothing new in Minneapolis. The city has, for years, bought truckloads of the charcoal-like material from a plant in Missouri. But then three city leaders visited Stockholm in May 2019 and now Minneapolis is starting to think even more expansively about how this carbon-catching soil conditioner might help the city address a number of emerging concerns — from climate change to stormwater management.

7) Echo2 (South Australia) biochar production and use

ECHO2 transforms green wastes from plantation forestry, agriculture, food and wood processing, that would otherwise end up as green-house gas emissions by being burned or landfilled, into bioenergy and biochar. Each tonne of biochar is over 80% pure carbon and removes 2.88 tonnes of CO2 per tonne of product, for centuries. The biochar is used for horticulture and agriculture. ECHO2 is the first Puro.earth-certified biochar producer outside Europe. For a detailed carbon footprint description email contact@puro.earth.

Explanation of avoided emissions - A Life Cycle Analysis of the Holla-Fresh/BioGro/ECHO2 system showed that 6.33 tonnes of CO2 eq. emissions are avoided for each dry tonne of biochar that is produced and that a net 2.88 tonnes of CO2 eq. is stored in the biochar. Over 95% of the energy in the incoming wood is utilised for drying the incoming wood, for heating the glasshouse or is captured in the biochar.

Conclusion

In December 2020 the New Zealand Government declared a climate emergency in recognition that climate change is one of the greatest threats we face. As a result of the Paris Agreement, 2015 the New Zealand Government has made a commitment to reach net zero greenhouse gas emissions by 2050 to avoid a more than 1.5°C rise in global warming. Since then it has become apparent that conventional mitigation strategies are not enough to limit warming to 1.5°C.

Recent scientific studies show that biochar has by far the greatest potential of any of the currently available Negative Emissions Technologies to sequester atmospheric CO_2. It is safely added to soils and generally improves their quality and fertility. It is used in many other ways including to improve animal health and as part of industrial processes and products which helps make them more carbon neutral while improving their qualities.

Biochar is very simple to produce and can be made very cheaply by one person with little inputs or as part of large scale energy production. It is the technology for both now and the future.

It has been said that we need to avoid pushing the burden to future generations but by leaving it to 2050 to become carbon neutral with the resultant increases of greenhouse gases we are explicitly pushing the burden to another generation. Biochar can help change this.

References

Bier et all (2020) Biochar-based carbon sinks to mitigate climate change. EBI Whitepaper https://www.syncraft.at/files/pdf/Whitepaper_Biochar2020-en.pdf

Cheng et al (2008) Stability of black carbon in soils across a climatic gradient. Stability of black carbon in soils across a climatic gradient. JGR Biogeosciences Volume 113. Issue G2 https://doi.org/10.1029/2007JG000642

Dufresne, J, Saint-Lu, M (2015) Positive Feedback in Climate: Stabilization or Runaway, Illustrated by a Simple Experiment. Bulletin of the American Meteorological Society 10.1175/BAMS-D-14-00022.1

El-Naggar A et al (2019) Biochar application to low fertility soils: a review of current status, and future prospects. Geoderma 337:536–554. https://doi.org/10.1016/j.geode rma.2018.09.034

Fawzy et al (2020) Strategies for mitigation of climate change: a review. Environmental Chemistry Letters (2020) 18:2069–2094. https://doi.org/10.1007/s10311-020-01059-w

Fawzy et al (2021) Industrial biochar systems for atmospheric carbon removal: a review. Environmental Chemistry Letters. https://doi.org/10.1007/s10311-021-01210-1

Gao & Deluca *Influence of biochar on soil nutrient transformations, nutrient leaching, and crop yield.* Advances in Plants & Agriculture Research eISSN: 2373-6402

Guo et al (2020) *Biochar-Facilitated Soil Remediation: Mechanisms and Efficacy Variations*. Front. Environ. Sci., 21 October 2020. https://doi.org/10.3389/fenvs.2020.521512

Griscom et al (2017) Natural climate solutions. PNAS 114 (44) 11645-11650 https://doi.org/10.1073/pnas.1710465114

He et al (2019) *Remediation of heavy metal contaminated soils by biochar: Mechanisms, potential risks and applications in China*. Environmental Pollution 252 846-855

IPCC, 2018: Summary for Policymakers. In Global Warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening global response to the threat of climate change, sustainable development and efforts to eradicate poverty. Delmotte et al. World Meterological Organisation, Geneva, Switzerland.

Leng et al (2012) Biochar reduces enteric methane and improves growth and feed conversion in local "Yellow" cattle fed cassava root chips and fresh cassava foliage. Livestock Research for Rural Development. Volume 24, Article #199. http://www.lrrd.org/lrrd24/11/leng24199.htm

Ippolito et al (2020) Feedstock choice, pyrolysis temperature and type influence biocharcharacteristics: a comprehensive meta-data analysis review. Biochar (2020) 2:421–438https://doi.org/10.1007/s42773-020-00067-x

Man et al 2021 Use of biochar as feed supplements for animal farming. Critical Reviews in Environmental Science and Technology ISSN: 1064-3389 (Print) 1547-6537 https://doi.org/10.1080/10643389.2020.1721980

Saleem et al (2021) Effect of engineered biocarbon on rumen fermentation, microbial protein synthesis, and methane production in an artificial rumen (RUSITEC) fed a high forage diet. Journal of Animal Science. 2018 Jul 28;96(8):3121-3130. doi: 10.1093/jas/sky204. PMID: 29912357; PMCID: PMC6095387.

Thomas & Gale (2015) Biochar and forest restoration: a review and meta-analysis of tree growth responses. New Forests (2015) 46:931–946 DOI 10.1007/s11056-015-9491-7

Vijayaraghavan (2016) Recent advancements in biochar preparation, feedstocks, modification, characterization and future applications. Environmental Technology Reviews ISSN: 2162-2515 (Print) 2162-2523 (Online) Journal homepage: https://www.tandfonline.com/loi/tetr20

Wang et al (2016) Biochar stability in soil: meta-analysis of decomposition and priming effects. Bioenergy 8, 512–523, doi: 10.1111/gcbb.12266

Zeng et al (2015) The effect of temperature and heating rate on char properties obtained from solar pyrolysis of beech wood. Bioresource Technology 182 (2015) 114–119

Zimmerman & Gao (2013) The stability of biochar in the environment. Chapter 1 Biochar and Soil Biota. CRC Press. Taylor & Francis Group

Zimmerman et al (2020) Quantifying the Effects of Biochar Application on Greenhouse Gas Emissions from Agricultural Soils: A Global Meta-Analysis. Sustainability Volume 12 Issue 8 10.3390/su12083436