INTERRA ENERGY®
food, energy, future.

About the Interra Carbon Reset^{TM}

Disclaimer

This primer is intended to provide general background on climate change and how biochar can offset greenhouse gas emissions. It introduces the Interra Resets™ and the methodology used to calculate the Interra Resets™. This document is not a Carbon Offset methodology and does not represent an endorsement or validation of the Interra Forge Project by Carbon Consulting LLC or their affiliates.

Acknowledgements

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Interra Energy, Inc. is providing support to the efforts of Carbon Consulting LLC and Leading Carbon LLC to development of a biochar offset protocol. As founding sponsors of this initiative, The Carbon War Room and ConocoPhillips Canada provided both financial and in-kind www.biocharprotocol.org .

February 2nd, 2012.

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Glossary

Additionality
Measure of whether a project is incremental to the business-as-usual case. Often used as a key measure of whether a project should be considered eligible for the creation of carbon offset credits. This term has different definitions and uses across carbon offset systems.

Aggregation
The practice of bundling small offset projects to overcome the economies of scale associated with carbon offset documentation, certification, and commercialization.

Baseline
The emission of greenhouse gases that would occur without the contemplated policy intervention or project activity.

C
Carbon.

Carbon offset or credit
Generic units used to describe the verified and certified reduction or sequestration of one ton of carbon dioxide equivalents (CO_2e).

Carbon offset system
Voluntary or compliance-based program for the certification and recognition of carbon offsets. These programs are typically broadly scoped across project types with codified rules designed to accommodate a diverse set of interests.

CDM
Clean Development Mechanism, the carbon offset certification body established under the Kyoto Protocol for projects implemented in developing nations.

CH_4
Methane a greenhouse gas with a global warming potential 25 times greater than CO_2 over a 100-year period.

CO_2e
Carbon dioxide equivalents.

Double-counting
The attribution of a GHG emission reduction or sequestration benefit multiple times. This is a significant concern for ensuring the integrity of carbon offset systems.

Emission Reductions (ERs)
The measurable reduction of release of greenhouse gases into the atmosphere from a specified activity or over a specified area, and a specified period of time.

Fossil Fuel
Coal, oil and natural gas are fossil fuels. Fossil fuels are formed from the organic remains of prehistoric plants and animals.

GHG
Greenhouse gas, typically including the six common gases of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). All GHGs can be related back to a common unit of CO_2e by multiplying the emissions of a given gas by its global warming potential.

Leakage
Term used to describe a situation where an emission reduction measured in one instance results in a measurable increase in emissions elsewhere.

Mean Residence Time
Mean residence time is a measure of the time it takes for the total stock of material (in this case C contained in biomass or biochar) to be cycled through a system (in this case broken down in soil and released back to the air as carbon dioxide).

N_2
Nitrogen gas. Produced in soil through denitrification, where heterotrophic denitrifying aerobic bacteria cause respiratory reduction of nitrate or nitrite to N_2O and N_2 under anoxic conditions.

N_2O
Nitrous oxide, a greenhouse gas with a global warming potential 310 times greater than CO_2 over a 100-year period. Produced in soil through denitrification, where heterotrophic denitrifying aerobic bacteria cause respiratory reduction of nitrate or nitrite to N_2O and N_2 under anoxic conditions.

Offsets
See Carbon offset above.

Permanence
A measure of whether the carbon emission reduction or sequestration has a lifespan greater than or equal to the lifespan of a GHG in the atmosphere. Permanence of reversible emission reductions or sequestration opportunities is assessed differently across carbon offset systems.

Protocol

A codified quantification methodology approved by a carbon offset system suitable for use as a carbon market access mechanism. Protocols include a quantification methodology and the overlay of carbon offset system guidelines, within a given document format. Each carbon offset system has a development and approval process for protocols.

VCS

Voluntary Carbon Standard, an international standard for use in the voluntary carbon markets. Largely viewed as a pre-compliance standard in the United States.

The problem

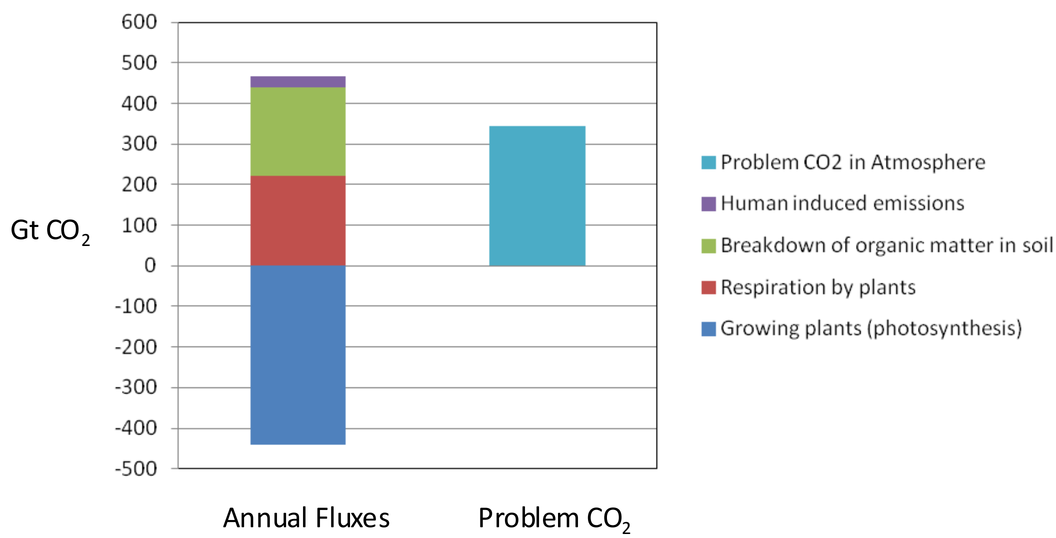
Atmospheric levels of CO_2 are rising. Current atmospheric CO_2 levels are approximately 393 ppm or 3,144 gigatons CO_2. 350 ppm of CO_2 in the atmosphere is generally regarded as a safe limit for CO_2. Today atmospheric CO_2 levels currently exceed the safe level by 344 gigatons.

To put these numbers in context, human-induced carbon emissions are in the order of 25 billion tons (gigatons (Gt)) carbon dioxide (CO_2e) annually.

By contrast, growing plants draw down 440 Gt CO_2 annually as they grow to produce carbon-containing biomass. Of the CO_2 captured by growing plants through photosynthesis, 50% is initially retained in plant biomass and 50% is immediately released as CO_2 through autotrophic plant respiration. Carbon is only stored in plant biomass temporarily. During plant decomposition, the carbon stored in biomass is re-released to the atmosphere within a matter of months to years. The annual release of CO_2 from soil to the atmosphere as plant material decomposes is 220 Gt CO_2.

Figure 1. The size of the problem

Slowing the breakdown of organic matter offers greatest opportunity to cut CO_2



Given the levels of CO_2 in the atmosphere today, simply reducing our rate of human-induced emissions will not fix the problem. We need to remove CO_2 from the atmosphere and stabilize it against re-release.

Biochar production represents a strategy to impact the release of CO_2 from the breakdown of organic matter in soil by converting organic matter into biochar using a process of thermal stabilisation. Biochar decomposes and releases CO_2 very slowly with long mean residence times in soil, ranging from 1,000 to

10,000 years, with 5,000 years being a common estimate.[1,2] Without thermal stabilization, the same biomass will release all the carbon it contains to the atmosphere in a short period of time, with much of the carbon being lost within a few months and with the majority of the carbon being lost within 10 years due to incorporation into soil, agricultural burning, composting, or even use for biofuels.

Stabilisation of carbon in biochar represents an opportunity to remove CO_2 from the atmosphere by converting biomass into a stable form of carbon and preventing the release of this carbon back to the atmosphere. Where prior management for biomass includes incorporation in soil, production of biochar from this biomass represents an opportunity to lock in and stabilize the carbon that decomposing biomass would otherwise release into the atmosphere.[3]

When added to soil, biochar continues to store carbon and enhance soil quality. Using biochar can increase agricultural production without increasing cropped area, all the while reducing fertilizer and water inputs.

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[1] Cheng, C., Lehmann, J., Thies, J., and Burton, S. (2008) Stability of black carbon in soils across a climatic gradient *J. Geophysical Res.* Vol 113. G02027, 10 pp

[2] Warnock, D. D. and Lehmann, J. (2007) 'Mycorrhizal responses to biochar in soil – concepts and mechanisms' *Plant & Soil.* vol 300. pp 9-20

[3] Lehmann, J., Gaunt, J., Rondon, M. (2006) Biochar sequestration in terrestrial ecosystems – a review. Mit. Adapt. Strat. Global Change, 11, pp 403-427.

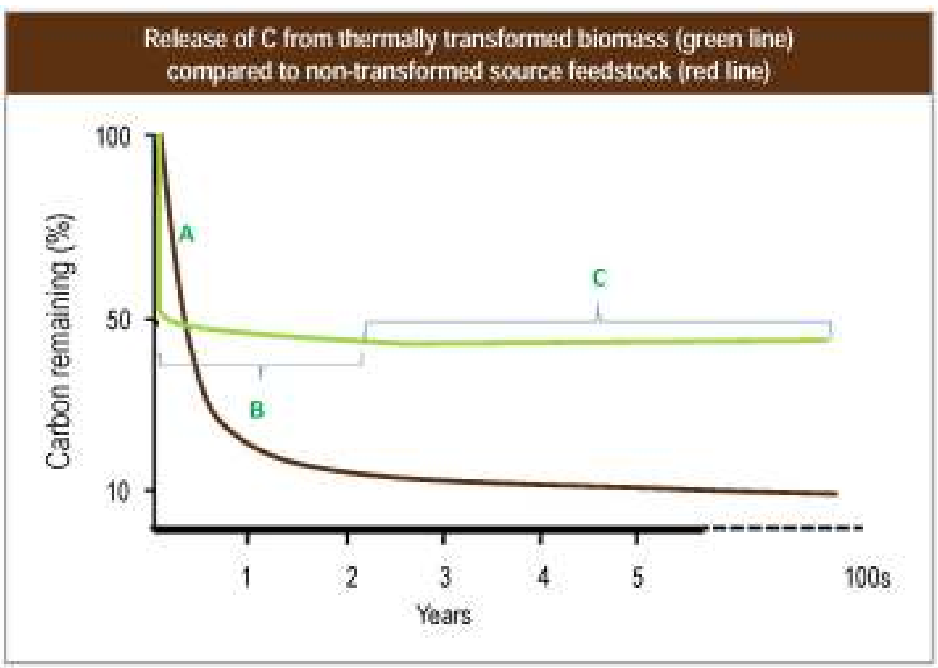
How does biochar reset carbon?

Typically 80-90% of C added to soil as plant biomass will be lost as CO_2 after 10 years. The amount remaining after 10 years is influenced mainly by soil type and environmental factors. In the schematic below (Figure 2) the red line represents the proportion of C added to soil that remains over time.

Although the decomposition of plant material in soil is a complex process, simple models have successfully described the long-term dynamics of soil C and are widely used to predict the carbon that will remain from the organic matter applied to soil. Such models have informed both national greenhouse inventory assessments and proposed carbon offset methodologies.

Biochar is formed when organic matter is heated in the absence of oxygen (or partially combusted in the presence of a limited oxygen supply). The release of C when organic matter is transformed into biochar differs markedly from non transformed organic matter. Carbon is released in three distinct phases, as biochar is produced and applied to soil: A) rapid release of approximately 50% of the C in the feedstock during thermal transformation (i.e. during pyrolysis); B) release of labile mainly volatile C through rapid biotic decomposition; and C) long-term slow release of C due biotic and abiotic breakdown of resistant C forms.

Figure 2. How pyrolysis leads to C sequestration
The difference between the brown line and the green line represents the carbon stabilised in biochar.



The release of C during pyrolysis (Phase A) is determined by process conditions (primarily the rate of heating, highest heating temperature and duration of heating. As this release of carbon is almost instant (within minutes to hours) this phase actually releases C more quickly than if the organic matter is added to soil. However, this is also the point where and bioenergy is produced. Typically less than 5% of the C contained in biochar is labile (Phase B). The remaining biochar (Phase C) has long mean residence times in soil, ranging from 1,000 to 10,000 years, with 5,000 years being a common estimate. There is some uncertainty around these numbers, particularly for materials which may not have typically been used to form charcoal.

Although stabilisation of C in biochar represents an important sequestration pathway, biochar combats climate change through:

Pathway 1: Avoided emissions when biomass residues are diverted as feedstocks for pyrolysis;

Pathway 2: Storage of C in biochar produced by thermal transformation of C contained in feedstocks and the application of biochar to land;

Pathway 3: Avoided fossil fuel emissions where pyrolysis is deployed as a bioenergy technology;

Pathway 4: Reduction in emissions of N_2O and CH_4 from soil resulting from the use of biochar in agriculture; and

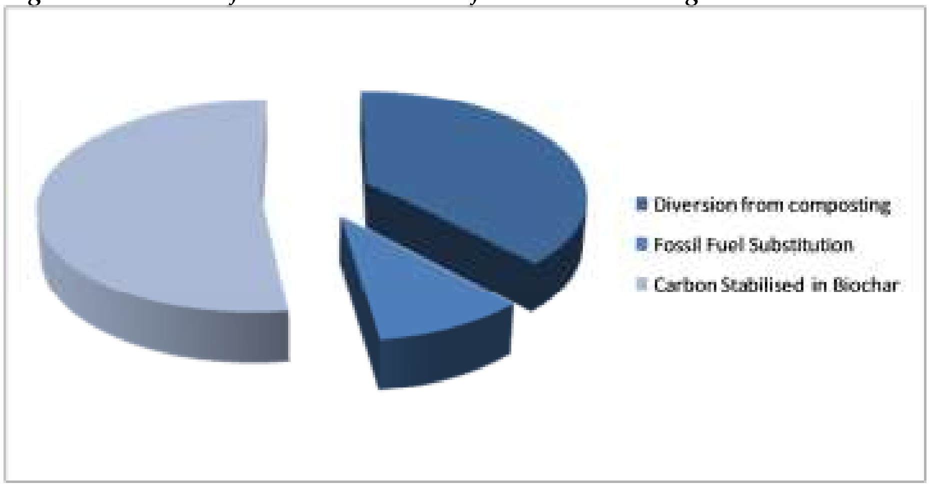
Pathway 5: Reduction in emissions due to reduced inputs of fertilizer and manufactured inputs as a result of the application of biochar to land.

While there is much to be learned about Pathways 4 and 5, which relate to how the properties of biochar can be managed to reduce agricultural and environmental performance, the factors that determine the C stability of biochar and avoided emissions associated with pathways 1, 2, and 3 are well understood.

The Interra Forge will result in both avoided greenhouse gas emissions and carbon sequestration. Avoided emissions are created because we divert green waste material from composting or landfill and use this as our feedstock. If composted the material releases nitrous oxides and methane, and if landfilled it produces methane.

The excess energy produced is used to produce electricity and is used to displace electricity produced from fossil fuel.

Figure 3. Sources of avoided emissions for the Interra Forge

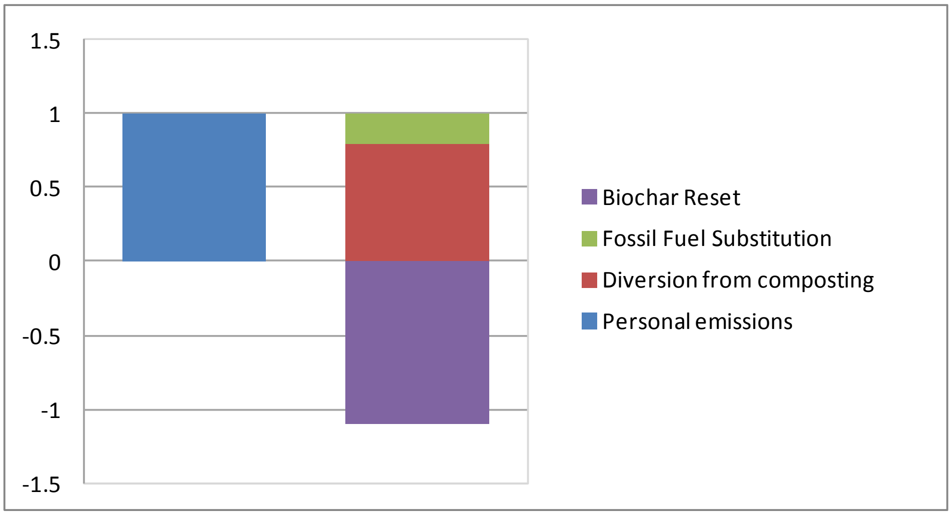


Interra takes a unique approach to offsetting greenhouse gas emissions. When you offset your emissions using Interra Resets™ the avoided emissions created when materials are diverted from landfill or composting are used to offset your personal emission. The Biochar Carbon Reset™ represents the carbon stored in biochar, which is CO_2 drawn down from the atmosphere.

Thus with an Interra Resets™ you go beyond offsetting. The Biochar Carbon Reset™ provides a unique opportunity draw down carbon dioxide from the air while also reducing fossil fuel and greenhouse gas emissions, giving future generations the time necessary to switch to sustainable carbon neutral technologies.

Figure 4. How Biochar Resets' draw down CO_2 from the atmosphere

Personal emissions (t CO_{2e}) are offset by avoided emissions created when biomass is diverted from composting and converted to bioenergy. The biochar byproduct is used to reset atmospheric CO_2. Approximately 1.1 Mg CO_{2e} is reset for every Mg CO_{2e} offset



What is a carbon offset and a carbon market?

Carbon offset markets allows emitters who can reduce their emissions at low cost to trade their extra emission credits with others who can only do so at a high cost, thus achieving an emissions target in the most cost effective way.

Greenhouse gases typically include the six common gases of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). All greenhouse gases contribute to climate change and can be related back to a common unit called a carbon dioxide equivalent (CO_{2e}) by multiplying the emissions of a given gas by its global warming potential.

Thus the common unit for a carbon offset is a unit of "avoided CO_2 emissions" or of CO_{2e} taken from the atmosphere.

The concept of "emissions trading" is not new; it has been successfully used, for example, to control sulphur dioxide and nitrous oxide emissions in the USA and for stream salinity and nutrient management in Australia.

Any two parties can agree a carbon offset agreement. In its simplest form all that is required is that the parties involved agree terms. There are both compliance schemes implemented by governments and non-compliant, voluntary programs.

Given the intangible nature of greenhouse gases and concern to know that the offsets claimed are real, protocols have been developed to provide specific guidance for quantification of emission reductions from project-based activities in order to substantiate verifiable claims for offsets. As such, these protocols serve as an access mechanism to primary carbon offset markets. The use of the protocols is then guided by the overall policy and market frameworks to ensure offsets are generated that meet the requirements of the relevant regime.

Such protocols do not yet exist for biochar projects. However, as leaders in this space, this should not deter us! As leaders in championing the role of biochar in carbon offsetting, it is important to Interra that we demonstrate to our customers and investors that we operate to the highest standards.

To ensure this we have teamed up with www.BiocharProtocol.org, which has helped us to prepare a transparent and rigorous methodology to account for the Carbon Resets™, and we are working with Carbon Consulting LLC (www.carbonconsulting.us) to calculate the avoided emissions associated with our project.

Protocols are discussed in more detail in the next section. But there are some really important criteria that a carbon offset needs to achieve.

The first two criteria that are important are **additionality** and **leakage**.

Additionality is a measure of whether a project is incremental to the business-as-usual case. This term has different definitions and uses across carbon offset systems and is often used as a key measure of whether a project should be considered eligible for the creation of carbon offset credits. At the heart of these definitions is **financial additionality**, which requires that the revenue from carbon revenues makes a difference to the economic viability of a project, and **technical additionality,** which determines if the carbon offset payment will enable the adoption of a new technology that is not already widely adopted.

Much as we would be happy if our business was financially viable today, and we would wish to see biochar being widely adopted, these are new innovations. What we are proposing is not a current practice and the income from selling carbon offsets will make a real difference. The projects we anticipate are clearly additional.

Leakage is the term used to describe a situation where an emission reduction measured in one instance results in a measurable increase in emissions elsewhere.

Because the Interra biochar production project is a disruptive technology, re-directing a waste resource for use as feedstock and creating a stable by-product, it avoids concerns regarding leakage. This may not always be the case for other biochar applications. If for example a harvested crop product was used as a feedstock, a project would have to demonstrate that use of this crop product as feedstock did not result in more area being sown to replace the feedstock used.

As the project meets additionality and leakage criteria, then our next concern is **permanence**. Permanence is measure of whether the carbon emission reduction or sequestration has a lifespan greater than or equal to the lifespan of a greenhouse gas in the atmosphere. As with additionality and leakage, permanence of reversible emission reductions or sequestration opportunities is assessed differently across carbon offset systems and associated protocols. However, given the extreme stability of biochar with a mean residence time of thousands of years, concerns of permanence are not a major issue.

However, to ensure that we do not get it wrong we assume that only a proportion of biochar C is stable.

More about protocols and carbon markets

In the previous section we discussed briefly the key attributes of an offset. To participate in the greenhouse gas offset markets, a project must be verified relative to an applicable greenhouse gas emission reduction quantification protocol.

Perhaps the most well known of these markets is the Clean Development Mechanism (CDM). The CDM was established as a result of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (2005). The CDM allows emission-reduction (or emission removal) projects in developing countries to earn Certified Emission Reduction (CER) credits, each equivalent to one ton of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

The CDM stimulates sustainable development and emission reductions while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets. CDM has been in operation since 2006 and offers a wide spectrum of methodologies for project submission.

The US did not ratify the Kyoto Protocol, despite this various carbon policy frameworks and market regimes exist within the North American context. See www.biocharprotocol.org/sg_userfiles/policy_primer.pdf and www.**nrel**.gov/docs/fy10osti/47312.pdf for discussions of the North American situation.

Given the variety of policy and market approaches, there are numerous sets of protocols being developed or under development. However, at macro-scale, there appears to be a convergence in the structure and quantification approaches in these protocols using approaches defined under the International Standards Organisation (www.iso.org). The ISO 14064 standard provides a high-level approach for developing protocols based on the systematic and comprehensive identification and analysis of the sources of emissions, carbon sinks and carbon reservoirs.

Despite this harmonisation the costs to an individual project of establishing a methodology are significant (well in excess of $100,000) and beyond the current reach of Interra. However, we are committed to providing transparent and rigorous methodology to account for the Carbon Resets™.

The initiative www.biocharprotocol.org is working to create a comprehensive protocol for biochar projects. The protocol is being prepared for submission to the Verified Carbon Standard (www.v-c-s.org).

The protocol development process of www.biocharprotocol.org is industry-led and has already involved significant consultation. Our methodology is based on the materials that have been developed by Carbon Consulting LLC and Leading Carbon for submission to VCS and will be modified to incorporate any revisions during the anticipated VCS review and approval process[4]. Our project and all Carbon Resets™ will be third-party verified against this methodology.

The emissions reductions mechanisms within the scope of biochar-based projects are summarised in the table below. For each mechanism we provide a brief description and identify key issues. For many of the emissions reductions mechanisms, projects and methodologies already exist. Where appropriate we indicate the analogous projects.

The emissions reductions mechanisms claimed by the Interra Forge project are shaded in blue. The only emissions reduction mechanism that will not use a previously established methodology relates to stability of carbon contained in biochar.

We propose to use two key measures to confirm i) that the Interra process has indeed thermally transformed the feedstock to produce biochar and ii) the amount of C contained in the biochar.

Indicator of transformation of organic matter

During the heating associated with pyrolysis and associated transformation of organic structures the molar ratio of H:C and O:C decrease as connections to protons and OH groups are shed.

Data summarized from a number of sources by Krull et al.[5] showed that H:C and O:C ratios tended to be highest in feedstock materials and low-temperature biochars, partially charred plant materials and biochars produced during very short heating intervals. Lower ratios were observed in naturally produced wood char, vegetation fire residues, biochar produced in the laboratory under high temperatures, and/or prolonged heating

The H:C and O:C ratios decrease with increasing production temperature or prolonged heating. The H:C ratio of unburned fuel materials, such as cellulose or lignin, is approximately 1.5. Kuhlbusch and Crutzen[6] used molar H:C ratios of ≤ 0.2 to define 'black carbon'. Graetz and Skjemstad[7] concluded that temperatures during biomass

[4] The full methodology is currently confidential and has significant commercial value. Part of our agreement with www.biocharprotocol.org is that we will not release this into the public domain before the consultation and submission process has been completed. However, access can be provided to customers under special arrangements for review. The methodology will be published as part of the protocol approval process.

[5] Krull, Evelyn S., Baldock, J. A., Skjemstad, J. O., and Smernik, R. J. (2009) 'Characteristics of Biochar: Organo-chemical Properties' in J. Lehmann and S. Joseph (eds) Biochar fo.r environmental management: science and technology. Earthscan. UK, pp 53-65

[6] Kuhlbusch,T. A. J. and Crutzen, P. J. (1996) 'Black carbon, the global carbon cycle, and atmospheric carbon dioxide', in J. S. Levine (ed) Biomass Burning and Global Change, MIT Press, Cambridge, UK, pp 161–169

[7] Graetz, R.D. and Skjemstad, J.O. (2003) 'The charcoal sink of biomass burning on the Australian continent', CSIRO Atmospheric Research, Aspendale

Emission Reduction Mechanisms					
Mechanisms	Description	Key issues	Analogues	Strategy	Source and key summary of methodology
Waste diversion	Organic materials are diverted from situations where they would produce CH_4 and or N_20 emissions.	Proving diversion can be challenging, thus adding complexity to establishing the baseline.	Considered in a range of protocols across a range of carbon policy frameworks and markets.	Use existing methodologies	Key reference IPCC and US EPA methodologies for landfill and composting.
Avoided waste combustion	Organic materials are diverted from incineration, producing CO_2 emissions.	Various models exist for predicting GHG emissions from these sources. Emissions from combustion of organic materials are biogenic emissions.	Contemplated as a project condition for incineration projects.	Use existing methodologies	Not applicable to Interra Forge
Stabilisation of carbon in biochar	Conversion of inherently unstable biomass to biochar sequesters carbon.	Soil C sequestration protocols should not be applied to biochar where risks of non-permanence are significantly lower.	No biochar protocol exists.	New methodology required	O:C ratio of <0.6 used to confirm formation of biochar. uses ASTM D3176 or equivalent. Fixed Carbon by ASTM D3176 or equivalent * 0.85
Soil Carbon accumulation	Incorporation of biochar in soil leads to the enhanced sequestration of non biochar soil carbon.	Soil C sequestration is difficult to measure. Concerns that carbon sequestration in soil is not permanent. Data on biochar benefit are limited	Carbon sequestration considered broadly in forestry and agriculture protocols.	Review and propose new or revised methodology	Not applicable to Interra Forge
Fertilizer efficiency	Biochar may improve fertilizer use efficiency, resulting in lower N_2O and reduced CH_4 production from soil.	Data on impact of biochar are limited. Difficult to measure changes in CH_4 and N_2O emissions at a field scale. Modelling of N_2O can be resource intensive.	Considered in other agriculture protocols, a number of fertilizer efficiency protocols are under development.	Review and propose modifications if needed	Not applicable to Interra Forge
Electricity displacement	Electricity produced from biochar projects offset electricity produced from fossil fuels.	This is an indirect emission reduction and may not be considered under all programs.	Landfill gas and energy from biomass combustion projects.	Use existing methodologies	Continuous metering with avoided emissions calculated using US EPA guidelines.
Fossil fuel displacement	Heat, power, and biofuels produced from the biochar projects may offset fossil fuel usage downstream.	Indirect emission reduction may not be considered under all programs. There are difficulties in direct measurement given the downstream nature of the emission reduction and conversions between equivalent units of energy.	Considered in projects where there is heat, power, or biofuels being produced, such as landfill gas and energy from biomass combustion projects.	Use existing methodologies	Direct metering or reconciliation of volume in storage (including volumes received). Avoided emissions calculated using US EPA guidelines.

burning are predominantly greater than 400°C (smouldering combustion) and that chars formed during these temperatures are likely to have H:C ratios of <0.5. Spokas[8]

The H:C ratio can be measured using a routine procedure called ultimate analysis; this is a quantitative analysis in which percentages of all elements in the substance are determined. International standards under ASTMS (www.astm.org) exist for ultimate analysis. The relevant method is ASTM D3176. The ongoing efforts by the International Biochar Initiative to establish a sustainability standard for biochar have proposed and a threshold H:C ratio of <0.7 as an indicator of transhormation.

Therefore we use a H:C ratio of <0.7 measured by ASTM D3176 or equivalent be used to indicate that the material has been transformed or stabilized through pyrolysis.

Estimation of stable C contained in biochar

The long-term stable C in biochar is that portion that remains after the labile components that are subject to biotic and abiotic oxidation processes when added to soil is lost.

Incubation studies indicate that the amount released is typically small and it is released relatively rapidly when biochar added to soil. A number of research groups are seeking to apply accelerated decomposition or oxidative procedures to measure this labile component. Such studies have typically shown the labile component to be very small. Typically less than 5% of the C contained in biochar is released during short-term incubations designed to measure the labile component of biochar.

Fixed C can be measured in biochar by proximate analysis. Proximate analysis involves establishing the loss of material as samples are heated to predefined temperatures and typically reports volatile matter, fixed carbon, moisture content, and ash present in a fuel as a percentage of dry fuel weight. International standards under ASTMS exist for this measure. ASTM D1672-84 measures volatile carbon by heating a sample to 950 Celsius in an inert atmosphere and any matter that leaves is considered volatile matter. The ash is generated by exposing the coal to air at 750 Celsius until all the available carbon is reacted to carbon dioxide and any metal salts are converted to the corresponding metal oxides.

Given research to establish biochar specific measures are under way we propose to adopt a conservative approach in the meantime. The fixed C measured by ultimate analysis is multiplied by a factor as a conservative estimate of the stable component.

Stable C is taken as the Fixed C content measured by ASTM D3176 or equivalent * 0.85

[8] Spokas, Kurt. (2010) 'Biochar: Impacts on Soil Microbes and the Nitrogen Cycle', USDA-ARS, Soil and Water Management Unit, St. Paul, MN, http://www.ars.usda.gov/SP2UserFiles/person/41695/Presentations/ISTC2010.pdf

Interra's Forge

The Interra Forge project will utilize feedstock materials that are diverted from the urban green waste stream, comprising arboricultural arisings and yard waste. These materials are currently collected and disposed of by composting. These materials will be pyrolyzed to produce charcoal. A portion of this charcoal will be formulated as biochar and then incorporated into soil by blending the biochar with green waste compost to create a home garden and landscaping product or otherwise utilized in a matter where the biochar will not be combusted.

In capturing the carbon in the biochar, emissions of carbon dioxide and/or methane from the aerobic, anaerobic decomposition of the organic waste are prevented. The fixed carbon in the biochar, as measured using the testing methods described herein, is sequestered over a time period well in excess of the 100-year time period typically considered for climate change products.

The co-products of the biochar production can include bio-gas, process heat, and/or electricity. There are emission reduction benefits to the effective use of each of these co-products in replacing fossil-based or generated sources.

Each Forge system will convert five to six tons per hour of biomass into renewable natural gas and biochar. The by product methane fuel is immediately converted to electricity using five Microturbines in a one-megawatt skid package, producing enough electricity to continually power approximately 1,200 Californian homes or 1,800 electric cars.

Indicative Emissions for Interra Forge

		Emissions (Mg CO2e Mg^{-1} DM)						Net emissions (Mg CO2e Mg^{-1} DM)	
		Baseline			Pyrolysis bioenergy & biochar				
Feedstock	**Baseline Management**	**CH_4**	**N_2O**	**Total**	**Replacing gas**	**Replacing coal**	**Biochar Carbon removal**	**Replacing gas**	**Replacing coal**
Green Waste	Compost	0.25	0.18	**0.43**	-0.05	-0.11	-0.59	-1.07	-1.13

Positive values indicate emissions; negative values indicate avoided emissions, or removals.

Assumptions

Summary of assumptions

Global warming potential			
			Source
CH_4	25		5
N_2O	298		5
Pyrolysis process			
Feedstock	Greenwaste		Source
Dry basis throughput	4.5	Mg h^{-1}	1
Electricity generated	177	kWh h^{-1}	1
Electricity exported	117	kWh h^{-1}	1
Biochar yield	33.9	% DM	1
Fixed Carbon	56	% biochar	1
Emission factors			
Natural gas- fired electricity	0.42	kg CO_2e KW_eh^{-1}	2,3
Bituminous coal fired-electricity	0.98	kg CO_2e KW_eh^{-1}	2,3
Emissions from Composting			
Methane	0.25	kg CO_2e t DM $^{-1}$	4
Nitrous Oxide	0.18	kg CO_2e t DM $^{-1}$	4

[1]Interra Energy internal data

[2] Emissions by fuel source: 2009 State of California Air Resources Board, 1990-2004 Greenhouse gas inventory, Technical Support document

[3] Heat rate for average 2005 US Natural gas and Coal fired power plant. NPC 2007

[4] Table 4.1 IPCC 2006. Guidelines for national greenhouse gas inventories. Vol 5

[5] Forster et al. (2007) Changes in Atmospheric Constituents and in Radiative Forcing. In: Solomon et al. (Eds.), 'Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change'. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.