Attachment A i – Discussion Paper EWDP 13-012R: Biomass ain't Biomass

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DISCUSSION PAPER

Biomass ain't Biomass

In a carbon constrained economy, where either legislated or market based incentives have been established to disincentivise the consumption of fossil fuels (oil, gas or coal), an obvious alternative source of carbon based molecules is biomass; the vegetative materials produced by the "solar powered" conversion of atmospheric CO_2 with water and soil nutrients (photosynthesis) to form the woody, lignocellulosic materials that were the original source of the fossil fuels that we now seek to replace.

However, recently grown biomass (<100 years) presents in many different forms, each more suitable and sustainably applied to different uses and functions if the full range of anticipated benefits is to be actually achieved.

Vegetative Biomass as a renewable resource

The attraction of vegetative biomass as a renewable resource stems from the fact that currently grown (< 100 yrs) vegetative biomass uses sunlight (solar energy) to drive photosynthesis, whereby atmospheric CO_2 is combined with water and soil nutrients to produce the lignocellulosic structures that present as the root, stem and branch and woody biomass materials that are ultimately the essential inputs into the emerging bio-products manufacturing sector.

The carbon "near-neutral" potential for using such materials to replace/supplement fossil resources, and as a source of energy, comes from an analysis of the carbon cycle, whereby the CO_2 absorbed by plant life during growth is released through combustion back to atmosphere in a short, no-net-CO_2-increase cycle, whereas the combustion of fossil resources releases CO_2 to the atmosphere that had been sequestered some 300 Million years ago, and whose release in today's modified environment causes a net accumulation of CO_2 in the atmosphere.

The agenda to replace or supplement fossil fuels with biomass derived alternatives is ultimately driven in response to the respective climate change, resource depletion and adoption of sustainable economic systems agendas. The achievement of these goals is heavily dependent on a detailed understanding of all the different types of biomass and their most appropriate application to all the different uses envisaged, the achievement of their respective Highest Net Resource Value (see EWDP 14-014R).

Biomass was the source of the fossil resources (coal, oil, gas) that we use today. The original biomass deposits were "pyrolysed" by geological processes (heat and compression in the absence of oxygen) during the last 300-350 million years, and in so doing, substantially decarbonised the then prevailing atmosphere, setting the platform for the more "friendly" climatic conditions we enjoy today. In effect, keeping most of the sequestered carbon from re-entering the earth's atmosphere is the essence of limiting climate change as it presents today.

However, using currently produced vegetative biomass operates on a net carbon neutral cycle; and where any portion of that carbon can be sequestered into long life products (such as stable biochar back into soils), net atmospheric CO_2 can even be reduced, whilst still providing the essential services previously supported by the use of fossil resources. Table 1 clearly shows that whilst biomass has demonstrable net GHG benefits over other "renewable" energy sources, it is also the only one that could result in carbon negative outcomes rather than simply carbon "reduced" or only carbon neutral outcomes.

Table 1: Comparison of benefits and properties of non fossil sources

Compares all other non fossil sources of energy, which includes biomass, but demonstrates that biomass can also produce (columns E, F, G, H & I) a wide range of carbon based materials previously only available from fossil resources and which are essential outcomes of an emerging biomass based sector.

Low carbon energy sources	Features/Properties								
	A	B	C	D	E	F	G	H	I
	Renewable	On demand supply	Heat	Power	Gas	Oil	Char	PetroChem industry manufacturing precursors	Potential to be Carbon negative
Fossil fuels with sequestration		✓	✓	✓					
Hydro	✓	✓		✓					
Wind	✓			✓					
Solar – thermal	✓		✓	✓					
Solar – PV	✓			✓					
Geothermal	✓	✓	✓	✓					
Wave/Tidal	✓			✓					
Nuclear		✓	✓	✓					
Biomass	✓	✓	✓	✓	✓	✓	✓	✓	✓

The obvious versatility of biomass as a basic source of carbon-based products presents the collateral problem that in a carbon constrained economy, the demand and competitive pressures for the full range of biomass supplies will be intense. With this in mind, it will be essential that the vegetative biomass sources selected for any particular use are absolutely appropriate for that purpose and are produced sustainably and delivered entirely fit-for-purpose. In this paradigm, the available vegetative biomass sources should be applied to the end use that demonstrates the Highest Net Resource Value (HNRV) wherever possible.

To be able to recognise and properly allocate biomass sources for HNRV, not only the precise characteristics of the various biomass sources need to be understood, but their net impact as a land use issue, their ability to provide collateral ecosystem services, and the socio-economic factors surrounding their selected generation and end use need to be recognised and accommodated.

Bio-molecular Profile of Vegetative Biomass

Focusing on plant matter, biomass presents in three major forms:

i) The lignocellulosic structural portion; stems, branches, roots etc. (the water **insoluble** hydrocarbon material);

ii) The water soluble carbohydrates, sugars, starches and proteins; and

iii) The lipids, oils and fats.

Hydrocarbons contain only carbon and hydrogen, have a high energy density and are used for energy storage by biological organisms where weight and volume are critical. Carbohydrates also contain carbon and hydrogen, but have approximately one atom of oxygen for each atom of carbon in the structure. Oxygen reduces the energy density of carbohydrates compared to hydrocarbons, but has other valuable biological outcomes such as making the molecule water soluble (proteins, sugars and starch) so that it can be easily transported within the organism, or aiding in the formation of polymers for structural roles (lignocellulose).

Humans are only able to successfully digest soluble carbohydrates and lipids; hence lignocellulose is not a direct human food. Animals are able to maintain the structural integrity of amino acids during digestion and hence use food protein for their own growth and development. This means that if protein can be separated from other biomass components, it can often have more value as an animal (including human) feed where the nitrogen and sulphur are an asset rather than a pollutant.

The energy density and physical properties of the biomass are critical factors for bioenergy feedstock considerations and need to be understood in order to match a feedstock to its most efficient processing technology.

The net result is that it is usually the lipids and water soluble carbohydrates that achieve their highest order use as sources of food (human and animal) and have provided the basis for first generation biofuels and the like, whilst the majority of biomass by weight and volume is the water insoluble lignocellulosic fraction.

It is this “dry”, lignocellulosic or “woody” material that is likely to be the most appropriate and cost effective to apply to industrial and agricultural uses as it does not compete with food.

It is also worth noting that it is usually the reproductive parts of plants that provide the high value lipids and sugars, starches and proteins, whilst the foliage has high moisture and is more nitrogenous, and the bark on woody parts is often the higher ash containing fraction. All these factors influence not only which biomass is optimum for fossil resource replacement, but which parts of which plants.

To reinforce the point, the following table, reproduced from the Rural Industries Research and Development Corporation’s *Sustainability Guide for Bioenergy* (RIRDC Publication # 05/190)[1] demonstrates that just using biomass isn’t enough, it’s which biomass and how applied.

[1] O’Connell, D., Keating, B., Glover, M., (2005), *Sustainability Guide for Bioenergy: A scoping study*, RIRDC Publications, https://rirdc.infoservices.com.au/items/05-190

Table 2: Balancing benefits and disbenefits of bioenergy

Biomass production/ recovery for Bioenergy can:	Which can present as a benefit…	Or as a disbenefit…
i) Provide a level of security of supply from the sun rather than fossil sources that are finite	If generated and recovered sustainably	If too much fertile land is quarantined or degraded in the process
ii) Provide more localised supply of heat and power	By reducing transport (fuel) and transmission (power) costs and impacts	Where smaller plant is less efficient in the conversion of the biomass – lack of efficiency equals waste of initial resource value
iii) Deliver substantial greenhouse benefits with short cycle carbon release and sequestration	Because fossil carbon is contained or not released	Where more essential land uses are denied
iv) Improve overall air quality	By provision of ecosystem services when growing and, if converted via sensitively designed and operated plant, when harvested as compared with traditional fossil fuel conversion	If the conversion pathway is inefficient, such inefficiency can squander much of the potential net benefit
v) Provide economic opportunities for rural and regional Australia	Where biomass energy sources provide a major new product range from the traditional food and fibre sectors or the stimulus for land remediation programs	Where the biomass is harvested unsustainably, the land has a finite capacity to sustain yields for offsite application and biomass harvesting could exacerbate soil degradation if conducted insensitively
vi) Impact soil quality, fertility, erosion and production	If the activity is conducted to improve soil quality, fertility, retention and production	If the activity is conducted so as to deliver negative soil impacts (over harvesting, insensitive monocultures etc.)
vii) Facilitate the remediation of degraded lands	Where the production of biomass yields is from land quite unsuitable for food production	If conducted inappropriately
viii) Provide local, catchment and global water cycle and management outcomes	If conducted sensitively and with due regard to the prevailing water cycle issues	Where inappropriate planting and over harvesting etc. deliver any or all of the outcomes as disbenefits
ix) Deliver net biodiversity outcomes in the soil and above ground	Where such issues are duly considered in the selection of plantings and the conduct of the specific management plan relevant for each locale	Where insensitive planting (mono cultures) and harvesting deliver negative biodiversity outcomes
x) Provide an intensive bioremediation opportunity for certain urban and industrial waste materials	Where the plantings and nutrient cycles are managed proactively	Where inappropriate wastes are put to land and managed inappropriately
xi) Deliver social / aesthetic outcomes / impacts	Over and above the economic benefits (v)	If inappropriate methodologies or management practices are adopted

Summary and Preferred Profile for Biomass Sourced for Fossil Fuel Replacement / Supplementation

In sourcing the most appropriate, assured and cost effective sources of biomass for fossil resource replacement/supplementation, the previous discussion on sustainability issues has defined some useful scoping criteria that could affect and influence any finally selected strategy:

i) To seek to optimise biomass use is to be in the **sustainability business**. This is not because fossil resources are about to run out, although they are likely to increase in cost as governments introduce a price on carbon. To be in the sustainability sector means doing it properly, to achieve the full suite of potential benefits available for taking this initiative. The Food vs. Fuel outcomes in the liquid transport fuel sector provide clear indicators of what happens if genuine sustainability principles are not adopted. Table 2 demonstrates how the same action can produce quite different outcomes if the detail is not observed.

ii) A program to optimise the use of biomass to replace fossil resources will be greatly challenged to present as a net cost cutting exercise (because of the convenience and energy concentration of existing fossil resources). However, by addressing the issue systematically, the cost increase is likely to be no more than is absolutely essential or unavoidable to achieve the primary sustainability goals. Having adopted the most cost effective biomass sources and supply chains, a sustainable competitive outcome should be achievable, especially where economic externalities are acknowledged.

iii) The agenda to reduce Greenhouse Gas emissions and adopt potentially renewable biomass to replace or at least supplement fossil resources is attracting systematic responses throughout the economy. Certainly proactive initiatives are evident in the metals smelting/manufacturing sector, the cement sector, the petrochemical sector and the agricultural fertilizers sector. Even the energy generation industry will have ambitions to adopt sustainably sourced biomass.

To respond to this situation, each sector should focus on biomass sources that are ideally suited to their particular needs, rather than on sources suitable for only heat/energy generation, such as in the cement making or power generating sector (Table 1). This focus should be on securing the most appropriate parts of the plants identified setting aside lipid or starch or sugars or the moist nitrogenous foliage, or stem material that has a demonstrable higher order use as construction, agriculture, pulp and paper or furniture and the like.

Attachment A ii – Discussion Paper EWDP 13-013R: Making Products from Urban Wastes

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EWDP 13-013R

DISCUSSION PAPER

Making Products from Urban Wastes

As society strives to minimise waste and wastefulness, and gradually seeks to dematerialise consumption and service delivery, the majority of materials presenting in urban waste streams will need to be productively reintroduced into the productive economy for use at, or close to, their respective Highest Net Resource Value. However, such materials are technically "indeterminate" raw materials and will require clear protocols and practices to be established between the traditional waste sector and those subsequent value adding activities that aim to produce quality assured products that include a proportion of the urban waste sourced materials in any final products.

As a matter of extended logic, the traditional waste sector will experience considerable challenges to existing business models as it seeks to present finished "products", manufactured predominantly from material recovered from urban waste streams, back into established wholesale and retail markets.

Whilst individual corporations may already acknowledge and address these issues in part or in full, they are nonetheless worth reviewing at a generic level to ensure that the emerging "biomass from urban waste flows into value added products" concept is developed for least risk and greatest level of completion assurance.

The generic waste sector is a fee for service sector that is paid to collect/receive urban wastes and that the cost of sales related to the receipt of the fee is transporting, processing, treating, disposing of the wastes collected in the manner prescribed by the waste generator/client and/or as required to comply with all relevant legislation, regulation, operating licences and the general "licence to operate" as conferred by the community in general.

In comparison, the manufacture or supplier of a finished product to an identified market relies almost entirely on the income derived from the sales of their particular product to a customer, and the cost of sales includes the labour and material costs to input the respective manufacturing processes.

A comparison of the two basic business models demonstrates how the need to protect and optimise core income streams can present quite different value propositions to the markets in general and end customers in particular.

In the logical pursuit of self interest, a waste sector manufactured product will tend to be:

- Generic – produced to just meet or exceed relevant standards and be as high a quality as could be expected to be produced from the indeterminate originating resource materials;
- Priced to clear quickly, often heavily discounted or marketed so that the production chain has capacity to receive more fee-for-service wastes income;
- Supplied into a market established and currently serviced by parties who source virgin or quality assured raw materials and where the market generally has yet to fully appreciate the performance benefits of the branded product vs. the generic or waste based offering.

In comparison, a dedicated brand or product manufacturer will tend to:

- Differentiate their offering, often supported by the value proposition their brand has diligently created and promoted to best address an identified market niche or need;
- Price the product to reflect real value to the customer when compared with any other commercial offer that could achieve the same or similar benefits whilst maintaining the highest possible margin over cost of sales; and
- Establish a unique market or maximize market share and so set the benchmark for performance and customer satisfaction.

Initial comparison of the two business models and their inherent skill sets presents them as quite different, and suggests that to optimise entire value/supply chains, the two models need to be acknowledged and accommodated. And there is a strong precedent and track record for the two generic sectors combining for maximum advantage to both. For example:

- The waste sector is now expert at recovering paper/cardboard, but they don't make the new boxes and packaging that can beneficially apply such recovered materials to replace/supplement virgin pulp.
- Similarly, the waste sector is expert at recovering cullet – but they don't attempt to make new bottles and jars.
- Metal recovery is another area where there is clear differentiation between the collection, aggregation and preliminary sorting and processing of scrap – but specialist metal manufacturers now accept such inputs into the manufacture of new metal products such that the resultant products never need to "apologise" for their origins.

However, recent initiatives to recover resource value from the residual organic/biomass fraction of urban wastes have focused on composting as both a waste treatment technique and simultaneously as a product manufacturing process. This has presumably emerged because composting and subsequent land application seems much less technically demanding than the above examples in the more traditional recycling sectors. There has been much activity in the last 5-10 years for those with a "waste sector" business model and approach to enter the established composting and soil amendments sector, and the results have been, at best, mixed; presumably for the reasons outlined above, all of which starts to outline some project principles for success to address the current potential to recover the biomass fraction from urban waste streams for application in the highest value markets available.

Where a product manufacturer will support a potential customer with pre-production or representative samples, and then follow up with initial supplies that confirm the initial promise, and then have sufficiently secure product quality control procedures in place to be able to follow up at any subsequent time with supplies of the same material to achieve the same result, a waste sector generated product will be more challenged. Because the primary incentive is to process as much of the "waste" feedstock as possible, the actual quality of each batch of product can be heavily influenced by the quality, on the day, of the actual qualities of the indeterminate values of the original "waste" raw materials.

In the cardboard, glass and metals examples above, the original products were manufactured from virgin or defined raw materials and whilst these sectors have now developed the capability to maintain product quality whilst replacing and supplementing much of the virgin feedstocks with secondary resources from the waste sector (mostly for price reasons only), they could revert to virgin supply if the secondary stocks were unavailable, of unacceptable quality, or ceased to offer important price advantages. In comparison, the waste sector produced products can tend to be characterized as the best-quality-possible-with-the-materials-available-on-the-day, if this issue is not addressed comprehensively from the beginning of any such projects.

A difference between the two business models can also show up in pricing issues. The ultimate commercial viability of a specialist finished product manufacturer is entirely dependent on realising a margin on cost of sales to provide the particular product. A waste sector derived product will often be priced-to-clear so that the production chain is available to accept more fee-for-service income by collecting/acquiring more raw material.

This has been painfully demonstrated in recent years in the compost sector, where the introduction of priced-to-clear compost products originating from the waste sector have reduced much of the pre-existing landscape/agricultural supply sector to “commodity” pricing, and where the tangible benefits to end users are often not adequately reflected in the price paid for the product. In other words, the waste sector approach to selling finished products can result in potential value being “wasted”.

Too often MSW derived “composts” are presented as the minimum quality necessary to demonstrate compliance with the relevant waste processing licence conditions rather than being directly related to an actual customer/market need. This is especially true in the bulk mine site remediation market or other less sensitive (non food growing) bulk market sectors.

Since products made **solely** from “indeterminate” wastes will struggle to meet even a basic level of quality assurance for end users, such product manufacturing must be willing and able to source additional process input materials to achieve final product quality. Alternatively, the waste sector suppliers could contract with a dedicated finished product manufacturer who had access to all the additional input materials necessary to optimise final product value, as exampled by the cardboard, cullet and metal examples above.

Attachment A iii – Discussion Paper EWDP 13-011R: The Business of Sustainability

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DISCUSSION PAPER

The "Business" of Sustainability

The climate change, resource depletion and circular economy agendas are providing tangible commercial opportunity for alternative, sustainable, renewable, non-fossil fuel policies, projects and activities to present as well supported alternatives. In the case of the emerging biomass based sector in particular, the measurable benefits are not achieved by just using biomass as an alternative industrial feedstock, but how such materials are applied.

As biomass based supply and value chains are established, the commercial incentives are usually underpinned by either a legislated price on carbon, or the various end markets demanding such materials in response to customer/societal demand.

However, in either case, if the actual activity cannot justify the CO_2-e mitigation advantages claimed, the alternative enterprise could be stranded and/or rendered entirely unviable.

The Sustainable Bioenergy Sector

Recently generated biomass (<100 years) has considerable potential to replace or supplement fossil based resources in the provision of heat, power, reductants, chemicals and fertilizers etc. but the net GHG benefits and ultimate sustainability of such an approach depends in large measure on the detail of the actual activity and implementation, rather than just the fact that biomass was used. A consolidated summary of the literature related to sustainable biomass use for such applications resolves around three core issues:

- Sustainable yield of the selected biomass resource;
- (Thermal) efficiency of the conversion pathways; and
- Targeted application of the products and services.

Very briefly:-

i) Sustainable Yield

The provision of biomass is ultimately a land use issue. Sustainability requires the finite biosphere to be able to provide a wide range of essential services such as:

- Food and fibre production;
- Materials for construction, engineering and industrial purposes;
- Social, recreational, aesthetic and passive uses;
- The provision of ecosystem services, including:-
    - water, nutrient and mineral cycles
    - soil manufacture and maintenance
    - biodiversity support
    - air quality maintenance
    - etc. etc.

These essential services are currently scheduled to service some 9 billion people within the current century, all with aspirations to achieve western style lifestyles.

The potential for the finite biosphere in general, and the productive soils in particular, to also take a primary role supporting the "solar power" conversion of CO_2 into biomass, to replace fossil resources will need managing with extreme caution and attention to detail. To achieve this, the accepted management philosophy must be based on a "maintain or improve" standard for global soils. That is to manage soils such that existing quality is maintained or improved as a result of any proposed activity. [A corollary to this requirement is that where soils are destroyed for some other essential activity (e.g. mining) such activity can only acquire a sustainable status where an appropriate mitigation or remediation plan is included in the approval process.]

The provision of quality, fit-for-purpose, biomass based products could have a crucial role to play in supporting this "maintain or improve" soil quality requirement, and could register for carbon benefits in the process, but all these benefits can be undermined if the original biomass yield was unsustainable, inappropriate and produced at a significant detriment to soil quality to begin with.

ii) Conversion Pathway Efficiency

Biomass is ubiquitous in the biosphere which is both an advantage and a crucial process efficiency issue.

The fossil resources that currently provide the main products and services, that are now being considered for replacement and/or supplementation with biomass based products, have been conveniently energy concentrated and deposited in point sources that have underpinned industrial development for the last 250 years. Major power generation or heavy industrial developments occurred adjacent to the fossil fuel (or raw material) source, and if more product or energy was required, more fossil resource was extracted. However, biomass, the original source for today's fossil resources, is neither energy nor geographically concentrated, and its harvesting relates more to agricultural rather than industrial business models.

In short, initial harvesting, transport and aggregation are substantial costs not experienced to anything like the same degree by fossil resource alternatives.

Similarly, the conversion technologies and product development, marketing and distribution channels are all nascent, even if currently undergoing rapid but incremental development and improvement. This issue almost ensures that any current project established with best available technologies and logistic pathways will be superceded by new developments and technologies during the project lifetime.

iii) Targeted Application of the Products and Services

Having sourced sustainably yielded biomass and adopted the most efficient conversion pathway, any net GHG, sustainability and even commercial benefit can be suboptimal if the end product or usage is not the most cost effective and appropriate.

For example, ONLY making power from biomass is likely to be suboptimal at all levels. At a more refined level, only supplying biochar as a carbon sequestration product (which it has very strong credentials to be) is to give up the opportunity to not also provide the optimum soil amendment and productivity characteristics at the same time. Perhaps biochar, for example, should be applied as a high analysis fertilizer "extender", rather than just a stand alone product.

A sensitively manufactured and used biochar product could generate revenue from one or all of the following characteristics:

- Carbon sequestration benefit – dependent on voluntary market or a prevailing Government scheme;
- Liming properties – pH modification traditionally achieved with the application of commercially available lime;
- Reduced high analysis fertilizer use over time – assessed by conversion with historical data;
- Improved yields -
  - Absolute – compared with historical data
  - Relative – yield value less input costs
- Improving soil quality and productivity over time – measured from future and past agronomic assessments; and
- Reduced disposal costs for original biomass inputs.

Any of these revenue producing benefits could be achieved at any one time, but to seek to optimise all such benefits with each project will ensure a competitive advantage for the product manufacturing activity.

Attachment A iv – Discussion Paper EWDP 13-014R: Striving to achieve Highest Net Resource Value (HNRV) from Materials reclaimed or recovered from Urban Waste Streams

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EWDP 13-014R

DISCUSSION PAPER

Striving to achieve Highest Net Resource Value (HNRV) from Materials reclaimed or recovered from Urban Waste Streams

The fossil resource based sector, and in fact most primary or extractive industry sectors in an advanced modern industrial economy, have grown to thoroughly analyse and understand the innate properties and characteristics of each and every deposit as it is discovered, to understand what each deposit could ***be best used*** *for and therefore the appropriate value/price each deposit should attract.*

In the emerging resource recovery sector, such grading and evaluation of potential biomass resources are not as well understood, or valued or priced.

The immediate importance of this issue to the emerging resource recovery sector is that it could materially affect the viability of early projects. If "high value" resources are applied, and relied upon, to produce only low value or "commodity" priced products, the entire enterprise could flounder when alternative or later projects are set up to convert the same "high value" resources into high value products, and thus attract the feedstocks away from the initial converter.

One of the features of modern, capitalist industrial economies is the market mechanism to allocate resources by pricing the supply and demand dynamics.

This market based mechanism is the best and most efficient framework for allocating resources that society has developed and adopted to date. But the mechanism works best with established and well understood commodities and resources. The contention here is that potential market failures can and do exist where new or not properly understood commodities come to the attention of nascent markets. Resources recovered from urban waste streams are case in point (see EWDP 13-013R).

The concept of Highest Net Resource Value refers to the practical philosophy of seeking to apply a particular resource to its highest (practical) end use application, net of acquisition, process and aggregation costs.

Such an approach is seen as vital in the early stages of the urban waste resource recovery sector to help to ensure that resource value and potential is not unreasonably allocated to some inappropriate end uses where:

a) The original investment could be jeopardised if and when a higher value market is established;

b) Higher value opportunities are frustrated by the inability to access reclaimed resources currently allocated expediently; and

c) The real value of currently unpriced externalities is not recognised.

As the market for recovered resources matures, these issues should self regulate, but, until recognised standards and pricing matrices are established, immediate investments in this sector should pay particular attention to this issue, using LCA if necessary to help guide their risk assessments prior to investment.

Attachment B 1 – Dubbo Case Study: A prospective “Producer” BioHub

Attachment B 1

Dubbo Case Study: A prospective “Producer” BioHub

Background

As a result of general discussions at a Waste Management Association of Australia (WMAA) Industrial Ecology Network (IEN) meeting in early 2012, Renewed Carbon Pty Ltd was invited to address a Sustainability Advantage cluster meeting at Dubbo 8/05/12 to speak to an agenda item on biomass issues and possibilities that might be pertinent to the Dubbo region, and to introduce the Renewed Carbon BioHub concept (attached A).

The meeting stimulated considerable interest and Renewed Carbon organised with Dubbo City Council business development team to conduct a special community meeting 13/09/12, at which invitations went to a broad spectrum of potentially interested parties.

The interest generated stimulated a specific project “stakeholder” meeting, again in Dubbo City Council meeting rooms, to confirm general enthusiasm to support the production of a specific Pre-Feasibility Study (PFS). Stakeholders present committed to support such an outcome and to support a formal submission to NSW Office of Environment and Heritage Sustainable Advantage program for supporting funding for the PFS.

Eco Waste Pty Ltd was then asked to prepare a specific funding request to OEH and the resultant contract to undertake the work was executed January 2013.

Supporting “stakeholder” group for the project included:

- Dubbo City Council
- NetWaste
- Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE)
- Orana Catchment Management Authority
- Western Plains Zoo
- NSW OEH Sustainable Advantage Program
- A local agricultural service contractor
- Carbon Farming Australia
- Renewed Carbon Pty Ltd

The main commitment by stakeholders was to provide detailed data and information as required and/or to help scope solutions and/or market possibilities.

An “observer” group was also formed consisting of all other interested parties who had come to previous meetings or sought to better understand the potential for a national BioHub network. These included Orana Regional Development Australia, on behalf of the 54 other national offices, and DIISRTE, who are also keen to understand the potential and barriers to optimised biomass utilization, on a national basis, as a sector of potential competitive advantage for Australia.

The observer group have undertaken to at least review drafts of this PFS and provide considered comments to help inform the final document.

Agreed scope of Work

The project was supported by the NSW OEH "Sustainability Advantage" program.

3.1 Project Prelims

- *Confirm stakeholder participation;*
- *Record benchmarks for success and/or conditions precedent, all or any, for each stakeholder; and*
- *Confirm study parameters and outcomes.*

3.2 Research Potential Regional Biomass Inputs:

- *Urban waste flows managed by Dubbo City council and/or local waste contractors including biosolids;*
- *Consider the potential for similar urban waste flows from adjacent communities such as Wellington, Narromine, Gilgandra and other?;*
- *Assess potential agricultural residues from cropping and grazing etc.;*
- *Assess potential residues/sludges etc. from local processing facilities;*
- *Assess potential land care/land management residues such as woody weeds, agroforestry etc.;*
- *Assess potential for sustainable biomass yields from current and future revegetation initiatives and localised vegetation management programs;*
- *Summarise short, medium and long term potential biomass inputs and the likely logistic and commercial conditions that might pertain to each in the even that a staged acceptance framework was proposed.*

3.3 Develop Schedule of Highest Net Resource Value Products

- *Reflect on the qualities, quantities, reliability and seasonality of the various biomass inputs available to support a possibles/probables list of potential products.*
- *Consider the most practical routes to market for each and the range of potential sales revenues that could be realised.*

3.4 Process Technology Review

- *With inputs assessed and outputs considered, the logical process systems and technologies to be reviewed at a generic, "desk top" level.*
- *Where crucial technological capabilities are identified, a high level vendor enquiry process to be undertaken to acquire first order data and costings to support subsequent financial analysis.*

3.5 Design, Develop and Populate financial Model

- *Model to allow key sensitivities to be tested and basic viability to be assessed.*

Of the project stakeholders, Dubbo City Council provided their most recent urban waste data; NetWaste contributed the information contained in a separate report that they had independently commissioned, "Organics Management: Options for the NetWaste Region" by Impact Environmental, May 2013 (copy available on request; Orana CMA in general, and the Buckwaroon Catchment Landcare Group (BCLG) provided detailed background information in relation to the Cobar Peneplain woody weeds issues; the Western Plains Zoo provided detail of their particular organic waste arisings; Saxa Spreading Services provided detail in relation to the needs, current practices in relation to seeding and fertilizer application in the greater Dubbo cropping sector; and Renewed Carbon provided a commercial and operational concept model for a regional BioHub to be specifically assessed in the scope of works for the study.

A summary of the findings of this study includes:

Table 1: Estimate of potential regional biomass arisings

Stream #	Category	Potential at start up	Potential on going concerns basis	Quality Issues	Most suitable resultant product
		Dates / t/pa	**Date / t/pa**		
1	Forest Harvest	Opportunistic	Opportunistic	-	-
2	Agricultural Harvesting	Opportunistic	Jan-Mar / 2,000 July-Sept / 2,000	Homogeneous High ash	Biochar & bioenergy
3	Forestry Process	Opportunistic	12 mths / 500	Homogeneous Low ash	Reductants & bioenergy
4	Agricultural Process	Opportunistic	12 mths / 2,000	Homogeneous High ash	Biochar & bioenergy
5	Zoo Poo	12 mths / 2,500	12 mths / 3,000	Homogeneous High ash	Biochar & bioenergy
6	Cotton Trash	Apr-July / 10,000	Apr-July / 10,000	Homogeneous High ash	Biochar & bioenergy
7	MSW 50% residue, 50% organic	12 mths / 48,000	12 mths / 52,000	Heterogeneous High ash	Biochar & bioenergy
8	Development Arisings	12 mths / 2,500	12 mths / 3,000	Homogeneous High ash	Biochar & bioenergy
9	Vegetation management	12 mths / 2,500	12 mths / 2,500	Homogeneous High ash	Biochar & bioenergy
10	Woody weed/INS	12 mths / 10,000	12 mths / 12,000	Homogeneous Ash various	Reductants &/or Biochar & bioenergy
Totals		**75.5 kt/pa**	**89 kt/pa**		

In summary, Table 1 presents some 48 kt/pa of residual MSW as potentially contractible for processing to separate the organic/biomass fraction, for conversion to biochar through the proposed BioHub; some 2.5 kt/pa of vegetative residues and manures arising regularly and some 10 kt/pa of regional cotton trash. These materials present with the potential to be initially contracted inputs into a local BioHub, to support the establishment of such a facility.

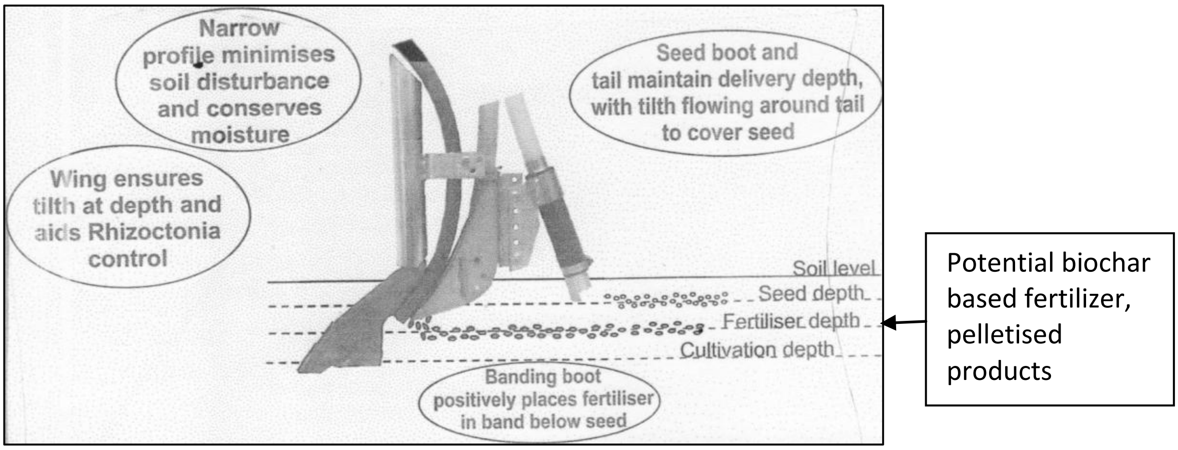
A further 15 kt/pa of "spot" or occasional biomass arisings were identified and being most likely to be presented to a regional BioHub for processing into value added biochar, bioenergy and/or charcoal products, if the proposed BioHub was available as a going concern. But the discretionary nature of the arising of these additional materials means that they are not available as contractible or assured supplies to support the initial capitalisation of a BioHub project in Dubbo.

In later years, after some 2-4 years, a further 13.5 kt of regional biomass arisings was identified as being likely to be presented to the regional BioHub once it was established and locally recognised in the market place.

Potential Products, especially with Local Demand

Discussions with local cropping property owners and local seeding and fertilizer spreading contractors identified the opportunity to beneficially and cost effectively apply a biochar/NPK blended "all in one" fertilizer product that could be applied via standard air seeders.

Figure 1: Air seeder



The proposed biochar based pellets will be designed to:

- Supply "starter" nutrients to support germination;
- Replace nutrients removed by the previous crop;
- Supply high analysis, slow release fertilizers to sustain the new crop; and
- Supply catalytic minerals to stimulate soil microbial activity and over soil quality
- Provide a substantial biochar component in each pellet, equivalent to a broadcasting rate of approx. 10 t/ha, but supplied only to the root zone to improve cost effectiveness.

Such products could be delivered in liquid or pellet form and by delivering the product direct to the root zone, only the exact amount of nutrient will be supplied to minimise the run off and loss of nutrient value.

An initial demand of some 10 Kt/pa for such a product was considered practical in the face of potential local demand. This amount could at least double over time needed to meet regional demand.

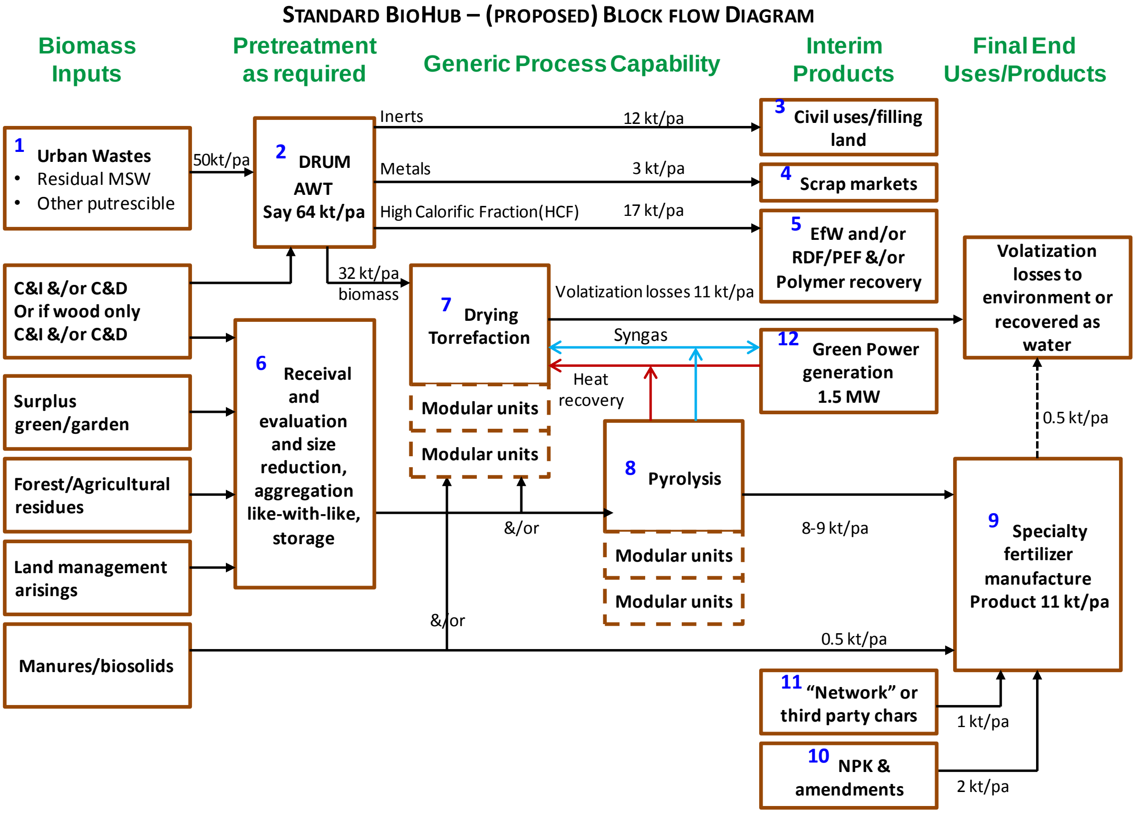
Initial physical pellet trials have demonstrated that they are entirely suitable for delivery via standard air seeders, and now Renewed Carbon and UNSW are developing an ideal biochar/nutrient/binder blend for field trials in the next planting season as part of their ARC Linkage project LP120200418.

Proposed Regional BioHub Process Capacity

To provide the services outlined and justified in the previous sections, and as a platform to manufacture the products and services proposed, and to be in a position to deliver all the services and collateral benefits outlined in Section 1 generally, the basic block flow diagram (BFD) has been developed to provide at least a basic framework for estimating first order viability of the project objectives as described and justified in previous sections.

For this PFS, the respective technologies proposed for each stage will be discussed and described as numbered in Figure 2.

Figure 2: Standard BioHub – (proposed) Block flow Diagram

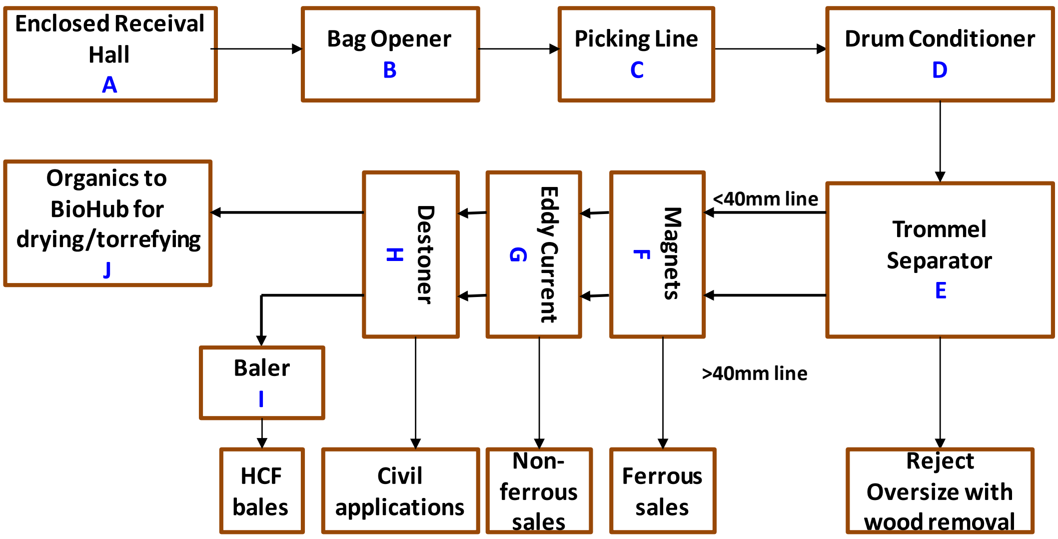


1) Urban wastes as described 2.3.

2) Generic "drum" style AWT to receive mixed residual wastes, provide an opportunity to recover Household Hazardous Waste (HHW) and/or bypass dry recyclables, process material to separate organic (<40mm) from non-organic (>40mm) materials (the "blister pack" separation standard) and post treat both major streams for inerts/heavy particle removal and ferrous/non-ferrous metals recovery.

   The generic Block Flow Diagram for this facility is shown in Figure 3.

Figure 3: Drum AWT Block Flow Diagram



- **A** **Enclosed Receival Hall** where incoming material is checked by small front end loaders (FELs) for gross contaminants before being pushed onto the in-floor plate feeder which will convey materials to the Bag Opener.
- **B** **Bag Opener** where materials are released and exposed for the subsequent picking line.
- **C** **Picking Line** – this capability is proposed to remove any obvious HHW materials and recover any obvious dry recyclables that were not more correctly discarded via the kerbside "yellow bin" service or originated in the C&I stream.
- **D** **Conditioning Drum** –by managing moisture, feed rate and particle rotations, the materials will be conditioned without shredding in preparation for subsequent trommel screening.
- **E** **Trommel Screens** process the conditioned materials such that the <40mm material will be predominantly the organic fraction (including conditioned cardboard and paper etc.), the <40mm to 150mm material will be predominantly the "plastic" High Calorific Fraction (HCF) and the >150mm oversize fraction will present for wood recovery from what otherwise will be a reject/inert fraction.
- **F** **Magnets** remove ferrous metals from both the <40mm and >40mm lines.
- **G** **Eddy Current** removal of non-ferrous metals.
- **H** **The Destoner** or ballistic separators remove inert materials such as glass, ceramics and masonry fragments, which being now separated from the putrescible, organic fractions, will be suitable for select civil applications.
- **I** **Baler** preparation of HCF for transport for sale or storage.
- **J** **Organics Interim Storage** or inventory control, will balance the urban waste derived biomass **inflow** with the subsequent BioHub drying/torrefying process **outflow** as an inline process to avoid the aerated organics generating potential odours.

3) Inert or non-putrescible materials will be suitable for select civil applications, perhaps blended with C&D masonry or crushed concrete for under-course applications.

4) Recovered metals for direct delivery to local scrap metals facilities.

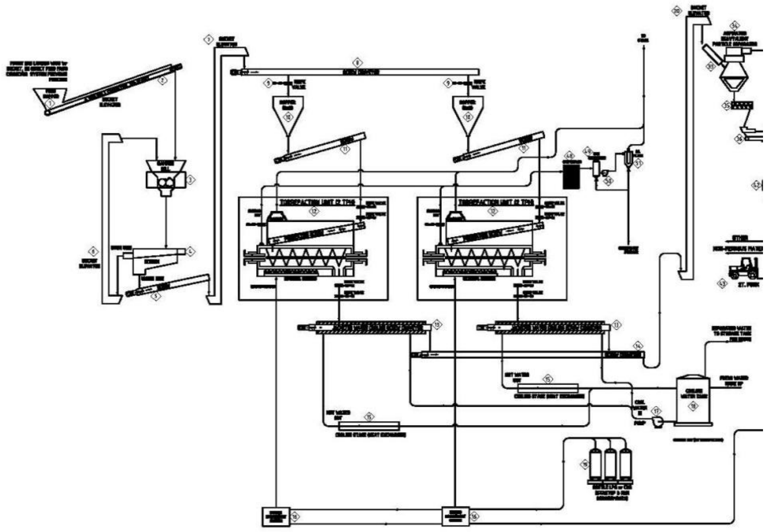
5) The high calorific fraction (HCF) will present as an RDF or PEF product for subsequent processing for kilns, EfW facilities or more specialised secondary plastics processing to create petrochemical industry platform products such as Naphtha.

NB: Facilities to process these plastics for such high value outcomes don't exist in Australia at present. One reason is that systematic and assured supply of such HCF materials cannot be demonstrated at present. So wherever such drum AWT facilities are established to supply biomass to a BioHub, or other, the short term use may be as baled and stored at landfills, and/or supplied as RDF to specialist facilities, but in the medium to long term they will begin to demonstrate assured supply to potential developers of such higher order facilities.

6) Other regional biomass arisings as described Table 1.

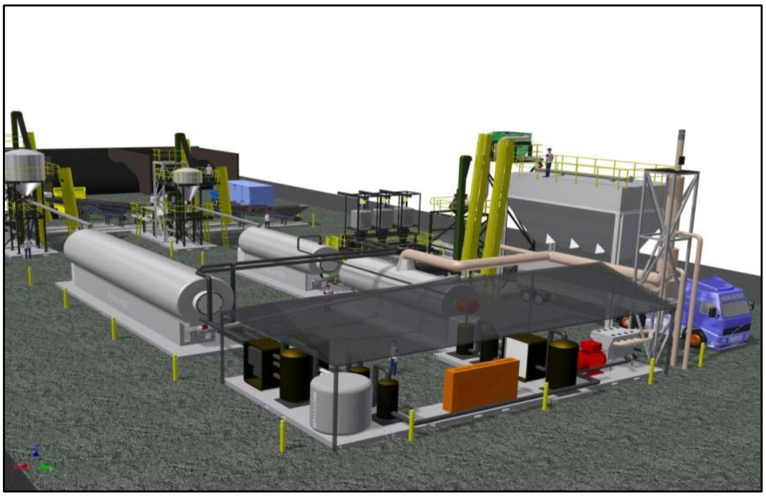
7) **Drying/Torrefying** (approx. 280-300°C) is the initial step in the thermal gradient of process stages from raw, wet biomass up to final slow pyrolysis temperatures (450-500°C).

Figure 4: Concept drying/torrefaction plant



8) Pyrolysis Plant

Figure 5: Typical pyrolysis plant concept



This facility accepts prepared materials to produce a char product and syngas. If supplied with quality low ash materials, the unit can produce metallurgical grade charcoal products. If supplied with high ash materials, the same unit can produce biochars for fertilizer manufacture. The proposed pyrolysis capability would be commissioned in discrete operational modules – usually 1, 2 and 4 t/hr feed rates, such that parallel units could be processing different feed streams.

NB: The main thermal units **7** Torrefaction, **8** Pyrolysis, **9** Fertilizer manufacture and **12** Green Power Generation would all be linked by a common heat exchange system, for optimum waste heat recovery and reuse, and a common gas supply system and all terminating in a single stack/emissions point to ensure better than EU W.I.D. minimum emissions standards.

9) Final fertilizer product manufacture – Working closely with the cropping sector, their preferred agronomists and their contract spreaders, it has become clear that the opportunity to apply biochar in board acre applications needs to directly address the entire fertilizer needs holistically. That whatever the benefits and values of biochar, each crop needs measured applications of high analysis NPK, select trace elements, soil microbial activity stimulants as well as the biochar and sundry catalysts and binders. This in effect presents biochar as an NPK “extender”.

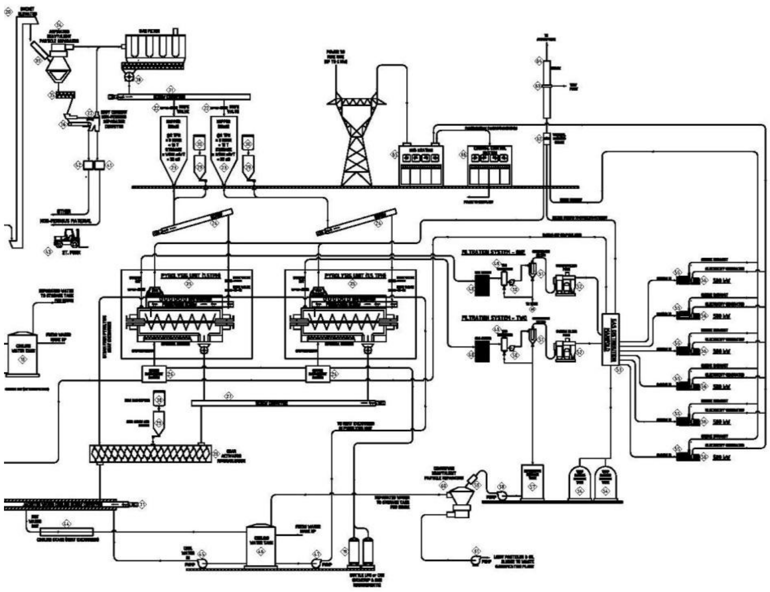
This fertilizer manufacturing facility will accept hot, fresh biochar and quench the material by mixing with all the other “moist” ingredients and binders to create the individual products for each customer, in the product binding, pelletising process, and then dispatch quality assured products to each property, tailor made to exactly match their express requirements.

10) Hoppers of third party ingredients to blend into the finished products.

11) BioHub specialising in fertilizer manufacture – in effect a Producer BioHub would be located where the demand for finished fertilizers and other products will significantly outstrip the availability of local biomass supplies. This opens up the need to import partially processed/torrefied materials from elsewhere to provide chars of the required specifications to supplement supply.

12) Syngas generated by the pyrolysis processing will be applied first, to power the pyrolysis process itself, and provide final energy balance to the drying/torrefaction process, and then all excess syngas will be diverted to modular gas engines, similar to those currently used to convert landfill gas.

Figure 6: Pyrolysis processing



NB: Single stack for onsite emissions to ensure better than EU-WID emissions standards as a minimum and full waste heat recovery for the drying processes.

This generic Standard BioHub layout provides a framework to develop a first order financial model around, which, if extrapolated into a possible “network” scenario, will provide guidance as to the effect, impact and benefits.

Financial Modelling

The project biomass inputs, the proposed product range and the CAPEX/OPEX estimates that arise from the process flows depicted in the BFD above have been modelled.

Analysis Summary

1. Input data - Dubbo Phase 1

Feedstock from MSW C&I[1]	50,000 tpa@<40% Moisture Content	Gate Fee $80/ton
Supplementary feedstock from forest waste	c14,000 tpa	Gate Fee $0, plus delivery cost
Network Materials	c2,000 tpa	Agreed transfer price
NPK and additives	c4,000tpa	Market prices

2. Output data - Dubbo Phase 1

Inerts sorted out by drum	c10,000tpa	Returned to Council for landfill
Metals sorted out by drum	c2,000tpa	Sold at scrap market price
HCF sorted out by drum	c3,000tpa	Baled and sold at market price
Product sales - NPK substitute	c16,000 tpa	Sold to Farmers
Green Electricity	1.5MW	Sold as Green Power under a Feed in Tariff agreement

3. Sources and use of funding - Dubbo Phase 1

Local Equity	c$5,000,000	25% Equity
Phase 1 Grant Funding	c$5,000,000	Generation of employment plus c$2m in tax rev pa
CEFC and Bank Funds	c$9,700,000	Commercial Terms
Total CAPEX Phase 1	c$19,700,000	+/ - 10%

4. Strategic Partner project Provisions

Site for 2 phase plant	Provided by local owners at peppercorn rent to project
Offtake Agreement - NPK replacement	By local farmers and spreading contractors
Offtake Agreement - green energy	By Diamond Energy or similar [to be tendered]

5. Financial summary - Dubbo Phase 1

Schedule used in modelling	12 month build, 12 month ramp up
Annual net revenue when operating	c$10million/year
Employment when operating	Direct Management and Staff - 20 FTE's
Debt Repayment	By end of year 7 of operations
Phase 1 IRR	21%
IRR Sensitivity to +/-$50 end product price	3%
IRR sensitivity to +/-$10/MW electricity price	1%
IRR sensitivity to +/-20$ waste "gate fee" price	2%
IRR sensitivity to +/- 10% CAPEX variation	5%

[1]Based on feedstock samples provided to and tested by RC and others in March 2013.

[2]See report for details of tangible/intangible benefits. Conservative CO_2e assumptions have been used in the modelling.

[3]Based on party estimates, allowing for site set-up, project development, FEED etc.

[4]Renewed Carbon does not have an AFSL. This data is provided for information only & not for investors/others.

[5]Assumed interest rate is based on risk adjusted & blended CFEC and commercial bond+ rate.

[6]NPV's have been calculated at various discount rates to provide an IRR approximation.

[7]Based on 2 phase project being designed at outset. Takes BioHub to sustainable economies of scale/meet demand and be the full validation model for the national roll out of BioHub transfer processing centres scheme.

Summary and Conclusions

If constructed and operated as proposed in this case study, such a BioHub would be profitable, returning an IRR of approx 20% for what is in effect basically a public service infrastructure project with some "merchant" capabilities and service offerings that are only viable because the basic facilities can be capital justified on the basis of the core service offering to the local community.

This basic MSW processing benefit can be delivered for no more than current "true cost" of landfill, and within a commercial framework that could be constructed to:

a) Provide predictable, no more than CPI escalation into the future;

b) Remove local CO_2-e liabilities that could accrue to the existing landfill operation;

c) Provide for a de-escalation of future gate fees as the "merchant" activities became established and started generating an alternative source of assured BioHub revenue; and

d) Provide a strategic platform whereby the existing Whylandra Waste and Recycling Centre could be operated simply as a regional materials management centre that need no longer fill up or have a defined lifespan as it would no longer be required to treat residual MSW by sanitary landfilling. The site could instead be a productive employment centre for market pulled, materials processing and quality product manufacture.

The Dubbo model, (commercially anchored on processing the local MSW as a priority input, so that all the other merchant activities can be conducted, and collateral service benefits realised), could be replicated in most regional centres throughout Australia, where a basic population of >35,000 could create critical mass within a 100 km radius of a "standard" facility.

Possibilities currently in early stage discussion include:

- Northern Rivers, NSW;
- New England, NSW;
- Mid North Coast (Kempsey), NSW;
- Orange, NSW;
- Lithgow, NSW;
- Wagga Wagga, NSW;
- Griffith, NSW;
- Albury/Wodonga, NSW/Vic;
- Ballarat, Vic;
- Latrobe Valley, Vic;
- Werribee, Vic; and
- Salisbury, SA.

But many groups of metropolitan councils are also suitable for similar strategies.

The other main feature of this proposed Producer BioHub is the addition of the specialist fertilizer production onto what would otherwise be a "Standard" BioHub configuration.

A standard BioHub could be expected to produce biochar products worth $100-$250/t and a bioenergy output only, but with the connected product manufacturing capability:

the locally sourced biomass is effectively doubled in value ($200 to $550/t) and a demand is created for additional biochar supplies from other “Standard” or “Feeder” BioHubs elsewhere in the proposed “network”. In fact the proposed Dubbo BioHub could support a number of satellite “Feeder” BioHub facilities that could access and pretreat a wide range of biomass arisings in the extended area, including forestry residues (to the North East), manures (from the North East), cotton trash (from the North) and INS biomass (from the West and South West). This presents as a real possibility because of the extent of the apparent demand for the proposed fertilizer products.

To progress this Dubbo proposal, a group of local business interests need to commit to supporting the project through full project feasibility studies and FEED on a dollar for dollar basis with appropriately sourced grant funding.

As and when the project achieves a commercially viable and strong financial close, suitable project funding and third party debt and equity funds will the need to be identified.

This project could present as an ideal candidate for CEFC support at that time.

Attachment B 2 – Woody Weeds/INS for Metallurgical Charcoal and Energy: an integrated BioHub Opportunity

Attachment B 2

Woody Weeds/INS for Metallurgical Charcoal and Energy: An integrated BioHub opportunity

1. Introduction

The following case study has been supplied by Renewed Carbon Pty Ltd (www.renewedcarbon.com.au) who is currently developing a woody weed/INS to charcoal and energy project with a number of specialist parties. This case study represents a summary of detailed project development collaboration with:

– The Buckwaroon Catchment Landcare Group (BCLG), now trading as Western Regeneration, **in relation to the biomass supply issues**;

– Collaboration between Renewed Carbon and various technology development parties **in relation to the biomass conversion/technology issues**; and

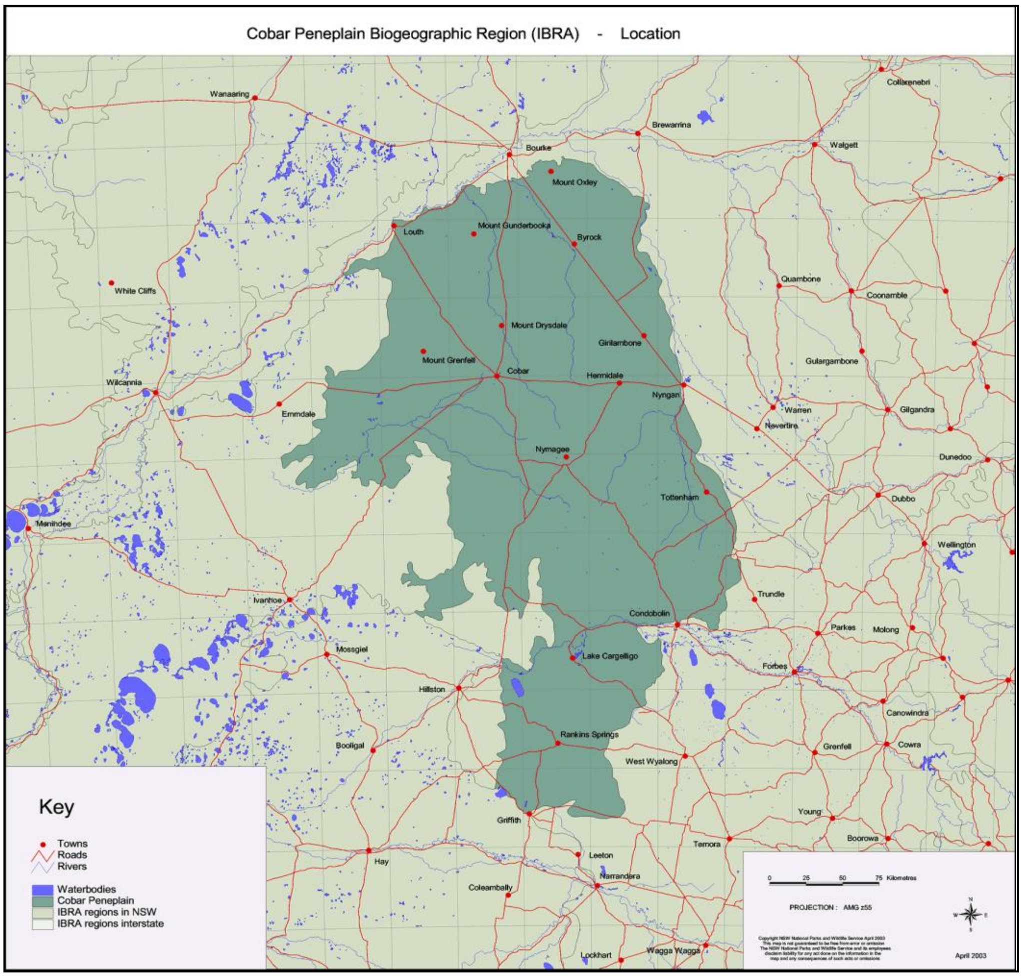
– The ISP (Integrated low emission Steelmaking Process) project, that represents a collaboration between BlueScope Steel, Arrium (formerly OneSteel) and CSIRO (Minerals Flagship – Monash) **in relation to the final product demand, quality and conditions of supply** (and as summarised attachment C).

2. Woody weeds/INS as a potentially sustainable source of biomass

2.1 Area of Woody weeds/INS under consideration

The main area of sustainably yielded biomass supply that is being considered for this proposed project is detailed in Figure 2-1.

Figure 2-1: The Cobar Peneplain Bioregion



The Cobar Peneplain area is managed by the Western Catchment Management Authority (CMA) who administers the Native Vegetation Act 2003 (NVA).

2.2 The woody weed/INS issue and history

Before European settlement, the region consisted of woodland with grassy understorey which had been maintained in this form by thousands of years of Aboriginal “fire stick” farming (Fig. 2.2).

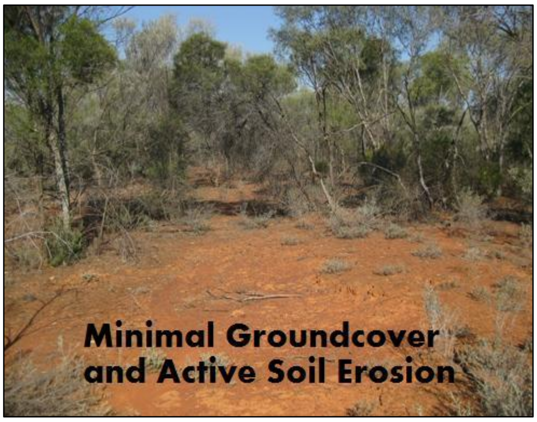
Figure 2-2: Woodland with grassy understorey

Europeans then reduced burning and ringbarked the woodlands. After a combination of devastating fires, rabbits, some high rainfall seasons, and over grazing, the net result was that the “weedy”, “early adopter” species, such as cypress pines grew back quickly and crowded out grassland and slower growing species.

Figure 2-3: INS dominated landscape

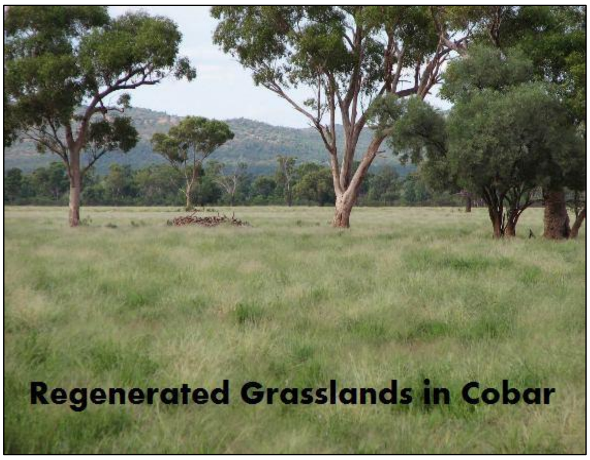
This overcrowding has caused a loss of ground cover and exposed the ancient soils to erosion.

Figure 2-4: Loss of ground cover and resultant erosion and soil compaction



In recent times, proactive land management practices and strategic clearing as sanctioned by the Western CMA has demonstrated the ability to restore the land to pre European grassy woodlands, ideal for sustainable and productive grazing once again.

Figure 2-5: Regenerated grassland achieved by proactive clearing and restoration activities



However, in restoring the grassy woodlands, the cleared vegetation is windrowed and burnt.

Figure 2-6: An unsustainably "wasted" resource

The invasive native species to be managed include a wide range of timbers, some slow growing hardwoods and some "early adopter" less valuable timbers (Table 2-2).

Table 2-1: Predominant Invasive Native Species of the Cobar Peneplain area

Scientific Name	Common Name/s
Acacia aneura	Mulga
Acacia homalophylla	Yarran
Callitris endlicheri	Black Cypress
Callitris glaucophylla	White Cypress
Dodonaea viscosa subsp. angustissima	Narrowleaf Hopbush
Dodonaea viscosa subsp. spatulata	Broadleaf Hopbush
Eremophila longifolia	Emu Bush
Eremophila mitchellii	Budda, False Sandalwood
Eremophila sturtii	Turpentine
Eucalyptus intertexta	Red Box
Eucalyptus populnea	Bimble Box, Poplar Box
Geijera parviflora	Wilga
Sclerolaena birchii	Galvanised Burr
Senna form taxon 'artemisioides'	Silver Cassia
Senna form taxon 'filifolia'	Punty Bush

Currently certain provisions are being reviewed by the NSW Environment Protection Authority (http://www.epa.nsw.gov.au/epamedia/EPAMedia13071101.htm) to reconsider the opportunities to generate power from such materials, rather than simply waste the material as shown in Fig. 2-6 – which is the only currently acceptable practice.

Within the provisions of the Native Vegetation Act as it currently stands, property owners are required to consult with the CMA to develop specific Property Vegetation Plans (PVPs) that establish an approved INS clearing and subsequent restoration plan for each property. The implementation of such plans has produced the results demonstrated in Fig. 2-5, from infestations that presented as shown in Figures 2-3 and 2-4 before active remedial management was planned, approved and implemented.

Current data on CMA approved INS management includes:

- Currently 45 INS clearing PVPs are approved and awaiting systematic implementation.
- These 45 PVPs cover some 802 kha of the Peneplain area.
- The approved INS clearing PVPs equate to some 28% (4,558 ha) of each property under management.
- Harvestable yield averages at some 50-100 dt (dry tonnes) per hectare.
- 802 kha @ 50 dt/ha equates to some 40 Mdt of biomass available for systematic value realisation as products and energy.
- Fully restored woodland grazing lands can then be managed to produce sustainable yields of select timbers and regrowth on 10-15 year rotations to sustain a specialist regional industry.

3. Proposed Charcoal and Power Project

3.1 General Configuration

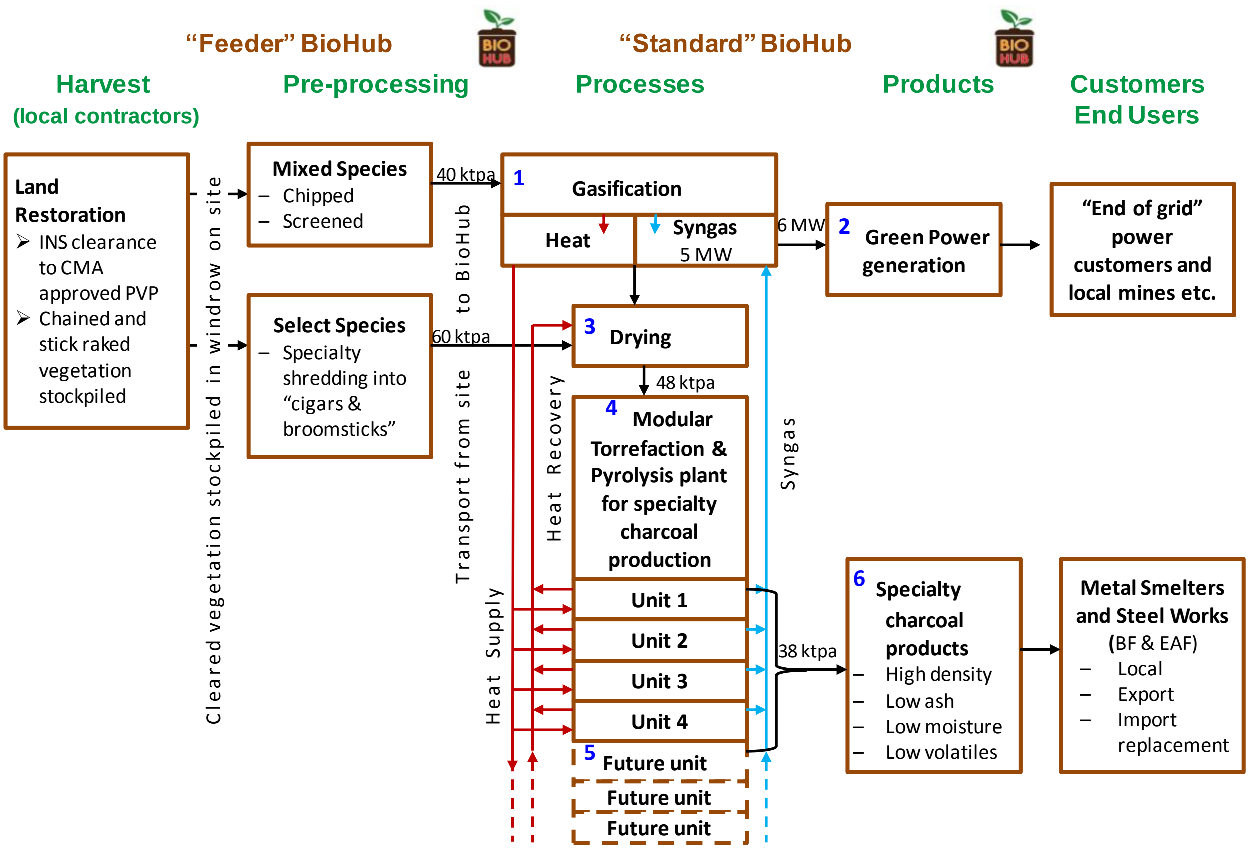
Current practice is for specialist contractors to implement approved INS clearing PVPs. The usual approach is to employ chaining and stick raking techniques to push up all cleared vegetation into occasional windrows/piles. Under current practice such materials is left to dry for up to 12 months before being burnt (Fig 2-6).

Under the proposed, full resource value recovery approach being proposed by Renewed Carbon, mobile or Type 1 Feeder BioHubs would operate in the field, following the clearing contractors, whereby the windrows/stockpiles would be processed to:

a) Pick out and trim all higher value select species to be either transported back to a specialist shredding site, or shredded by mobile plant, (or even transported as trimmed stems if the timber was of “furniture” quality for highest value resource recovery whenever such market opportunities presented); and

b) Chip and screen all the lower quality residual vegetation such that i) soil and bark and tops are left for raking back onto the soil for nutrient retention and erosion control and ii) the chip is forwarded to the gasification/heat and power plant (Fig. 3-1).

Figure 3-1: Cobar Peneplain/Metallurgical Charcoal/Energy Project – Concept Block Flow Diagram



Renewed carbon

Key:

1 Dual purpose gasification plant. Primary purpose to provide heat and syngas to:

a) Provide the primary heat to the specialty charcoal manufacturing process; and

b) Blend the syngas by-product from the charcoal units with primary syngas to generate "green" power for the "end of the grid" customers in the Cobar region, including the local mining sector.

2 Green power generation plant.

3 Select species "trim drying" to remove any moisture not removed whilst the original material was stockpiled in the field. (NB: The "cigars and broomsticks" characteristic referred to for these preprocessed select species materials reflects the "gnawing" type of shredding process employed to create whole wood pellets, rather than the "cross grain" chipping that is usually adopted for simple size reduction for gasification alone. Whole wood pellets make higher quality charcoal than cross grain chip that disintegrated during the specialty charcoal manufacturing process).

4 The specialty charcoal process required to make dense metallurgical charcoals requires the material to be placed into a dedicated kiln where the material remains static and the process conditions (time, temperature, heat gradient, CO_2 levels etc.) are controlled from a central operations centre.

5 The processing units are modular and arranged in an interconnected battery. Additional units can be added or subtracted to balance market demand.

6 Specialty metallurgical chars – as described attachment C.

In this configuration the project requires both a Type 1 Feeder BioHub to process and forward the biomass arisings wherever the harvesters are working at the time, and a Standard BioHub to be established centrally to service the respective "Feeder" operations and the regional community as a whole.

3.2 Summary of Commercial Viability

Analysis Summary
Cobar Charcoal Case Study

1. Input data - Cobar

Feedstock from Local Properties	60,000 tpa@<20% Moisture Content	Payment Gate Fee of $10/tonne

2. Output data - Cobar

PP#2	Sinter Fuel	c15,000tpa	+/- 10%
PP#6	Steel Recarburiser	c5,000tpa	+/- 10%
PP#7	Charge Carbon	c10,000tpa	+/- 10%
PP#8	Slag Foaming Agent	c8,000tpa	+/- 10%

3. Sources and use of funding - Cobar Charcoal Case Study

Local Equity	c$10,500,000	60% Equity
Debt Funding (Balance)	c$7,000,000	Employment >30
Green Electricity	c$1,000,000	Taxable Income - Commefcial Rates

4. Financial summary - Cobar

Offtake Agreement - green energy	c$1 million/year
Employment when operating	Direct Management and Staff - 30 FTE's
Cashflow Positive	By end of year 1 of operations
Average Annual net revenue % of Total Revenue	20%
Employment Costs as % of Revenue	26%
Interest on Debt	12%
Forecast Project IRR	37%

Sensitivities	Variation	IRR
Increase in Product Prices	10%	51%
Decrease in Product Prices	10%	25%
Increase in Total Cost of Goods	10%	34%
Decrease in Total Cost of Goods	10%	41%
Increase in Operating Expenses	10%	31%
Decrease in Operating Expenses	10%	44%

This summary of the integrated project commercial model indicates that the proposed project could be commercially viable and produce not only the power necessary at the "end of the grid" to support the developing Cobar mining sector, but also produce very high value metallurgical charcoal products for both the local export market and import replacement sector.

Attachment C – Mathieson et al, *The potential for charcoal to reduce net greenhouse gas emissions from the Australian steel industry*, 2012

THE POTENTIAL FOR CHARCOAL TO REDUCE NET GREENHOUSE GAS EMISSIONS FROM THE AUSTRALIAN STEEL INDUSTRY[1]

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Abstract
Life cycle assessment (LCA) of forestry and pyrolysis has been used to show that charcoal can be produced with net negative CO_2e emissions. The scenario described involved sustainably grown forest plantations, the capture and utilisation of bio-oil as a fuel and the production of electricity from the excess combustible gases from pyrolysis. Cradle-to-gate assessment of the use of charcoal in ironmaking and steelmaking has shown that the co-product credits available from the pyrolysis step flow through to enhance net CO_2e reductions available from the use of charcoal to between 41% and 75% for the integrated BF-BOF route, and to between 10% and 15% for the EAF mini-mill route, where emissions are dominated by those associated with electricity generation by coal. Of the eight applications investigated, the most significant was found to be the injection of pulverised charcoal into the blast furnace, which is already practiced in mini-BFs in Brazil. Charcoal properties, particularly volatile matter and density, can be adjusted during pyrolysis to optimise performance. Quality criteria have been proposed for each of the applications. R&D and plant trials have indicated that charcoal performance may be superior to that of conventional fossil-based fuels for blast furnace tuyere injection and as a liquid steel recarburiser. Many technical and economic challenges remain, with the greatest being to initiate economic supply of the large quantity of charcoal needed to meet the potential demand of the steel industry.
Key words: LCA; Greenhouse gas emissions; Integrated and EAF steelmaking; Charcoal quality.

[1] *Technical contribution to the 6th International Congress on the Science and Technology of Ironmaking – ICSTI, 42nd International Meeting on Ironmaking and 13th International Symposium on Iron Ore, October 14th to 18th, 2012, Rio de Janeiro, RJ, Brazil.*
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1 INTRODUCTION

Since late-2006, BlueScope Steel and OneSteel have partnered with Australia's national research organisation, CSIRO, to conduct an R&D program aimed at the development of technologies that can deliver deep cuts in net greenhouse gas emissions. "The Australian Steel Industry CO_2 Breakthrough Program" contributes internationally via the World Steel Association's similarly named program. In the area of sustainable biomass utilisation, our studies are examining the entire chain from biomass supply and pyrolysis technologies, through to a variety of applications of optimised charcoal types in ironmaking and steelmaking processes.

This paper provides an overview of the scope of the biomass program and addresses the following questions:

a) Under what conditions can the use of biomass-derived fuels and reductants, *e.g.* charcoal, be considered to be associated with either zero or negative net CO_2 emissions?
b) What applications of biomass-derived fuels and reductants appear to be technically feasible within the integrated blast furnace, basic oxygen furnace (BF-BOF) and electric arc furnace (EAF) mini-mill steelmaking routes, and what would be the resulting reductions in greenhouse gas emissions?
c) Are biomass-derived fuels and reductants likely be superior or inferior to the traditional fuels and reductants (coal, coke, chars)?
d) What chemical and physical properties optimise charcoal performance for each of the ironmaking and steelmaking applications?

2 CHARCOAL: POTENTIALLY A RENEWABLE, SUSTAINABLE FUEL

Charcoal and other forms of biomass-derived char have traditionally been considered to be renewable fuels because the carbon cycle for wood and other biomass forms is very short (from a few weeks to a few decades), versus those for the non-renewable fossil fuels (coal, oil, natural gas) which are of the order of 50 to 300 million years, allowing long-term build-up of CO_2 in the atmosphere. Because the carbon released as CO_2 from renewable fuels can be captured into new biomass by photosynthesis in real time, *e.g*. in plantation forests, the use of sustainably produced renewable fuels has often been taken to be associated with zero net CO_2 emissions. However, energy is required for the establishment and management of plantations, harvesting, processing to charcoal (pyrolysis) and transport of raw materials and products to the sites where they will be converted or utilised, meaning that life-cycle assessment (LCA) is a useful process for determination of the overall position.

Norgate et al.[1] have recently conducted the most complete LCA study to date of charcoal production and utilisation in ironmaking and steelmaking. This study contains extensive comparisons with earlier work, and for clarity and simplicity, such comparisons will not be discussed further here.

The main scenario for charcoal production studied by Norgate et al.[1] was based around a conceptual Mallee eucalypt plantation in Australia. Key assumptions were generally conservative and based on literature values and experimental data, as follows:[1]

- The moisture content of green biomass was taken to be 45% (wet basis, wb) at harvest.
- the wet biomass was transported 70 km to a conceptual charcoal-making pyrolysis plant.

- the biomass was allowed to dry naturally to 20% moisture (wb) before being used as feed for the pyrolysis plant. Feed carbon content was assumed to be 44.4% (dry basis, db).
- the charcoal-making plant employed “slow pyrolysis” to maximize charcoal yield, which was assumed to be 35% (db).
- product charcoal properties were: 4.5% moisture (wb), 88.3% carbon (db), ash 2.3% (db), sulfur 0.2% (db), and a calorific value (CV) of 31.1 MJ/kg (db).
- the co-product yields were: 2% (db) bio-oil. 23% (db) aqueous condensate (not utilised) and 40% (db) combustible gases.
- the pyrolysis plant was modelled on the basis of published plant data, corrected to account for slower pyrolysis.
- it was assumed that all of the bio-oil produced was available to replace fossil diesel fuel in an external application. This was later credited back to the charcoal produced.
- although pyrolysis plant energy consumption was not directly available, electricity production from the excess combustible gases was modelled to be 0.36 MWh/t feed (db), replacing black coal. This was later credited back to the charcoal produced. In the absence of other information, it was assumed that plant energy needs were satisfied by the combustible gases not available for electricity generation. Assuming that the biomass-derived combustible gases had a similar calorific value to coke ovens gas, this would mean that only 25% of the gases became available for electricity generation.

Norgate et al.[1] set up their LCA model of charcoal production based on the assumptions listed above and the inventory data given in Table 1. The main environmental impact category considered was aggregated greenhouse gas emissions, termed “Global Warming Potential” (GWP); measured as the mass of equivalent CO_2 and denoted as CO_2e. The study used the international standards framework for conducting life cycle assessments contained in the ISO 14040 series, with a functional unit of one tonne of charcoal.

Before accounting for the bio-oil and combustible gas credits, the results of the LCA of charcoal production indicated that the non-renewable GWP impact for charcoal production was 105 kg CO_2e/t charcoal, which reflects the fossil fuel used in its production (*i.e*. plantation establishment, management, harvesting, biomass transport and pyrolysis). Noting that 1.0 t of the charcoal (db) is stoichiometrically equivalent to 3.2 t of CO_2 (renewable), the non-renewable GWP impact of charcoal production is thus only 3.2% of the resulting CO_2e emissions when charcoal is combusted.

As noted above, Norgate et al.[1] estimated that the bio-oil yield for this scenario would be a conservative 2% (db). The CV of the bio-oil was estimated to be half that of diesel, meaning the bio-oil credit would be 32 kg CO_2e/t dry biomass, or 91 kg CO_2e/t charcoal.

Table 1. LCA inventory data for charcoal production.[1]

Plantation establishment	*Energy inputs*[a] 0.17 kg diesel/t green biomass 0.5 kWh/t green biomass
Plantation management	*Energy inputs*[a] 0.63 kg diesel/t green biomass 1.8 kWh/t green biomass
Harvesting	*Energy inputs*[a] 1.57 kg diesel/t green biomass 4.5 kWh/t green biomass
	Sustainable forest yield 19.2 t/ha/y
Transportation to charcoal plant (70 km)	*Energy inputs* 2.2 kg diesel/t green biomass
Pyrolysis to charcoal	*Energy inputs (process heat needs, raw materials and products handling)* Modelled by the implied quantity of combustible gases employed (*ca*. 75%) *Credits* Bio-oil (2% of dry feed), 20.5 MJ/kg Combustible gases equivalent to electricity generation of 0.36 MWh/t dry feed

a. Assumes 58% of energy consumption is diesel (CV 41 MJ/kg); with the balance electricity produced at 987 kg CO_2e/MWh (black coal at 35% efficiency).

Assuming that the excess combustible gases produced would be used for electricity generation at 35% efficiency, their credit was estimated to be 357 kg CO_2e/t dry biomass, or 1020 kg CO_2e/t charcoal.

Application of the bio-oil and combustible gas credits to the non-renewable GWP impact of 105 kg CO_2e/t charcoal led to the total net GWP for producing 1 t charcoal in this scenario being negative, *i.e.* -1006 kg CO_2e/t charcoal. However, it is important to note that this result is: (a) strongly dependent on the co-product yields in the pyrolysis plant, and (b) on the energy requirements for processing. The values used were estimates, rather than fully validated plant data.

Although the LCA was for a single representative scenario, the orders of magnitude of the contributions were established, and it was clear that charcoal production can make a zero or negative contribution to Global Warming Potential, providing that:

- The biomass is sourced from a sustainably managed resource, *e.g.* plantation forestry;
- the energy and GWP employed for forest establishment, maintenance and harvesting, plus biomass transport and drying, remain relatively insignificant compared with that of the charcoal produced; and
- a significant proportion of the pyrolysis co-products, such as bio-oil and combustible gases, are captured and utilised.

3 THE POTENTIAL FOR CHARCOAL UTILISATION IN THE BF-BOS AND EAF STEELMAKING ROUTES

3.1 Potentials Based on Direct Materials Substitution

Mathieson et al.[2, 3] have identified and quantified the potential for the use of biomass derived chars in both the integrated (BF-BOF) and mini-mill (EAF) steelmaking routes. These have been updated and presented in Tables 2 and 3. It is important note that the CO_2 emissions reductions shown are on the basis of direct materials substitution and do not include either the GWP credits relating to charcoal manufacture or any process efficiency gains or losses.

In general, charcoal is similar to low volatile coal or coke in terms of its general chemistry, but with very low ash levels (0.5 - 2.0%), and therefore normally would not present additional chemical risks in replacing the conventional fuels/reductants. However, in some cases charcoal's physical properties could be limiting and accommodations may be necessary to deal with its lower bulk density and strength, or its ability to absorb moisture.

With respect to the integrated route (Table 2), because of its low crushing strength, charcoal has not been proposed as a direct substitute for the lump coke charged to medium and large blast furnaces. However, although this application has not been proven, it has been proposed to replace some or all of the nut coke that is often mixed within the ferrous burden layers, because this is non-load-bearing.

Table 2: Proposed applications for biomass-derived chars and consequent CO_2 reductions within a typical Australian integrated steelmaking operation. Assumption: Results are based on direct materials substitution only

Application	**Basis**	**Net Emissions Reduction**	
		t-CO_2/t-crude steel	% of CO_2 Emissions
Sintering solid fuel	50 – 100% replacement of coke breeze or anthracite at 45 – 60 kg-coke/anthracite / t-sinter (and 1.7 t-sinter/t-HM)	0.12 – 0.32	5 – 15
Cokemaking blend component	2 – 10% of coking coal blend, with coke used at 300 – 350 kg-coke / t-HM	0.02 – 0.11	1 – 5
BF tuyere fuel injectant	Full replacement of injected coal (PCI) at 150–200 kg-coal / t-HM	0.41 – 0.55	19 – 25
BF nut coke replacement	50 – 100% replacement of 45 kg-nuts / t-HM	0.08 – 0.16	3 – 7
BF carbon/ore composites or BOF pre-reduced feed	5 – 10% of iron in charcoal/ore pellets to BF or charcoal-based pre-reduced feed to BF or BOF.	0.06 – 0.12	3 – 5
Steelmaking recarburiser	Full replacement of 0.25 kg-char / t-crude steel	0.001	0.04
	Totals	0.69 – 1.25	31 - 57

Notes: HM is hot metal
PCI is Pulverised Coal Injection
PCI coal assumed to be 75% C
Coke, coke breeze, anthracite and recarburiser assumed to be 85% C

Table 2 shows that the aggregated potential for biomass-derived products to mitigate CO_2 emissions in the BF-BOF route is quite substantial (31 – 57%), based on total emissions of 2.2 t-CO_2/t-crude steel for this route; typical for Australia. Replacement of pulverised coal as the BF tuyere injectant is the application with the greatest potential for CO_2 mitigation.[4] Charcoal Powder Injection (CPI) is already practised in mini-BFs in Brazil[5] at injection rates of 100 – 190 kg/t-HM.[6] Others have estimated that CPI rates of 200 – 225 kg/t-HM may be feasible for large BFs.[7] Efficiency gains, *e.g*. decreased coke rate, are expected for this application.[2]

Biomass-derived products have been tested in the laboratory to replace a minor proportion of the coking coal blend.[8] However, new work has commenced at CSIRO aimed at increasing the proportion to 10% or more.[9]

With respect to sintering, pilot-scale testing by CSIRO has shown that low-volatile, or preferably dense, low-volatile charcoal can successfully substitute for coke breeze, with higher productivity being possible, albeit at a slightly higher fuel rate.[10] Although full substitution may be possible, most integrated producers need to utilise indigenous coke breeze, so a more realistic limit for charcoal usage may be around 50% of the total solid sintering fuel.

Several authors have proposed that unreduced carbon-ore composite pellets or briquettes be added as blast furnace feed[11,12], and Konishi, Usui and Harada[13] have proposed that the carbon source could be charcoal. Although the extent of this application is currently uncertain, it would be expected that perhaps 5-10% of the ferrous burden could be pre-prepared in this way. On the basis of their bench-scale experimental work, Nakano et al.[11] have predicted a BF coke rate reduction of about 9 kg/t-HM for a 10% addition. If the composites were pre-reduced they could be used as BF feed, with additional fuel savings, or as a scrap substitute in steelmaking.

Liquid steel recarburiser is normally a coal-based char and is added both to the ladle during BOF/EAF tapping, and as a trimming addition during secondary metallurgy, *e.g.* at a ladle metallurgy furnace. Charcoal has been shown to be suitable for this application by Wibberley et al.[14] and in more detail by Somerville *et al.*[15, 16] as part of the current biomass project. Indeed, carbon recovery to steel appeared to be superior during the trial period.[15, 16]

Because the EAF route commences with scrap steel (rather than iron ore), the overall CO_2 emissions per tonne of crude steel are typically relatively low at around 0.5 t (used for Table 3), a little under a quarter of those typical for the integrated route. However, only a small proportion of this is in the control of the steelmaker. The CO_2e associated with generating the electrical energy for the EAF process constitutes about 88% of such emissions in Australia, where electricity is produced predominantly using coal. Thus, Table 3 shows that the opportunity for Australian EAF steelmakers to mitigate CO_2 using biomass is only around 8 – 12%, unless electrical usage can be reduced as a consequence.

In Table 3, charge carbon is normally the lump coke added with the scrap to control steel bath chemistry. The slag foaming agent (also called inject carbon) is normally coke or coal-based char fines. Charcoal has been successfully trialled for this application by Wibberley et al.[14]. Steel recarburiser has been discussed above for the integrated route.

Overall, this analysis indicates that the largest potential gains are within the integrated route, with year 2050 targets for CO_2 reduction (50%) being within reach. BF pulverised fuel injection has the greatest impact, and theoretical and combustion studies of this application have been completed by Mathieson et al.[2-4] as part of the Australian Steel Industry CO_2 Breakthrough Program.

Table 3: Proposed applications for biomass-derived chars and consequent CO_2 reductions within a typical Australian EAF steelmaking operation. Assumption: Results are based on direct materials substitution only

Application	**Basis**	**Net Emissions Reduction**	
		t-CO_2/t-crude steel	% of CO_2 Emissions
Charge carbon	50 – 100% replacement of 12 kg-coke / t-crude steel	0.019 – 0.037	3.8 – 7.5
Raw materials, electrodes, *etc*	0% replacement of 4.5 kg-C / t-crude steel	0 (of 0.017)	0 (of 3.5)
Natural gas heating	0% of 3 Nm^3/t-crude steel (0.54 t-C / t-crude steel)	0 (of 0.002)	0 (of 0.5)
Slag foaming agent	Full replacement of 5 kg-coke / t-crude steel	0.016	3.1
Steel recarburiser	Full replacement of 1.4 kg-char / t-crude steel	0.004	0.9
	Totals	0.039 – 0.057	7.8 – 11.5

Notes: Coke, foaming agent and recarburiser assumed to be 85% C
No improvements in electrical usage are considered here.

3.2 Potential Based on LCA

The LCA scenario discussed in Section 2 indicated that charcoal produced from sustainably managed plantation woody products could have a negative effect on overall CO_2e emissions, as measured by GWP, provided the co-products were used beneficially, *e.g*. directly as fuels or for electricity generation.[1] Using -1006 kg CO_2e/t (db) as the net GWP for the charcoal produced, and noting that the charcoal used has a carbon content of 88.3% (db), or a stoichiometric equivalent of 3,236 kg CO_2/t charcoal (db), this means that net CO_2 to the atmosphere is reduced by 4,242 kg CO_2e/t charcoal (db) when charcoal is substituted in ironmaking and steelmaking applications.

Norgate et al.[1] set up LCA models for both the integrated and EAF mini-mill steelmaking routes, with the functional unit being one tonne of crude steel. Cokemaking was internalised within the steelworks. Minor inputs such as ferroalloys, refractories and gases were not included as it was considered that such would be both minor and unchanged upon the adoption of charcoal. Also, detailed modelling of the intra-works gas systems was beyond the scope of the work.

The current study has updated the previous work[1] in three ways:

(a) transport of charcoal to the steelworks, although a minor contributor to GWP, has been included (400 km by rail (diesel), estimated as 8 kg CO_2e/t charcoal), reducing the GWP credit for charcoal use from -1006 to -998 kg CO_2e/t (db);

(b) the improvement in BF coke rate with charcoal as tuyere injectant predicted by Mathieson *et al.*[2] has been included (23 kg/t-HM at 150 kg charcoal/t-HM and 30 kg/t-HM at 200 kg charcoal/t-HM), and

(c) the BF coke rate reduction allowed by the use of carbon/ore composites as predicted by Nakano et al.[11] was modelled (4.5 kg/t-HM at 5% addition and 9 kg/t-HM at 10% addition).

In order to add in the GWP credit, charcoal was substituted for the coke/chars shown in Tables 2 and 3 on a fixed carbon basis (FC), and the coal used as the BF tuyere injectant was replaced on an equivalent energy basis (CV)[1]. Substitution factors are given in Table 4 based on the cases shown in Tables 2 and 3. The substitution effects shown in Table 4 have then been applied to give the cradle-to-gate GWP savings associated with the use of charcoal in the ironmaking and steelmaking applications for the BF-BOF and EAF routes. These are shown in Tables 5 and 6.

Table 4: Effects on GWP of charcoal substituting for conventional materials in ironmaking and steelmaking applications

Material Substituted by Charcoal	**Substitution Ratio (Mass)** (fuel/charcoal)	**Additional GWP Savings** (kg CO_2/t substituted)
PCI injection coal [CV = 32.5 MJ/kg (db)]	0.961 (CV)	72 (150 kg/t-HM) 93 (200 kg/t-HM)
Coal for carbon/ore composites	0.963 (FC)	14 (5%) 28 (10%)
Coking blend coal	0.963 (FC)	-
Nut coke, coke breeze, recarburiser, charge carbon, foaming/inject carbon	0.963 (FC)	-

Table 5: Cradle-to-gate non-renewable GWP reductions for the proposed applications of biomass-derived chars within a typical Australian integrated steelmaking operation

Application	Basis	Reduction in Non-Renewable GWP	
		t-CO_2e/t-crude steel	% of CO_2e Emissions
Sintering solid fuel	50 – 100% replacement of coke breeze or anthracite	0.16 – 0.41	7 – 19
Cokemaking blend component	2 – 10% of coking coal blend	0.02 – 0.14	1 – 6.5
BF tuyere fuel injectant	Full replacement of injected coal (PCI) at 150–200 kg-coal / t-HM	0.54 – 0.73	24.5 – 33
BF nut coke replacement	50 – 100% replacement of 45 kg-nuts / t-HM	0.10 – 0.20	5 – 9
BF carbon/ore composites or BOF pre-reduced feed	5 – 10% of iron in charcoal/ore pellets to BF or charcoal-based pre-reduced feed to BF or BOF.	0.08 – 0.16	3.5 – 7
Steelmaking recarburiser	Full replacement of 0.25 kg-char / t-crude steel	0.001	0.04
	Totals	0.90 – 1.64	41 – 75

Table 6: Cradle-to-gate non-renewable GWP reductions for the proposed applications of biomass-derived chars within a typical Australian EAF steelmaking operation

Application	Basis	Reduction in Non-Renewable GWP	
		t-CO_2e/t-crude steel	% of CO_2e Emissions
Charge carbon	50 – 100% replacement of 12 kg-coke / t-crude steel	0.02 – 0.05	4.9 – 9.7
Slag foaming agent	Full replacement of 5 kg-coke / t-crude steel	0.02	4.0
Steel recarburiser	Full replacement of 1.4 kg-char / t-crude steel	0.006	1.1
	Totals	0.05 – 0.07	10.0 – 14.9

Tables 5 and 6 indicate that when the credits related to charcoal manufacture are propagated through iron and steelmaking operations under typical Australian conditions, there is potential for GWP reductions of between 0.9 and 1.6 t-CO_2/t-crude steel (41 – 75%) for the integrated route and between 0.05 and 0.07 t-CO_2/t-crude steel (10 – 15%) for the EAF mini-mill route. For the integrated route such large reductions appear to be unavailable from any fossil-fuel-based current or proposed process, even with carbon capture and sequestration (CCS)[17,18]. Savings from the EAF mini-mill route are highly dependent on the availability of low-carbon electricity.

4 QUALITY CRITERIA

Charcoal is a manufactured product and this presents an opportunity for optimisation. Physical and chemical properties can be tailored for each of the applications, a concept described as "designer char". The production of charcoal with specified properties will require careful control of the pyrolysis process via the selection of raw materials and the use of processing temperatures from around 400°C to 800°C. Somerville et al.[19] have found that density can be usefully increased through the use of densified biomass fuel pellets (DBF) as the feed material for pyrolysis. Charcoal is a very porous material and moisture levels as high as 50% are possible if saturated, meaning that good drainage, or preferably protection from rainfall, may be required to maintain normal air-dry moisture levels of around 10-12%. Table 7 summarises the current state of our knowledge of quality criteria for each of the applications.

Table 7: Proposed quality criteria for optimised charcoal types for ironmaking and steelmaking applications

Application	**Key Parameters**†	**Comments**	**State of Knowledge**
Sintering solid fuel	Low VM: <3% High density*: >700 kg/m^3 Size: 0.3 - 3 mm	Protection of off-gas systems Preferable for reactivity control After crushing and screening	Pilot scale testing[10]
Cokemaking blend component	Low to mid VM: <10% High density*: >700 kg/m^3 Size: <3 mm Low alkalis	To reduce coke fissuring May help control reactivity Improve assimilation Check against BF limits	Current R&D[9]
BF tuyere injectant	Higher VM: 10 - 20% Low ash: <5% Low alkalis	Optimises BF heat balance Provides additional value Check against BF load limits	Theoretical analysis[2] & combustion testing[4]
BF nut coke replacement	Low to mid VM: <7% Higher density Size: 20 - 25 mm	Combustibles loss to off-gas Probably an advantage Nut coke size	Proposed
Carbon/ore composites	Low VM: <5% Size: 80% passing 75 μm	May improve DRI strength Further optimisation possible	Current R&D[20]
Steel recarburiser	Low VM: <3% Low moisture: <2% High density*: >500 kg/m^3	Safety and high C recovery Limits H transfer to steel Less bags to handle	Full-scale trial[15, 16]
EAF charge carbon	Low to mid VM: <7% Size: 20 - 30 mm Low alkalis	Higher VM may be feasible Nut coke size Minimise fume emissions	Proposed
EAF foaming agent/ inject carbon	Low to mid VM: 2 - 7% Moisture: 1 - 7% Size: 0.5 - 5 mm Low alkalis	Reduced flames Higher may be possible To suit injection equipment Minimise fume emissions	Full-scale trial[14]

† Applications not requiring very low moisture levels require relatively dry charcoal, say <12% moisture.
** This is particle (not bulk) density, e.g. made from DBF pellets.*

5 THE CHALLENGES AHEAD

The Australian Steel Industry CO_2 Breakthrough Program has identified eight process applications where biomass-derived fuels and reductants can contribute to net CO_2 reductions in the integrated (BF-BOF) and mini-mill (EAF) steelmaking routes. R&D is progressing for each of the applications and several are either ready for industrial trial or have already been tested. This technical work has been supported by studies of biomass and charcoal supply and techno-economic evaluations.[21,22]

Australia currently has a very small charcoal-making capability that supports silicon manufacture and the barbecue fuel market. However, the potential market within the steel industry is around 1 Mt/yr, if the optimised products shown in Table 7 can be provided at prices competitive with their fossil-based equivalents. Competitiveness is now assisted in Australia by a carbon pricing scheme that commenced in July 2012. The economics of charcoal supply can be optimised by use of clean non-prime feed materials such as forest harvest residues, rather than woodchips or sawlogs. The sale or utilisation of co-products is also important to the economics.[22]

Surveys conducted as part of this project have indicated that sufficient feed materials already exist in south eastern Australia to satisfy a large part of the potential demand from the steel industry.[21] These principally consist of plantation forest harvest residues and waste wood from domestic and industrial demolition.

Decreasing demand for newsprint may also free some existing resources. Nonetheless, there is a large challenge ahead to initiate a significant and distributed charcoal-producing industry, under stringent environmental controls, and with a need to capture and utilise the liquid and gaseous co-products for both greenhouse and economic reasons.

6 CONCLUSIONS

The use of charcoal and other renewable biomass-derived fuels and reductants has often been considered to be associated with near-zero net CO_2 emissions. Clearly this is untrue if the raw materials have not been replaced, *e.g.* via new growth in plantations. The charcoal production scenario reviewed indicated that energy usage and CO_2e emissions for plantation establishment, management, harvesting and transport were minor in comparison with the CO_2 savings afforded by using charcoal as a fuel or reductant, and that utilisation of the pyrolysis co-products as transport fuels or for electricity generation would mean that net CO_2e could be negative. Thus, charcoal produced from sustainable resources, with the capture and utilisation of co-products, can be justly called a renewable, sustainable fuel.

The potential for reduction of net greenhouse gas emissions for eight applications of various charcoal types has been evaluated for the BF-BOF and EAF steelmaking routes and quality specifications have been proposed for each application. Work to date indicates that charcoal may be superior to conventional fossil based fuels/reductants for blast furnace tuyere injection and as a liquid steel recarburiser. In sintering the use of dense charcoal can potentially increase productivity, but requires a slightly higher fuel rate. The use of charcoal/ore composites in the blast furnace may also produce benefits. Efficiency changes have not been evaluated for the other applications.

Cradle-to-gate LCA analysis indicated that when the full production chain from forest to crude steel is considered, savings in global warming potential of 41 to 75% are possible for the integrated route and 10 to 15% for the EAF mini-mill route under Australian conditions. Thus, without replacing the very strong fossil-based coke needed for the operation of medium and large blast furnaces, profound cuts in emissions are possible.

Although the results described in this paper have been developed on the basis of Australian conditions, it is hoped that they are valid more widely and will inspire others to consider the use of biomass-based fuels and reductants as probably the most effective means for reducing the steel industry's CO_2 emissions; at least in the short and medium terms.

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Attachment D – IEA Bioenergy Workshop, “How can sustainability certification support bioenergy markets?”, World Biofuels Markets, Rotterdam, 12 March 2013

IEA Bioenergy

IEA Bioenergy workshop
"How can sustainability certification support bioenergy markets?"
World Biofuels Markets, Rotterdam, 12 March 2013

SUMMARY

Introduction

At present numerous biomass and biofuel sustainability certification schemes are being developed or implemented by a variety of private and public organisations. Schemes are applicable to different feedstock production sectors (forests, agricultural crops), different bioenergy products (wood chips, pellets, ethanol, biodiesel, electricity), and whole or segments of supply chains. There are multiple challenges associated with the current status of sustainability certification, i.e. the proliferation of schemes has lead to – to name a few – confusion among actors involved, market distortion and trade barriers, an increase of commodity costs, questions on the adequacy of systems in place and how to develop systems that are effective and cost-efficient.

Within IEA Bioenergy a strategic study was initiated among Tasks 40, 43 and 38 to monitor the actual implementation process of sustainability certification of bioenergy; the study was executed between January 2012 and January 2013. The main goals were to

- examine the implementation status of sustainability certification of bioenergy,
- hold a worldwide survey on stakeholders' views and how they are affected by sustainability governance and certification initiatives,
- describe the current and anticipated impact on worldwide bioenergy trade,
- give recommendations for the improvement of sustainability certified markets.

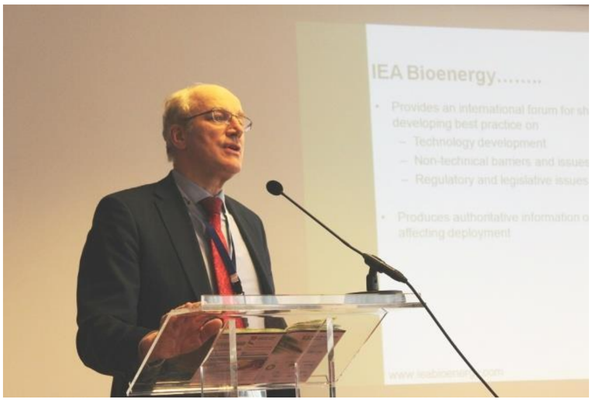
The main conclusions of the study were presented in the workshop of 12 March 2013 in Rotterdam. Around 60 people participated in the workshop.

8th annual
World Biofuels Markets
WHERE THE BIOFUELS WORLD MEETS TO DO BUSINESS
12–14 March 2013
Beurs-World Trade Center, Rotterdam, Netherlands

IEA Bioenergy

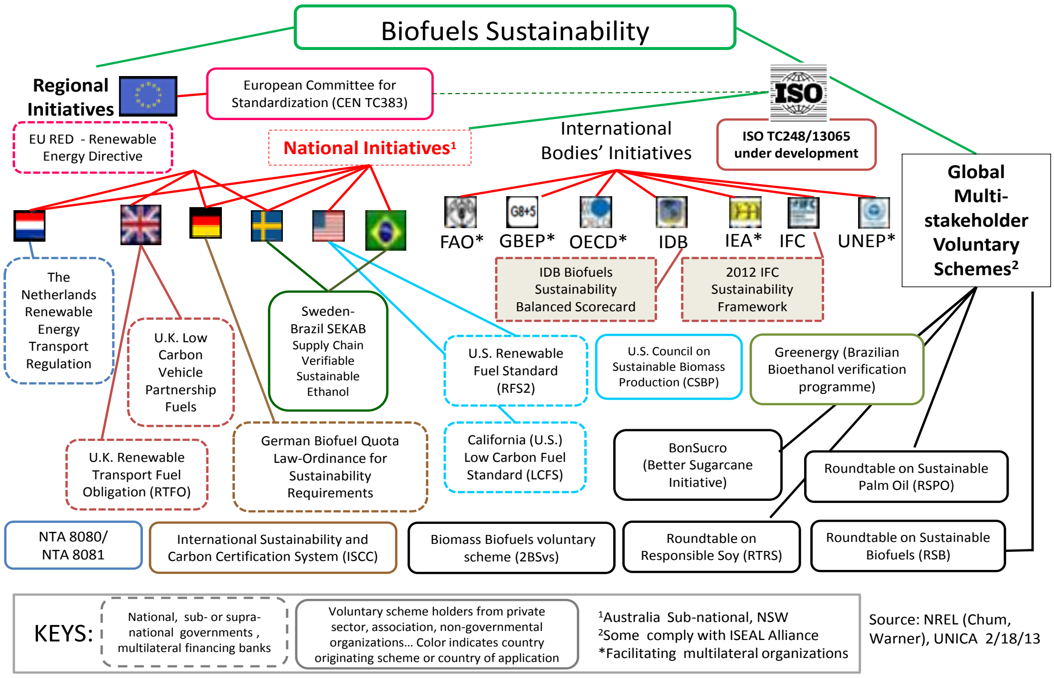
Presentations

Kees Kwant (NL Agency) was the chairman of the workshop. He welcomed all workshop participants, presented the structure of IEA Bioenergy, and introduced the study on sustainability certification.



Luc Pelkmans (VITO) *(on behalf of his colleague Liesbet Goovaerts)* presented the results of the first part of the study: looking at the implementation of schemes for biomass and bioenergy sustainability, in terms of standard setting and governance, Chain of Custody and information handling along the supply chain, conformity assessment and the relation with policies and other schemes.

Helena Chum (NREL) made a presentation on multi-stakeholder development of biofuel sustainability schemes. She showed the complexity of the relations between schemes, regulations and international bodies. She explained some of the background of the ISCC and RSB schemes, also putting forward the ISEAL Alliance, defining codes of good practice for developing sustainability standards.



Peter-Paul Schouwenberg (Essent) presented the approach of the International Wood Pellet Buyers (IWPB) consortium to develop a common approach for sustainability, contracts and technical specifications to facilitate trade. One of the main targets is to develop an effective and credible sustainability certification scheme. Nine general sustainability principles have been developed, which still need to be worked out in further detail. He stressed that the 'roundtable' governance model takes a lot of time, and continuous improvement of principles remains necessary.

Chun Sheng Goh (Univ. Utrecht) presented the analysis of the study to determine the impact of sustainability requirements on markets. Worldwide trade is a reality, but liquid biofuels and solid biomass have different market and trade dynamics. He stressed that data availability is very limited, and the study focused on a few countries (NL and UK). So far feedstock prices were the biggest factor influencing supply, however more stringent sustainability requirements are starting to limit certain areas and feedstocks.

Inge Stupak (Univ. Copenhagen) *(also on behalf of Tat Smith, Univ. Toronto)*, presented the views and experiences of stakeholders on the basis of a worldwide survey performed mid 2012. She concluded that a mix of voluntary certification and regulations is needed, systems should converge to a certain level, while a diversity of schemes may still be important, and continued development of verification tools is needed.

Luc Pelkmans (VITO) closed the presentations session with the main findings and recommendations of the study. He concluded the following key actions would be needed:

- agree on a common and cross-sector approach regarding sustainability principles, criteria and certification implementation and verification;
- coordinated policies and regulations (governmental intervention) to provide coherence across sectors;
- consistency and transparency among certification schemes to enable unilateral or mutual recognition and reduce administrative complexity and costs;
- communication and engagement among all stakeholders to ensure meaningful solutions, enhance participation and avoid unintended effects;
- guidance to ensure all stakeholders can participate (smallholders, developing countries);
- tools to support operators and to monitor implementation of certification (getting the facts right).

Roundtable discussion

Participants:
- Onofre Andrade (Argos)
- Mieke Vandewal (Control Union)
- Mairi Black (Drax Power)
- Kees Boon (PEFC Netherlands)
- Helena Chum, (NREL, US Department of Energy)

Moderated by Kees Kwant (NL Agency) and Luc Pelkmans (VITO)

Discussion topics (on the basis of the main conclusions and recommendations, see presentation Pelkmans):

1. Proliferation of schemes: is this good or bad?
2. Do we need convergence of schemes and unilateral/mutual recognition?
3. Complementarity of certification schemes with policy and regulations: can certification serve as on-the-ground implementation of policies and regulations?
4. How can we reach global harmonized principles and common language between different sectors/applications of biomass?
5. How to deal with differentiating low vs high risk regions; how can developing countries catch up?

Opening remarks of the panellists:

- ARGOS: One of the main aspects of certification is to assess the mass balance (through several supply chains, certification schemes, countries). A certification scheme is important to keep track of certified material.
- Control Union: There is a difference between certification and verification: verification is verifying a specific standard for a specific moment (on the basis of available documentation); certification has an add-on that it contains a note for non-compliance and a deadline to solve these non-compliances (if not, the certificate is lost).
- DRAX: Use meta-standard approach to show compliance for the UK requirements (ROCs). A certification scheme can be very helpful in this.
- PEFC: Certification of forest products should be for any markets. Forest certification schemes do not cover additional requirements demanded by specific markets (like GHG for the energy market). PEFC endorses national schemes, which were developed taking into account national legislation.

Debate:

Scheme proliferation:

- A variety of schemes creates competition, which may force development of better solutions. In practise a handful of schemes will probably remain. A similar development has been achieved for forestry schemes where the PEFC system has endorsed a large number of national schemes. FSC and the FEFC system are now the main forestry certification systems globally, covering about one third and two thirds of the world’s certified forests land, respectively. These

schemes should continue to learn and improve through regular and need-based updates of standards and other scheme elements.
- There is little difference between the biofuel schemes which only focus on RED compliance. The market does not need a multitude of schemes for this.
- Schemes should serve to demonstrate compliance with requirements, but they should differentiate to create market incentives, e.g. for double or quadruple counting.
- For a wide range of feedstocks, it may be acceptable to have a range of certification schemes designed for these feedstocks specifically.

Convergence & recognition:
- Should schemes converge? Standards aim at different levels, so it is important that they cooperate (recognition among schemes). As long as they are at credible levels, they do not have to converge into one system, as they may serve different applications.
- It is important not to lower standards – this would be the wrong result if convergence is being sought.
- Recognition: Is it more the task for policy to recognize which schemes comply with regulation? Endorsement between schemes is also very important. Energy schemes can endorse schemes for sustainable forest management (as is being done by for example GGL, Laborelec and ISCC). Energy schemes can also recognize each other, e.g. an NTA8080 audit is automatically accepted by GGL. This shortens audit times. On the other hand, when one schemes makes significant changes, this requires a new benchmark exercise.

Complementarity with legislation:
- The main purpose for certification can be to demonstrate compliance with legislation. The 3rd party verification makes it much more credible.
- Is certification a goal in itself? It should fit into a policy framework, a.o. aiming to achieve global sustainable land use. Certification is a tool to demonstrate sustainable forest management.
- US EPA biofuels sustainability requirements: these legal requirements will also need quality assurance and verification.
- Certification is also a tool for sectors that have no alternatives to show they are acting in a responsible (sustainable) way. But certification does not always settle the situation or stop unsustainable practises (when it remains voluntary).
- Involve iLUC in certification? At the moment this is in the process of legislation. Once the decision of policy makers is clear, it can be considered how certification can deal with it.
- Remark from the audience: why is there so little focus on energy efficiency in certification schemes? It is mainly regulations that include such requirements. For certification schemes it would be fairly easy to verify energy efficiency/consumption throughout the value chain, as this is closely linked to GHG assessment.

Common language & different sectors:
- Common language: a remark was made that various initiatives have already been taken to develop a common language among standards and schemes, e.g. ISEAL guidelines ('setting standards for standards'), tools for identifying high conservarion value (HCV), social guidelines, even if the market does not always make use of this work.
- Certification is the best available tool to prove that responsible practises are being applied. The transparency that it has lead to for biofuels is in great contrast with the situation in the food sector. The biofuels may serve as forerunner in this regard.

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Closing words (Kees Kwant):

Certification systems generate increased administrative complexity and costs, but they have a clear purpose and the markets can work with them. They mainly create trust (though 3rd party auditing) and can serve to show compliance with legislative requirements. Nevertheless there is still a large potential for them to improve their functioning and various other issues are still to be resolved.
It is important to emphasize that sustainability governance is not only about energy applications, but also land use in general, agriculture, forestry and other biomass applications as well. Lessons learned in the bioenergy related sectors and markets are also useful in other sectors.