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A BioHub Network

A proposal to provide the enabling systems and infrastructure necessary for the timely development of the emerging biomass processing industry

First Order Pre-Feasibility Study

Commissioned by

Australian Government
Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education

July 2013

Confidential information in this report has been redacted.

These redactions do not change the conclusions of this report.

Data presented is based on best available information provided to Eco Waste Pty Ltd at the time of the study, which has not been independently verified. As such, the data can only be considered as a guide to meet the objectives of this pre-feasibility study, and should not be relied upon for any other purpose.

Executive Summary

Establishment of Biomass Processing Sector in Australia

Biomass is set to become an important raw material to provide the essential carbon based molecules that our complex industrial economy is dependent upon, in an age when the use of fossil resources (gas, oil, coal) is discouraged or too expensive or they are exhausted.

The establishment of a competitive biomass processing sector in Australia has been slow. Major barriers to establishment include difficulties in identifying potential feedstock, as well as a lack of infrastructure to facilitate and connect supply lines.

Table 1-1: A selection of issues and barriers to biomass achieving its full potential as an alternative feedstock to fossil fuels

Issues (All as discussed in detail within this report)	Current Constraints
1. Geography/Logistics Biomass is ubiquitous but disparate, and, as a supplementary or replacement raw material, is usually needed at centralised locations, distant from the biomass source.	Other than for certain food or fibre primary industries, the systems and infrastructure to receive/harvest, aggregate and allocate suitable biomass is completely absent.
2. Quality/Energy Density Biomass, in all its forms, initially presents with low bulk/energy density and often with high moisture content.	Most suitable biomass requires pre-treating or value adding <u>before</u> transporting and aggregation, or at least as close to source as practical.
3. Temporal/Inventory Management Issues Suitable biomass often presents on a seasonal or campaign basis (much like most agricultural products) whilst the end uses or markets need supply all year round.	Storage and inventory management systems and infrastructure are not currently available.
4. Highest Value allocation There cannot be enough sustainably sourced biomass to replace all the uses fossil resources are currently satisfying today, especially power generation. Investment in biomass processing capabilities could be "stranded" if based on an inappropriate biomass source.	A sophisticated market is needed that can appreciate the inherent properties and values of any potential biomass source (as exists with fossil resources) to inform "best use" allocation of biomass within the emerging sector.
5. Sustainability Raw biomass resources provide a wide range of ecosystem services, amenity and biodiversity benefits as well as eventually providing a secure industrial input. If the biomass source cannot demonstrate sustainability of yield, all subsequent potential advantages over a fossil resource alternative are devalued and will undermine all subsequent "carbon" or sustainability claims.	A universal standard for assessing and certifying sustainability of biomass yield is essential to support all subsequent "carbon" or sustainability claims, or GHG mitigation assessments.

This report explores the feasibility of a specific proposal, the BioHub, a local biomass processing centre, as one cost effective solution to address those barriers. The BioHub concept provides the essential enabling systems and infrastructure to promote the establishment of a biomass processing sector in Australia. The concept is similar to metal scrap yards for systematic metals recovery, as BioHubs would act as a “first point of receival” for unwanted material, in this case biomass. Each BioHub would have all the essential process equipment to pretreat or process received materials into products for local use, or sufficiently processed and value added to afford the transport within the network to other specialist sites or Biorefineries or process plants.

As a fully developed national network, the BioHubs are proposed to service metropolitan, regional and rural communities by receiving locally generated biomass, and providing locally valuable services, such as processing urban wastes. Some BioHubs might also manufacture specific products to service a particular regional need or market. This possibility is explored in the case study for a proposed BioHub to service the Dubbo region of Central Western NSW on an initial investment of <$20Million. The proposed products would be biochar based, all-in-one fertilizers to specifically service the region’s cereal cropping sector.

However, once capital justified and established to service localised needs, the resulting BioHub network is then in a position to direct specific higher value biomass material to support highly specialised Biorefineries, providing the contractually assured supplies of biomass such facilities require to justify the much higher levels of investment for the production of jet fuels or targeted petrochemical industry inputs.

Sector Opportunities

Australia has the right settings to become an internationally recognised, sustainable provider of biomass and the “drop in” or direct replacement products that could be manufactured from such biomass due to:

- Available/suitable land –Australia could generate a wide range of collateral benefits by (selectively) re-vegetating marginal or degraded land, and optimising the net output from land currently dedicated to food and fibre production.

- Drought tolerant native species to address the fact that water is the most constraining factor.

- Sunshine – the primary energy source for biomass production is plentiful.

These factors can provide a platform for Australia to be able to provide sustainably yielded biomass, and biomass derived products with certainty of supply to the emerging sector that will need such certainty to secure the long term investment needed.

Further, once Australia becomes a reliable producer of quality biomass based products and services, the existing fossil resource based value chains that already exist can be supplied with supplementary/replacement biobased products.

Sector Challenges

In general it is not currently cost effective to use biomass as an industrial feedstock, except in limited situations such as sugar, starch and some forestry operations. Major barriers are that suitable sources of biomass aren’t identified and the supply lines are non existent to support the investment in complex conversion and "refinery" facilities necessary to achieve the full potential of this crucial source of "drop in" products and fuels.

One Solution – The BioHub Concept

The concept outlined in this document, the **"BioHub" network**, is being proposed as a crucial first step to break this impasse. It utilises a strategy of first accessing the market with lower risk, lower value, and lower manufacturing cost products as a way of establishing supply lines to enable growth into higher value product markets. The network will provide the essential, embedded systems and infrastructure to receive, value add and/or distribute all forms of biomass, as and when they are available, and eventually could enable the commercially viable production of many other, higher value biomass based commodities.

Physical and Practical Limits to the Production of Biomass

There are physical and practical limits to the production of biomass. These constraints demand that available biomass be applied for its highest and best use, as a strategic supplement or replacement for fossil reserves. The sustainable production and yields of biomass should be channelled to those applications for which biomass is optimally suited, for which alternative energy sources cannot present as effective alternatives. For example, electric powered air travel presents as completely impractical.

Before biomass based materials and products can present as "drop in" or direct replacement products and materials, they must first be gathered and transformed into such "drop in" products.

This essential harvesting, aggregating and conversion supply chain is effectively completely missing today. The systems and infrastructure to receive biomass as and whenever it presents to supply these new market opportunities is non existent; and where the products are needed is invariably very distant from where the biomass occurs; these low value raw materials cannot justify the extensive transport without being value added close to the providing source.

BioHubs: Creating a National Network

The BioHub national network is proposed as a cost effective solution to this problem; the essential enabling systems and infrastructure response to unlock the full potential of sustainably generated biomass in a carbon constrained age.

Just as metal scrap yards occur throughout the community to receive scrap metals as and when they present for systematic resource recovery, so too BioHubs would be available to receive biomass, in all its forms, as and when it was available.

Once received, the BioHub would have all the essential process equipment to pretreat or process received materials into products for local use, or sufficiently processed and value added to afford the transport within the network to other specialist sites or Biorefineries or process plants.

The most accessible markets for biomass based commodities are currently the bio-based charcoals for the metals manufacture and soil improvement/fertilizer sectors, as well as bioenergy. Australia is a major global supplier of coking/metallurgical coal, and the agricultural fertilizers are both locally manufactured and imported.

The metal market is accessible because biomass can be readily processed to a coke/coal alternative that can be "dropped in" to the iron and steel smelting process without delay. Similarly the fertilizer market is accessible because biomass requires only basic processing to produce biochar which can then be mixed with other ingredients to produce a comprehensive fertilizer and reduce the demand for fossil based alternatives.

It is envisioned that the market pull from these sectors will establish the supply lines, from which the higher value petrochemical platform chemicals sector and specialty liquid (jet) fuels market will be able to access smaller volumes of high quality material with sufficient assurance of supply to justify their considerable investment in advanced bio-refinery facilities.

This concept of locally available, network connected systems and infrastructure is universal in the agricultural sector. In the cropping sector, the railhead silos effectively connect the individual growers to national and international value adding, processing, marketing and distribution networks. This is at the core of the actual and strategic services and capabilities that the BioHubs aim to provide, and which have been explored throughout this Pre-Feasibility Study.

Proposed BioHubs Functions and Services

As with railhead silos for the cropping sector, or scrap yards for systematic metals recovery, BioHubs will act as a "first point of receival" in practical terms, and "receivers of last resort" in commercial terms. If the biomass generator has a more beneficial or cost effective use for their biomass, they will be able to use that option; but if not, the BioHub option will always be available to offer market based receival conditions.

At the BioHub, the final product(s) quality assurance/control processes start with the materials being thoroughly checked for quality, quantity, and the sustainability status of the yield of such materials. Received materials will then be graded and stockpiled with other materials of like quality in readiness for pre-treating/processing into either finished products for local use, or as interim but stabilized products for transfer to specialist sites within the network as required.

Three Formats: Feeder, Standard, and Producer BioHubs

BioHubs are proposed to be established in three generic formats:

Type 1 – Feeder BioHubs – could be mobile or temporary, employing skid mounted equipment to address a seasonal or short term harvesting opportunity, and value adding the biomass for direct transfer to a "Standard" or "Producer" BioHub for final value adding/processing.

Type 2 – Standard BioHubs – a core regional facility servicing between 50-250k population and/or a 100 km radius catchment area, providing all basic biomass receival, sorting, pretreatment and basic product manufacturing capabilities.

Type 3 – Producer BioHubs – would be similar to Type 2 facilities, but with much enlarged product manufacturing capability to service a localised market by being supplied with additional biomass materials from other Type 1 or 2 facilities.

The proposed BioHub concept, delivered as a national network of collaborating facilities, is primarily designed to:

- Receive biomass as and when it is available, close to source, to avoid excessive transport and handling costs before the materials have been initially value added;

– Initially assess, value add and pretreat received biomass as a precursor to:

  i) Transport to a distant conversion, refining or specialist product manufacturing facility; and/or
  ii) Support local finished product manufacture.

Such a network of BioHubs would be capital justified by:

– The value of the products manufactured for local use;

– The value of the services and products generated by the network as a whole; and

– The value created by providing supply assurance to the highest order biobased "drop in" products such as jet fuel or essential petrochemical precursors or finished products.

BioHubs: Opportunity for Collateral Services and Additional Economic Benefits

In addition to the physical and practical capabilities, the proposed BioHubs, individually and as an integrated network, will provide a wide range of collateral services and economic benefits, including:

- **Sustainable yield assessment and certification** – this service will underpin the full value proposition for all and any resultant products;

- **Biomass trading and brokering** – this activity will go to establishing fair market value for all types of biomass in this emerging sector;

- **Value adding to primary activities** – by creating value for the wastes, residues and by-products from the primary activities of the forestry, agriculture as well as urban waste streams, thus improving viability;

- **Supply assurance** – many complex, advanced biomass processing and refining facilities are only possible or viable if secure and reliable supplies of tightly specified biomass is cost effectively available – the precise service the BioHubs aim to provide;

- **Encourage new technology development** – the entire biomass harvesting, processing and final product manufacture supply/value chain requires a wide range of new and improved technology solutions. BioHubs will provide real time functional Best Available Technology (BAT) implementation opportunities for new technology developers and vendors, and also provide opportunities for pilot or demonstration offerings to prove themselves in real life but non-critical circumstances;

- **Optimisation of agroforestry and sustainable land management practices** – many revegetation or woody weed management programs are limited by the availability of funds. The provision of BioHubs offering fair market value for any surplus biomass arisings over time will support much expanded activity in this area; and

- **Transforming how urban waste minimisation initiatives are achieved** – the ability to recover and reclaim the entire residual biomass fraction from urban waste streams (approx. 60% of the approx. 20 Mtpa of residual urban waste) for less than the current "true cost of disposal "will provide a "game changing" advance for state and local authorities.

Biomass Sources

There are five generic biomass sources identified in this study:

1. forestry and agriculture **harvesting** residues;
2. forestry and agriculture **processing** residues and by-products;
3. urban waste arisings;
4. land management programs; and
5. dedicated plantations (oilseed, algae etc).

In relation to Sources 1-4, the biomass is currently produced as an undervalued by-product or secondary activity. The fifth source, specialty plantations, does not exist in Australia yet on a commercial scale.

Nationally, some 40-50 Mtpa of sustainably yielded "secondary" or "by-product" biomass resources have been identified that could benefit from the "first point of receival/receiver of last resort" characteristic of the proposed BioHub network[1]. This quantity of biomass has been shown to be available without a single specialist plantation, agricultural or special oil seed crop (e.g. sugar) or specialist oil seed plantation being initiated.

At such time as market demand for additional biomass is established, or for biomass sources of particular characteristics, then specialist plantations or oil seed crops or algae manufacturing plants will all benefit from access to a BioHub network to value add process by-products and sludges.

Product Opportunities

The main product lines from the proposed national BioHub network processing just the currently available "by-product" biomass arisings could produce:

i) 8 Mtpa of quality assured feedstock for the emerging specialty liquid (jet) fuels sector;

ii) 3 Mtpa of high density, low ash, metallurgical charcoals;

iii) 5 Mtpa of higher ash biochar products for land application and carbon sequestration; and

iv) 2- 2.5 GW of bioenergy (produced as a major by-product of the production of ii) and iii) above).

Suitable Technologies and Process Options

The BioHubs will utilise commercially available technologies for harvesting, transporting and processing biomass. For example, the "rotary drum" technology proposed to separate the organics from mixed municipal solid waste (MSW) (Fig. 5-2 – p. 44) is one of the most tried and tested techniques ever employed with some 500 facilities commissioned since 1958, and as employed last year in one of the world's largest MSW processing facilities in Doha. In addition, the torrefaction and pyrolysis technologies are now established as "commercial ready" in Australia with the result that they can be delivered with confidence, as described, and will not present as an undue risk.

[1] If this quantity of biomass was grown as a standard blue gum plantation it would cover some 2,500km^2 on a 10 year rotation.

Viability Assessments

A case study specifically exploring the viability for a potential BioHub to be established to serve the Dubbo region in central western NSW concluded that on an initial investment of <$20M, which could reasonably achieve an Internal Rate of Return (IRR) of approx. 20%:

- Some $10M per annum of revenue would be created;
- Some 9 FTE jobs would be created;
- Some 16 ktpa of high quality fertilizer would be created; and
- Some 1.5 MW of bioenergy would be available,

all based on processing some 70-80 ktpa of locally sourced biomass.

Extrapolating this data to estimate the benefits of a national network:

- Some 196 BioHub facilities were identified to address medium term opportunities;
- Which would process some 40 Mtpa;
- For a capital investment of $3,283M;
- Generating some 3,200 FTE jobs during construction and some 1,600 FTE jobs in steady state operations.

The Role of this Study in establishing the Viability of the BioHub Concept

The Commonwealth has engaged Eco Waste Pty Ltd to undertake a first order, or Pre-feasibility Study into a concept proposal that envisages the establishment of a network of biomass processing centres, throughout South East Australia or even nationally. Such biomass processing centres, or BioHubs, have been proposed as an important systems and infrastructure response to unlocking the full potential for biomass to play its optimised role in the alternative energy, fossil fuel replacement and systematic response to the climate change agendas.

Pre- Feasibility Study Objectives

This study explores the viability of the specific BioHub proposal.

In the engineering and development sectors, this process of project viability assessment has been refined over time as an iterative process that seeks to match the level of development funding expended to the level of project design and project detail in discrete stages.

This approach ensures that crucial issues are revealed and addressed before the considerable expenditure required for any detailed design and engineering is committed, and that the basic project scope and boundary conditions have been confirmed before progressing to the ever more expensive project detailing work is commissioned. This (high level) Pre-Feasibility Study is focused to assess the original BioHub project concept, as detailed in Section 1 (p. 1).

In this crucial initial phase, a project concept is developed and refined until it reaches a stage where stakeholders deem it appropriate to formally review the concept in a structured manner. This is the role of this first order, or Pre-Feasibility Study (PFS), commissioned at a time when the initial concept is still crystallizing and community responses to the core project drivers are developing.

After summarising the functions and objectives of the BioHub concept being proposed (Section 1), this Pre-Feasibility Study then addresses:

i) Generic biomass categories (Section 2);

ii) Actual sources of available/suitable biomass supplies and an estimate of the costs and likely commercial terms for receiving the materials identified (Section 3);

iii) The full range of final and/or interim products that are proposed and a realistic pathway to market for each and the expected revenues that are likely (Section 4);

iv) Conversion systems and technologies to convert ii) into iii) and the practical implementation issues, costs and options (Section 5);

v) First order commercial viability assessment (Section 6); and

vi) Summary and conclusions (Section 7).

This Pre-Feasibility Study will follow the scope as defined above and highlight issues and shortcomings, which if subsequently addressed, would support the transition to the full feasibility stage.

The Discussion Papers in Attachment A are provided to support and inform the philosophical context of this study.

Pre-Feasibility Conclusions

The data gained in this study indicates that BioHubs, either as individual sites or operating collectively can be inherently profitable. It is proposed that the way forward is for at least one BioHub project, but preferably three, is iteratively developed as a partnership between a group of potential plant owner operators and Government in discrete stages, in a gates and milestones format.

Project 1 – for example Dubbo “Producer” BioHub – focused on producing biobased fertilizer products tailor made for the local cropping sector.

Project 2 – for example a “Standard” BioHub – based at Cobar, NSW (or Hughenden, Qld) to support the local catchment management, wood weed/INS management programs and simultaneously provide high value charcoals and reductants to the national and international metals smelting sector.

Project 3 – a metropolitan based, fixed “Feeder” BioHub that processed biomass recovered from urban waste streams for pretreatment and transfer to a “Producer” BioHub, probably Dubbo, to support the end product manufacturing activity with volumes of interim processed chars, which also provide essential trace elements for blending into finished products.

These three projects could be initiated in parallel, and alternative sites could be identified if necessary. (Projects at Western Sydney, Lithgow, Ballarat, Latrobe Valley (Vic) and Hughenden (Qld) are just some that have been identified in the course of this study and that could be quickly actioned).

The suggested staged or gates and milestones approach to progressing either one or all three projects could be as follows:

Stage 1 – A prospective local investor group be established who are attracted by the concept described herein and who would commit to the provision of equity up to 25% of the projected capital cost of the respective projects to be matched with grant funding from an appropriate source.

Stage 2 – The accumulated budget then be drawn down against a pre-agreed gates and milestones schedule of works. At this point a detailed Feasibility Study will be undertaken to establish the factors, values, technologies and product market certainties.

Such feasibility studies can be a considerable expense to the project developers (perhaps some 3-5% of the capital cost of the project), and need to have been conducted to sufficient levels of certainty to ensure that any resultant capital funding will not be exposed to unnecessary risk. Spending on a feasibility study will often be an order of magnitude more than the Pre-Feasibility Study, and the Feasibility Study will visit all the issues and topics addressed in the Pre-Feasibility Study, but in complete and verified detail with previous “assumptions” fully tested and confirmed.

Other detailed work would include:

- Confirm and describe all committed biomass supply arrangements;
- Process design to progress from current concept to completed F.E.E.D.;
- Complete biochar product development with UNSW and then made up trial batches for broad acre trials;
- Secure off take agreements for finally confirmed biochar based fertilizer products; and
- Complete licencing and approvals process.

Stage 3 – Achieve financial close and approach the Clean Energy Finance Corporation (or other financing entity) for a debt and equity package for the final 50% of the project value.

In the event that the currently proposed “Industry Innovation Precinct” program selects a “biomass” based precinct as an emerging industry for the future, this BioHub concept would present as an ideal program for such a precinct to oversight and promote.

Table of Contents

List of Tables

List of Figures

Glossary

Anaerobic Digestion	Microbial degradation of biodegradable materials in the absence of oxygen
Availability value	The value created by just being there to enable transactions that would otherwise not occur
Biosolids	Water treatment plant sludges
Blister pack separation standard	An industry separation standard – biomass (cardboard) from plastic (HCF)
Capex	Capital expenditure
CEC	Cation exchange capacity
CFI	Carbon Farming Initiative
Circular economy	An industrial economy that is restorative and in which biological nutrients re-enter the biosphere productively and technical nutrients circulate at high quality without entering the biosphere
C&D	Construction and demolition waste streams
C&I	Commercial and industrial waste streams
CMA	Catchment Management Authority
CTIP	Clean Technology Investment Program
CV	Calorific value
Downcycling	Processing materials or wastes into products or uses that represent a reduced value or functionality than the original material could justify.
“Drop in”	Biomass based products that can supplement or directly replace established fossil based products and services
Ecosystem services	Those natural systems that recycle nutrients, process wastes and provide clean air and water; all products and outcomes on which life on earth depends
EPC(m) contractor	Engineering, Procurement, Construction and Management contractor
EfW	Energy from Waste
F.E.E.D.	Front End Engineering Design
Feeder BioHub	A mobile or “temporary” BioHub established to harvest and/or pretreat biomass available on only a seasonal, campaign or occasional basis
FEL	Front end loader
FTE	Full time equivalent
Gate fee	The charged levies upon biomass received at the BioHub
GJ	Gigajoule
GW	Gigawatt
HCF	High calorific fraction – plastics and synthetics

HHW	Household hazardous wastes
Hydrophobic	Resistant to water absorption
Industrial Ecology	The optimisation of material and energy flows throughout the economy to optimise value and efficiency and minimise impact
INS	Invasive native species
IRR	Internal rate of return, a profitability metric
Ktpa	Kilo-tonnes per annum
Long term	>10 years
Medium term	5-10 years
Merchant plant	A process plant built to manufacture products or provide services generally, without specific supply or off take arrangements in place as a condition of initial project finance
MSW	Municipal solid waste
Mtpa	Million Tons Per Annum
MW	Megawatt
NVA	Native Vegetation Act
Opex	Operational expenditure
PEF	Process Engineered Fuel
Producer BioHub	A BioHub focused to manufacture products in excess of the biomass availability from the local catchment
RD&D	Research, Development & Demonstration
RDF	Refuse Derived Fuel
PVP	Property Vegetation Plan
Short term	<5 years
Standard BioHub	A BioHub servicing a region where local biomass arises in approximate balance with local demand for biobased products
Stranded	An investment that ceases to remain viable due to foreseeable and unforeseeable changes in the initiating terms of trade
Syngas	Gas mixture consisting primarily of hydrogen, carbon monoxide, and very often some carbon dioxide.

1. Summary of the BioHub Concept

1.1 Summary of Strategic and Economic Need

The basic logic of the BioHub proposal is that for **biomass to supplement or replace fossil resources, by producing "drop in" alternatives (direct replacement) , the standards for managing such biomass, and the systems and infrastructure to receive, aggregate and process such materials need to be developed.**

In response to the "need", **the BioHub** concept is proposed as **a network of biomass processing facilities to provide the necessary specialised systems, technologies and infrastructure to facilitate efficient biomass valuation and application**.

Australia has the settings to become a major player in the emerging global biomass industries.

Australia has:

- A surfeit of sunshine;
- Vast areas of potentially suitable land with a considerable need/opportunity to selectively revegetate areas of sensitive or degraded lands. This stands in stark contrast to most other countries with which Australia might compete that would be obliged to sacrifice native forests or scarce agricultural land to generate biomass for such industrial purposes;
- Existing drought tolerant species, in many cases currently presenting as fast growing woody weeds;
- Existing export experience and key infrastructure to supplement/replace many fossil based products with biomass based "drop in" alternatives; and
- Local industries that need to focus on "smart" or "carbon lite" products to be able to differentiate their respective offerings from the traditional products now produced more efficiently overseas.

However, the establishment of the sector in Australia has been slow. Major barriers to establishment include difficulties in identifying potential feedstock, as well as a lack of infrastructure to facilitate and connect biomass supply lines.

Table 1-1 summarises the key issues and barriers identified for sustainably procured biomass to achieve its full potential in a carbon constrained economy. BioHubs have been proposed as independently viable facilities that could efficiently address all this issues, and it is an outcome of this study to identify the efficiency and effectiveness with which a network of such facilities could deliver on this potential.

Table 1-1: A selection of issues and barriers to biomass achieving its full potential as an alternative feedstock to fossil fuels

Issues (All as discussed in detail within this report)	Current Constraints
1. Geography/Logistics	
Biomass is ubiquitous but disparate, and, as a supplementary or replacement raw material, is usually needed at centralised locations, distant from the biomass source.	Other than for certain food or fibre primary industries, the systems and infrastructure to receive/harvest, aggregate and allocate suitable biomass is completely absent.
2. Quality/Energy Density	
Biomass, in all its forms, initially presents with low bulk/energy density and often with high moisture content.	Most suitable biomass requires pre-treating or value adding <u>before</u> transporting and aggregation, or at least as close to source as practical.
3. Temporal/Inventory Management Issues	
Suitable biomass often presents on a seasonal or campaign basis (much like most agricultural products) whilst the end uses or markets need supply all year round.	Storage and inventory management systems and infrastructure are not currently available.
4. Highest Value allocation	
There cannot be enough sustainably sourced biomass to replace all the uses fossil resources are currently satisfying today, especially power generation. Investment in biomass processing capabilities could be "stranded" if based on an inappropriate biomass source.	A sophisticated market is needed that can appreciate the inherent properties and values of any potential biomass source (as exists with fossil resources) to inform "best use" allocation of biomass within the emerging sector.
5. Sustainability	
Raw biomass resources provide a wide range of ecosystem services, amenity and biodiversity benefits as well as eventually providing a secure industrial input. If the biomass source cannot demonstrate sustainability of yield, all subsequent potential advantages over a fossil resource alternative are devalued and will undermine all subsequent "carbon" or sustainability claims.	A universal standard for assessing and certifying sustainability of biomass yield is essential to support all subsequent "carbon" or sustainability claims, or GHG mitigation assessments.

This project explores the feasibility of a specific development proposal, the BioHub, as one solution to address these barriers if the biomass processing sector in Australia is to be optimised. The concept is similar to metal scrap yards as BioHubs would act as a "first point of receival" for unwanted material, in this case biomass. Each BioHub would have all the essential process equipment to pretreat or process received materials into products for local use, or sufficiently processed and value added to afford the transport within the network to other specialist sites or Biorefineries or process plants.

The basic rationale for the BioHub concept as proposed is based on a simple logic:

i) In the face of the related global agendas of:
   - Climate change;
   - Resource depletion, and the need to establish
   - Sustainable economic systems;

   a definitive conclusion is the need to limit the use of fossil fuel resources and so to reduce Greenhouse Gas accumulation in the atmosphere.

ii) Modern complex economies cannot operate without the carbon based molecules currently supplied by fossil resources, for a wide range of uses including:

   - The complete range of chemicals and products from the integrated petrochemical sector;

   - Coke/coal/reductant materials that are essential for the metals manufacturing/smelting sector;

   - The agricultural fertilizer/soil productivity sector; and

   - Specialised and liquid transport fuels sector, with special focus on aviation fuels;

iii) Biomass was the original source that created the fossil reserves that have been the basis of industrialisation over the last 200 years. If the use of such reserves is to now be limited, restricted or eliminated, the logical alternative source of the carbon we need to operate the economy is back to biomass itself. Biomass, representing "solar powered" CO_2 "harvesting" from the atmosphere, and presented in familiar lignocellulosic structures wherever photosynthesis can prevail.

However, recently (<100 years) grown biomass presents at much lower bulk and energy densities than traditional fossil reserves. Rather than being geographically concentrated into efficiently extractable lodes, deposits or wells, biomass, whilst ubiquitous, is geographically disparate and presenting as more of an agricultural rather than industrially convenient raw material.[2]

Recent (<100 yrs old) biomass **can only meet a fraction of the demand** for carbon based products and energy currently supplied by fossil reserves[3]. This fully supports the originating premise for the design and function of the proposed BioHub program:

   i) For biomass to provide the Greenhouse Gas and/or sustainability benefits as an alternative to fossil resources, it must come from sustainable sources. This is ultimately a land use issue and founded on the principle that the earth's soils should be maintained or improved, but never degraded or destroyed without subsequent remediation, such as mine site rehabilitation, to bring land back to full production capacity;

   ii) Sustainably yielded biomass should be applied for its highest and best use or application;

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[2] Baseload, embedded and peaking electrical power are often considered as another major potential application for biomass, however, as outlined in Attachment A i – Biomass ain't Biomass, there are many other suitable and cost effective sources of renewable energy available and being improved and implemented (eg. wind, hydro, geothermal, wave, tidal etc.) but only biomass can supply the actual carbon based molecules to not only present an essential "drop in" product, but also to have taken the CO_2 from the atmosphere in so doing. In this context, bioenergy is invariably produced as a by-product to be optimised, but the starting position for this PFS is that biomass usually presents as too valuable to be solely converted for power, even though power contribution will be considerable as biomass is adopted for its inherent high value initial applications.

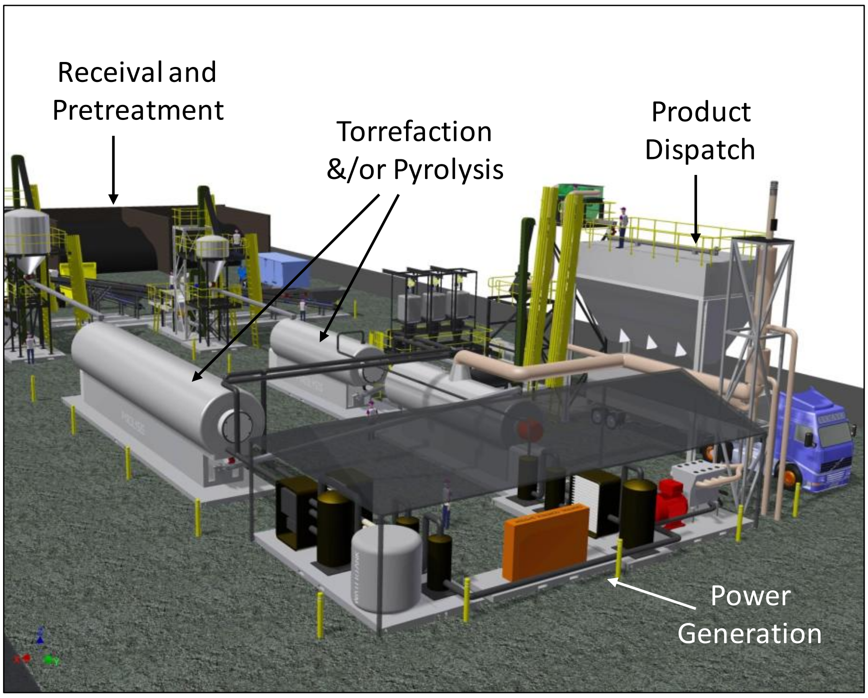
[3] Pearman, G., "Limits to the potential of bio-fuels and bio-sequestration of carbon", *Energy Policy*, 59 (2013), 523-535

iii) That not withstanding international protocols, government programs or agendas or even specific regulations or legislation, the vital initiating decisions regarding biomass generation and/or yield will be made by individual land owners/managers, in real time, in the pursuit of self interest (see 1.4.6 below). As such, dedicated systems and infrastructure need to be readily accessible to assess, receive and value add whatever biomass materials are presented, whenever they are available and to offer fair market value to the generator/presenter of such biomass.

1.2 Proposed Functional Capabilities of BioHubs

A BioHub is proposed as a facility available in each community, much as a metal scrap yard, or a landscape supply centre, or a railhead silo receival facility, open to the entire community, and accessible by private vehicle and/or trailer or commercial truck deliveries. Each site will have receival, load checking, and various pretreatment capabilities as required, as well as storage/stockpiling areas and onsite processing equipment to produce either finished products for local use or interim, stabilized products for transport to other more specialised product manufacturing centres.

***Typical BioHub plant concept**



* As described in detail in Section 5.

The following capabilities are proposed to respond directly to the practical considerations identified in the summary of need.

1.2.1 First Point of Receival/Receiver of Last Resort

First Point of Receival

The first point of receival function **addresses the geographical issue**. Biomass is a low bulk density material, and in its original form is also a low value material. Therefore it is crucial that the **initial** transport distances from the point of generation to the first point where the material will begin an iterative value adding process is as short as practical.

A 100km maximal radius has been assumed as the catchment area for the sourcing of raw biomass materials, but a <50km radius is optimal where biomass arisings and population concentrations permit.

As summarised in the report, "Bioenergy in Australia – status and opportunities"[4] transport of forest or crop biomass is normally limited by volume more than by weight[5]. The interaction between truck payload, truck volume, and the **moisture content** of the biomass **affects the cost** of energy delivered by the biomass. In Figure 1-1 this is shown for a 36 m^3 truck with a 26 t payload that is weight limited when carrying wet biomass but volume limited for drier loads (upper chart). More energy is carried when the loads are drier. However the cost per tonne carried increases for dry biomass loads (lower chart) but the more important cost per GJ of energy delivered is optimum when the biomass is around 30-40% moisture content, wet basis. **Thus road transport over long distances will benefit from drying, compaction or comminution of the biomass to achieve the maximum payload possible**.

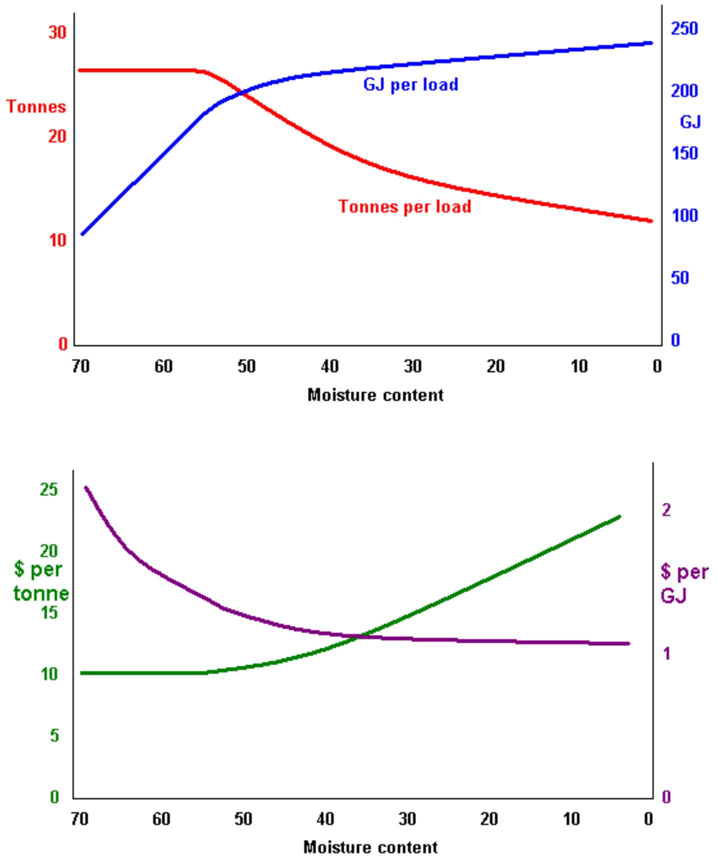


Figure 1-1: Example of the interaction between biomass moisture content and transport costs.

Large quantities of biomass are already harvested in well-designed systems. For example, the sugar cane industry has considerable experience of harvesting and handling up to 3Mt biomass per

[4] Downloadable from www.bioenergyaustralia.org.
[5] Hall P, Gigler J K and Sims R E H. 2001. Delivery systems of forest arisings for energy production in New Zealand. Biomass and Bioenergy 21 (6), 391-399

year /y at any one plant. **Where practically feasible, using existing, commercially available equipment (perhaps after modifying it) is often the most viable option**. For example oilseed rape (canola), used for producing biodiesel is harvested using conventional cereal combine harvesters. Vegetative grasses to be used for combustion feedstock can be cut with conventional crop mowers or windrowers, and then baled using conventional hay balers. The balers could then be used for making silage bales in spring, hay bales in summer, straw bales in autumn, and energy crop bales in winter. This **would give all year round work to the owner-contractor**, and therefore spread the fixed costs over a greater number of bales per year, thus minimising the costs per bale. **Where no commercial equipment is available**, or there is limited opportunity for reducing costs of existing systems via technical innovation, the **need to develop specialist harvesting and handling equipment** can arise. Many prototype machines have been developed around the world but few have proved successful enough to reach the commercial manufacturing stage. There is often a perception of risk associated with such development due to the unknown market for such machines. This, along with the significant up-front costs of a thorough RD&D development program, can stifle attempts to improve supply costs through innovative new equipment.

Harvesting operations, transport methods, and the distance to carry biomass feedstock to the conversion plant, also **impact on the energy "balance"** of the overall biomass system. That is, any fossil fuels utilised in the biomass supply chain will detract from the greenhouse gas mitigation benefits achieved by the production of renewable electricity or transport fuels when the biomass is processed. The heat or power generating plant, or a multi-product bio-refinery, should be located on a site where transport costs are minimised since the biomass usually has a low energy density and hence is costly to transport. Where direct access to a specialised bio-refinery is impractical, the BioHubs would act as the first point of receival in an iterative value adding supply chain that could eventually support the "supply" needs of such complex and specialised facilities.

The receiver of last resort characteristic

The receiver of last resort characteristic reflects the fact that **of the five generic sources of potentially available biomass (Section 2), four are by-products or wastes, or generated as a result of some other primary activity**.

In these circumstances, the generator will naturally look to put such materials to the most cost effective end use that they can achieve, after ensuring that their primary activity receives the most immediate focus. In these situations, **the surplus, waste or undervalued sources** of biomass will usually only be supplied to a regional BioHub **when all other potential applications have been exhausted**.

It's also worth noting that as by-products or wastes/residues generated as a result of some other primary activity, such biomass arisings can be problematic to contract as an assured supply into a BioHub facility, since this material will not be generated if the primary activity is reduced or terminated. If there is no crop, there will be no straw; if the wood chip export demand is reduced or terminated, there will be no forest residues; and although urban waste streams tend to present as predictable material flows based on historical trends, there is still no absolute mechanism to contract the community to make waste to satisfy some secondary or resultant process.

A benefit of establishing BioHub facilities that will be in a position to systematically value add by-products, residues and wastes is that they present simultaneously as a **source of lower cost inputs** into the BioHub product manufacturing activity and a **realisation of improved revenue for the primary activity**. However, this is in effect a "merchant plant" investment model that may only be commercially practical after the initial phase of network development.

There may be occasions where the easy access and transparently communicated BioHub option will present as a convenient and ready outlet for the available biomass, for fair value, when compared with other options that may require disproportionate effort to achieve little greater net benefit.

As receiver of last resort, BioHubs **would always accept surplus biomass materials**, and this service offering will be reflected in the **gate fees (ie the charges levied upon biomass received at the BioHub)**. The fees will also reflect prevailing market circumstances, and the "availability value" of the local BioHub facility to such biomass generators.

For each of the five generic sources of potential biomass (Section 2) the existence of a local BioHub provides management options for the biomass generators that don't exist currently.

The provision of the **physical infrastructure** to provide local first point of receival convenience, coupled with the receiver of last resort certainty, is anticipated to transform the potential biomass sector by providing a convenient and logical option for materials that might not otherwise be put to a fully productive use.

1.2.2 Quality Control and Creator of Critical Mass

Realising the highest end product value, the biomass will require a detailed assessment of the qualities of biomass received (attached A i – Biomass ain't Biomass).

In this regard, the BioHubs function similarly to scrap metal yards that exist in all significant population centres. At these facilities scrap metals are received and assessed for quality and quantity within an established "market" system. The materials that have passed the inspection are stockpiled like-with-like to optimise end market returns on the materials, and to avoid unnecessary "downcycling" (converting to lower quality products) just to maintain volume or throughput. The same applies to biomass received at the proposed BioHub facilities.

1.2.3 Supporting a "Streaming/Cascading" Strategy

To realise the highest net resource value (HNRV) from all materials received or gathered into a BioHub, a **foundation concept** is **to generate maximum value and revenue by providing the ability for materials presented to be streamed, like-with-like, towards the production of the most valuable end markets that their respective qualities, quantity and reliability of supply will support**. However, given that most such markets are seasonal, cyclical, or occasional, BioHubs would be ideally placed to offer "next best" opportunities, or cascading opportunities for materials presented, rather than be obliged to accept only a binary option of disposal or rejection or basic energy recovery alone.

1.2.4 Pretreating

Value will be **created** for the original biomass generator/supplier if materials can be assessed, screened, stabilized (if reactive when presented), size reduced, decontaminated or partially processed to the level of at least an intermediate quality product.

This could be especially relevant for the biomass sources listed below in the Table 1-2:

Table 1-2: Generic pretreatment options

Waste/Residue	Generic Treatment
MSW sourced organic fraction	Separation and sterilization
Surplus green/garden waste	Screening and size reduction
Processing wastes and sludges	Digestion and/or stabilization
Wood waste/forest residues	Screening, streaming, size reduction, decontamination
Manures and agricultural residues	Blending, stabilization, streaming

Pretreated materials can then be **transported as "interim" products** to other sites where product manufacture, based on these materials, is a specialty; or traded/brokered to specialist third parties.

1.2.5 Product Manufacturing

The BioHub concept, when delivered as a **network of cooperating regional facilities**, will have the ability to **address the inevitable imbalance** where some regions can attract a surplus of biomass, and some regions may be able to focus on supplying markets with finished products that far exceed the ability of the local region to supply the volume or type of biomass required.

Hence the pretreatment function at all fixed BioHub sites, and even the production of some basic products, such as bioenergy, would occur in most locations. However, certain locations will need to focus on larger scale product manufacture, supplied not only from whatever biomass is available in the region, but also from the importing of intermediately processed products from other sites and sources, where the resultant transport and logistics can be cost effectively absorbed.

For example, in the Dubbo case study for this report (attached B 1), the apparent demand for tailor made, biochar based, all-in-one fertilizer products looks to grossly exceed the capacity of locally sourced biomass to sustain.

At other sites, such as South East NSW/North East Victoria or the peneplain area of NSW, the opportunity to specialise in the production of low ash, high density industrial reductants and/or coke/coal replacement products may be appropriate, and in so doing, supply a market that is potentially far larger than any single site or region could satisfy in isolation.

Such "Producer BioHub" sites (see below) are proposed to form part of an integrated network over time.

Within this proposed framework, the BioHub facilities may all be **established with a common level of basic technological capabilities** to receive, sort, screen, stockpile and pretreat materials, but final product manufacturing capabilities may be selected to exactly suit the respective local conditions, such as torrefaction, pyrolysis, energy production, fermentation, digestion, fertilizer blending and pelletising etc.

Fixed regional BioHub facilities will also be able to offer **contracted extension services** for:

- Vegetation management services;
- Seasonal harvesting services; and
- Campaign based land management/clearing/Property Vegetation Management Plan (PVP) execution services etc.

Additionally, certain **"Feeder" BioHub sites** (with skid mounted and transportable plant and equipment) might be established on an occasional/seasonal/campaign basis and operated only for weeks or months each year in any one particular location, the equipment being rotated to other sites afterwards as required.

As a network, an important primary purpose is the ability to supply highly specialised product manufacturing or bio-refinery facilities with the **supply certainty** and specific biomass materials that they need from **established infrastructure** that is capital justified, not only from meeting such a high value demand (eg. Jet fuel), but also from the lesser value products manufactured for local consumption in each region.

1.2.6 Summary of Proposed BioHub Physical Capabilities

To meet the broader network needs, three types of BioHubs are proposed, of which one type, the full scale "Producer" BioHub version is reviewed in the "Dubbo" case study – B 1.

Type 1 – Feeder BioHubs

Certain biomass arisings occur on a seasonal, campaign or occasional basis, and thus can't support a permanent BioHub facility, and so need to be serviced out of an established site that calls in mobile and/or skid mounted equipment as required. These facilities would offer biomass receival capabilities tailored to suit sporadic or light local demand due to low population, or seasonal availability of certain agriculturally sourced biomass, or specific campaign based availability as with forestry etc.

The basic site would be equipped with load checking (for type, quality and quantity) and storage bunkers for like materials. Process technology might be mobile or skid mounted such that sorting, shredding, screening could be performed by equipment that can service multiple sites a day or two at a time. Similarly, any material that required stabilization could be processed by a fixed or mobile drying/torrefaction unit such that the processed material would be dried, energy concentrated (torrefied), stabilized to eliminate odour or biological decomposition and rendered hydrophobic (water resistant) to facilitate any subsequent storage.

The product of such facilities would be **predominantly value added feedstocks for delivery to other "standard" or "producer" BioHubs** in the network, **for conversion into final products or even selling to specialist third parties as required**.

Type 2 – Standard BioHubs

These are the **standard or typical BioHub format**, **servicing 100-200k population (metro) or 100 km radius catchment (rural)**, and offering the full scope of biomass receival, sorting, pretreatment and basic product manufacture. These more standard facilities would offer all the same services to the local community as the "feeder" BioHubs but would include the fixed pyrolysis capability (or Anaerobic Digestion or other as required from site to site) so as to be able to produce finished products and bioenergy from locally sourced materials and partially process materials (from Feeder BioHubs). Standard BioHubs will retain the capability to partially process some materials and forward to specialist "producer" BioHubs if required.

Type 3 – Producer BioHubs

These facilities will be **similar to Type 2** facilities, but with a **dedicated product manufacturing capability** added on to service the locally identified markets, be they fertilizer products, specialty reductants, bioenergy or liquid fuel precursors. They would service 50-100k population.

To **service the agricultural sector**, "producer" BioHubs will be located so that they can access discrete regional markets, making customer specific, all-in-one, biochar based fertilizer products (e.g. the Dubbo case study attached B 1). To service the industrial sector, producer BioHubs would be located adjacent to major customer facilities to fully optimise by-product flows of heat/syngas/bio-oils etc. For example, producer BioHubs located adjacent to a steelworks or metal smelting operation would be able to provide surplus heat or syngas as a valuable additional supply of bioenergy. This would avoid the need to install power generation equipment to utilize these valuable by-products.

Estimates extrapolated from the Dubbo Case Study have identified that to fully service NSW, some 14 Type 1 facilities would be required, that would feed into some 35 Type 2 facilities and some 5 Type 3 facilities for a gross capital cost of some $905 Million Capex (capital expenditure). This considerable investment is nevertheless justified by the very high quality products manufactured as described in Section 4 and modelled in detail in Section 6.

Table 1-3: Concept model of BioHub network to service NSW

BioHub Type	Approx. No./530 km^2 of suitable land for NSW	Receival, sorting, screening, pretreatment & torrefaction	Pyrolysis & energy recovery	Final Product manufacturing and wholesale	Approx. Capex $M each
"Mobile" Feeder BioHub	14	✓			$5
Standard BioHub	35	✓	✓		$19
Producer BioHub	5	✓	✓	✓	$34
Totals	**54**				**$905M**
Facilities processing min. 70 ktpa (Capex $19M), max. 250 ktpa (Capex $34M)					
Processing estimate 6,500 ktpa ∴ 54 facilities processing an average of 120 ktpa biomass each					
Average Capex/BioHub - $16.75M					

1.3 The Proposed Services to be provided from Proposed BioHub Facilities

In addition to their core business as above, the BioHubs will be able to offer a range of collateral services that will present as economic benefits and will be independently valuable or supportive of achieving the greatest potential value from the actual products manufactured.

1.3.1 Sustainable Yield Assessment and Certification

The drivers for optimising biomass as a sustainable source of carbon, to replace or supplement fossil resources, stem from the emergence of at least three generic global agendas:

i) Address climate change by avoiding the release of “fossil” CO_2;
ii) Address natural resource depletion; and
iii) The observance of sustainable economic practices.

The growth and production of biomass is essential for the provision of much more than just sustainable carbon molecules to support complex, integrated industrial economies. Such higher order benefits include, at least:

- The provision of ecosystem services;
- The provision of sufficient food and fibre to sustain the global population;
- The provision of amenity and recreational services; and
- The provision of biodiversity and habitat.

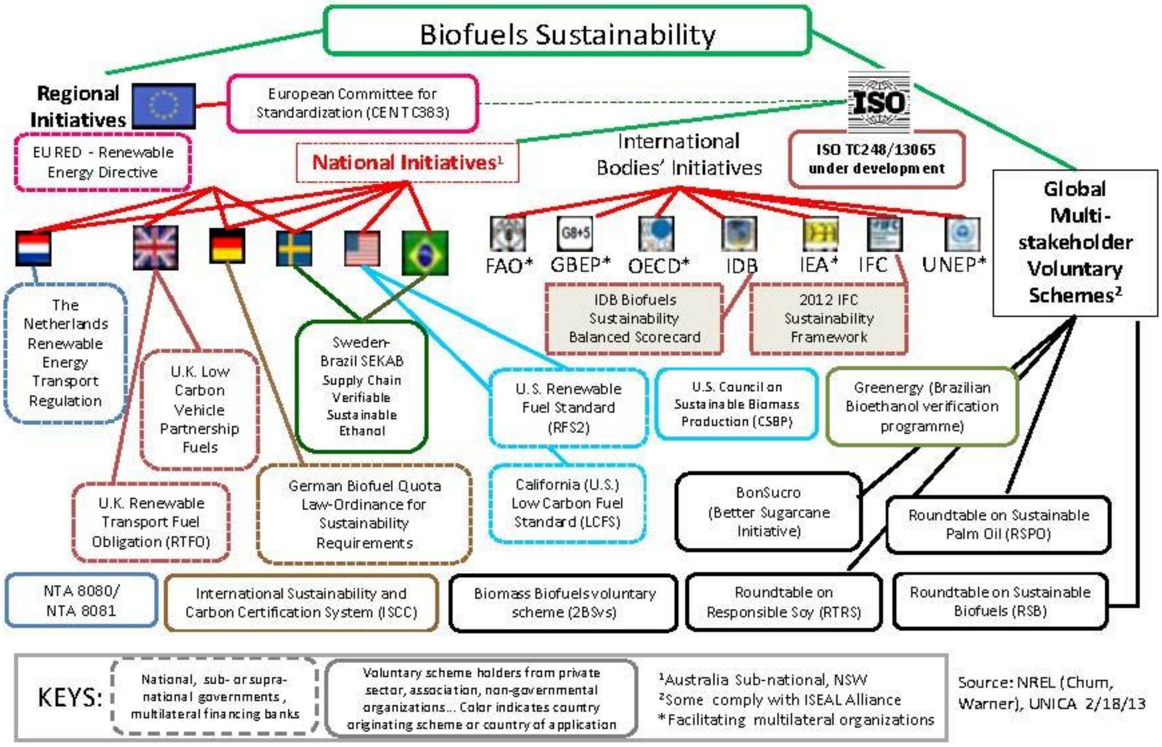
In the face of a wide range of competing requirements and values, the provision of biomass to provide carbon based molecules to supplement or provide those core or “drop in” functions currently provided by fossil resources is just one option amongst the wide range of competing uses. As such, the sustainability of any such biomass yield needs to be assessed in relation to the requirement that the earth’s soils should be **maintained or improved in quality**, but never degraded (unless a satisfactory post use rehabilitation plan is agreed at the time)[6].

A recent meeting (March 2013) of an IEA Bioenergy Workshop (attached D) attempted to address the myriad parallel and competing initiatives to provide an objective basis for assessing, verifying and/or certifying sustainability of the feedstock biomass.

The number of international attempts to define sustainability in this context demonstrates the importance placed on achieving a universal standard, however at the current time, even the ISO TC248 project is incomplete and limited to indicator measurement only. For this biomass utilization sector to reach its full potential, considerable national effort will be required to articulate this crucial indicator of success and compliance.

[6] Bioenergy – a Sustainable and Reliable Energy Source – Main Report, IEA Bioenergy: ExCo:2009:06, page 71. www.ieabioenergy.com.

Figure 1-2: Summary of current international sustainability standards and criteria programs



Many parties and countries are currently grappling to establish bioenergy/biomass sustainable use and yield standards. It is clear that the final value of any products and services generated from a BioHub will be greatly enhanced where the **sustainability status** of all biomass presenting to a BioHub can be verified, confirmed and/or certified.

BioHubs, in the essential role as point of first receival for all such biomass, will be ideally placed to assess the source and sustainability of the yield of all materials presented, as the basis for all subsequent downstream sustainably/carbon assessments. **The provision of this expert service will be of tangible value to all parties in a resultant supply/value chain.**

1.3.2 Trading, Brokering – Establishing Fair Value in the Biomass Market

As discussed 3.2 below (and attached A i), biomass presents in a wide range of different forms, at different times and for different reasons, with each form being best suited to the manufacture of different materials, products or energy in response to varying market demand.

The wide range of biomass discussed and categorised (Sections 2 and 3) are currently wasted, undervalued or simply lumped together into high level generic categories, considered only suitable for leaving on the ground in a passive attempt to return nutrients to the soil, for composting or for energy production as a primary activity.

The active involvement of BioHubs, operated as described herein , either as individual sites servicing a local region, or as an integrated network supporting national markets, will not only raise awareness of the different properties and values of the various biomass types presenting, but will also establish benchmark pricing for each type. They will also be able to broker volumes of such materials between BioHub facilities and to third parties, such as specialist end users looking for assured supplies. Such a service could be crucial to the development of highest order end uses, such as jet fuel.

The establishment of fair value for the various biomass materials and the establishment of a reliable platform to trade and broker supplies of biomass materials is a significant collateral benefit of BioHubs, but one which cannot yet be valued in this initial PFS.

1.4 Collateral Services and Benefits Provided by the proposed BioHubs

Whilst it is the task of this PFS to assess and evaluate the viability of the core functions of the proposed BioHubs: a wide range of strategic, commercial and social benefits will also be provided as a result. These benefits have commercial and economic value but will not be estimated in this PFS other than to be noted for future reference and for assessment of net community benefits, hence a possible future role for Government.

1.4 1 Adds Value to Primary Activities

By providing the cost effective and sustainable realisation of value from wastes, residues or surplus biomass sources (as listed 2.1-2.4 below), the efficiency and sustainability of the respective primary activities will be enhanced and their viability improved.

Even biomass source in Section 2.5 (specialised plantings etc.) below will benefit from accessing established systems, infrastructure, markets and trading values.

1.4.2 Sustainable Yield Certification

One of the core drivers of the move to optimise the use of biomass as a raw material into a complex modern industrial economy is the need to negate or minimise the impact of the unsustainable release of fossil CO_2 to the atmosphere. In jurisdictions where a price has been attached to such carbon emissions, the switch to biomass resources will only qualify to offset or reduce such liabilities if the source of the applied biomass can be certified as arising as a sustainable yield and application.

As the first points of receival for such materials, BioHubs will provide tangible value to end users (or carbon liable parties) by providing an assured basis for all subsequent sustainability and carbon evaluations.

1.4.3 Supply Assurance for Specialist End Users

Many of the potential end uses and markets for specialist biomass derived products (Section 4) are currently unviable to industry because suitable supplies, by quality and quantity, are not available in either absolute terms or for all practical purposes, due to geography and/or the lack of the logistics systems.

BioHubs will create tangible value by being able to provide contracted supply assurance to end users or specialist processors.

1.4.4 Platform for Continuous Technology Development

The emerging supply/value chains for the various sources of biomass, from generation, harvesting, processing and final product manufacture to ultimate use and application, are providing a rich framework of need and opportunity for a wide range of technology developers and vendors.

The proposed BioHub concept will provide at least two crucial benefits to such technology developers and vendors:

i) **Better scoping and definition of the actual functional specifications at each stage of the value chain, for which new or improved technological solutions are required; and**

ii) **Offer actual sites where pilot or demonstration technologies can be applied to fast track their logical development and commercialisation, without necessarily needing to secure their own supply and off take arrangements during the nascent stages of their development.**

1.4.5 Encourage and Facilitate the Highest Net Resource Value (HNRV) Realisation of all Biomass Materials under Management

Due to the disparate nature of existing biomass supplies there is a natural tendency for the emerging biomass processing sector to overlook or oversimplify the wide differences in biomass types or the wide range of end products needed and possible, and focus on simple products such as bioelectricity.

This situation arises because biomass supplies are not readily differentiated or reliably available, or the potential end markets are not yet commercially established.

The BioHubs are proposed to address this issue in detail and create tangible value in the process.

1.4.6 Supports Agroforestry, Vegetation Management & Sustainable Land Use Programs

The broad range of land management activities that involve invasive species management, reforestation, and revegetation of areas such as riparian zones, shelter belts, ridge lines, biodiversity/wildlife corridors etc., are all activities that have a primary motive but which also have the potential to yield sustainable supplies of biomass whilst supporting integrated farm management plans that could:

i) Optimise sustainable biomass yields;
ii) Avoid monocultures;
iii) Optimise product carbon sequestration; and
iv) Improve farm productivity.

Having a local BioHub as a receiver of last resort is proposed to open up options for land owners and managers that can improve the viability of the primary activity by ensuring that the secondary benefits of producing surplus biomass can be delivered for fair value to a local BioHub.

This provision of service by the BioHubs has a parallel in the cropping sector, where the installed capacity provided by the railhead silo infrastructure addresses the ready access to markets and distribution infrastructure for the grower, who is then able to concentrate on the core business of growing the crop.

In the case of "woody weeds" or Invasive Native Species (INS) which occur in different forms all over the country, management or eradication programs are often limited by the budgets available to address such issues. However, with a regional BioHub offering fair value for the resultant biomass arisings and providing extension harvesting services, such crucial programs should be able to be much more dynamic and effective.

1.4.7 Direct Support for Urban Waste Minimisation Programs

Australia currently produces some 30 Mtpa of urban waste. Some 60% is “biomass” and, if this material is separated from the balance of the material (plastics, metals and inerts etc.), the considerable societal cost of disposal and treatment would be greatly reduced or eliminated and significant resource recycling would occur in support of the sustainable circular economy.

The biomass fractions of urban waste streams present in certain generic categories:

- Timber/wood waste;
- Garden/green waste;
- Organic fraction in residual waste streams; and
- Biosolids (water treatment plant sludges).

All of these can be accepted, treated and converted into value added products at a BioHub as a specialist service for respective local communities.

1.5 Summary of BioHub Services and Benefits

This PFS will not be able to cost the collateral benefits that are proposed to be provided as above. The detailed business modelling will need to occur at the subsequent full scale Feasibility Study stage, especially where a related Front End Engineering Development (F.E.E.D.) process has established accurate Capex/Opex values as an outcome of a detailed vendor enquiry process. Nevertheless, primary viability can be estimated based on establishing a net value for available biomass inputs, projected values for products and services provided and the best estimate values for providing and operating the essential equipment necessary to achieve the conversion processes.

However, to support any subsequent economic analysis or cost/benefit assessment, or in identifying a supporting role for Governments, the various collateral benefits are listed in Table 1.1 for reference.

Table 1-4: Collateral services and benefits offered by BioHubs

No.	Service or Benefit	Potential Value
1	Assessment and certification of the sustainability status of the materials presenting at the BioHub	To be assessed
2	Platform to trade or broker biomass resources, as presented or partially processed, to third parties (eg. local compost operations) or between other BioHub facilities in the emerging network	To be assessed
3	Value adding various primary activities (forestry, cropping, grazing, waste management or land management) by placing a market value on current by-products or residues	To be assessed
4	Providing "supply" assurance to high value product manufacturers (eg. liquid fuels, reductants, petrochemical precursor chemicals etc.) to enable them to justify capital expenditure and specialist operations secure in the knowledge that the necessary and appropriate biomass feedstocks will be available	To be assessed
5	Support for specialist technology developers and vendors by: i) Providing functional specification information direct from the supply chains to inform their respective focus and activities; and ii) Offering approved sites for pilot and demonstration activities, where inputs and off takes are readily available.	To be assessed
6	Providing receiver of last resort facilities for biomass materials recovered from urban waste streams	To be assessed
	Economic value of these services	**$?**

1.6 Key Messages from Section 1

- **The crucial lack of standards, systems and infrastructure to identify, harvest, aggregate and incrementally value add suitable biomass sources is identified and scoped to benchmark the need to be addressed.**

- **The potential for Australia to confirm its sustainable competitive advantage as a reliable supplier of quality, biobased products and services is outlined.**

- **The key issues and barriers to Australia realising this potential are identified.**

- **The functional description of the proposed BioHub network concept is presented as a practical response to the needs and opportunities outlined.**

- **The collateral and economic benefits that would be achieved as a result of a fully functioning BioHub network being operational are described, but not yet valued.**

2. The Generic Biomass Categories

Generic biomass arisings have been addressed under five headings. These headings differentiate the physical and commercial characteristics of the biomass, and facilitate a subsequent analysis of the cost and conditions of such materials if they were to present at the gate of the proposed BioHub.

2.1 Forestry and Agricultural Harvest Residues

These refer to the **primary harvesting residues** where the **tops, roots, straw or reject material** are left on the forest floor or in the paddock, because they have insufficient value to be worth harvesting (separately from the primary material) and/or they can at least offer nutrient retention and/or erosion mitigation benefits.

Various strategies are available to greatly improve the harvesting efficiency of these materials, but nutrient retention, soil protection and erosion control are important benefits and vital sustainability outcomes to be observed. If such secondary harvesting is to occur, it must be conducted such that the essential criterion of sustainable yield is achieved and only genuinely surplus material is harvested for secondary uses (attached A iii).

These materials can present as **relatively homogeneous and therefore valuable supplies** into a biomass based, product manufacturing sector. However, such materials will usually present occasionally, on a campaign basis, or seasonally, at harvest time, and therefore the post harvest, first point of receival systems and infrastructure to optimally value add these materials must be established with these inherent supply characteristics in mind.

The **Australian Bioenergy Roadmap**[7] includes a **Resource Appraisal** which indicates some 24 million tonnes per year of grain crop stubble residues and 4 million tonnes per year of sugar cane trash and tops. This report also indicates 2.2 million tonnes per year of public and private native forestry harvesting residues and 3.8 million tonnes per year of public and private plantation harvesting/thinning residues.

Recent estimates (2011) suggest that SE Australia alone (the subject of this PFS) generates some 3.5 Mt/yr of forest residues and some 750 ktpa of agricultural residues. These statistics need to be confirmed, and then discounted to reflect what could be economically collected and what should be left at source for soil quality protection purposes.

2.2 Forestry and Agricultural Processing Residues and Wastes

These materials refer to all the **post harvest processing residues and by-products**, including **bark, offcuts, sawdust, shavings, husks, cotton trash, pulp and sludges** that arise from the entire post harvest to final product wholesale of the food, fibre, pulp and paper, saw log and wood chip sectors.

These materials are addressed quite separately from harvest residues above because they **present in quite different forms and at various levels of homogeneity, assured quantity and reliability/regularity of supply**. In many instances on site energy production from such materials is common (eg. Heat and power production from bagasse, production of heat at saw mills and timber processing for green wood drying, and heat and power production for internal use and even export).

[7] Australian Bioenergy Roadmap, Clean Energy Council, 2008

One recent estimate (Parratt) has formed the conclusion that some 70% of forest harvest residues are left on the forest floor, and that some 43% of crop stubble is currently harvested and used. However, these estimates are based on best available information at the time and are not made to a predictable methodology. Each prospective BioHub development would need to confirm all such arisings with local operators. Some biomass supplies may be available on a fixed contractual arrangement; others may remain “opportunistic” and rely on the “merchant” status of a regional facility.

Alternatively, such materials may present as low value by-products or wastes to be removed to avoid constraining the primary activity. However, in cases where secondary value adding activities can be established, basic heat and power generation may represent a suboptimal end use for such materials. This is because such materials can present as homogeneous and reliably supplied material for subsequent value adding when combined with similar materials from multiple sources. Higher value product manufacturing may well be viable when compared with the current and traditional practices. Establishing biomass value adding facilities adjacent to, or in collaboration with major agricultural or forest products manufacturing facilities, such as sugar mills (bagasse), feedlots, piggeries, chicken sheds, saw mills, pulp and paper plants etc. may well provide an important critical mass for such operations.[8]

Some examples of biomass of this category are:

- The results of cyclone damage to sugar cane and banana crops. For instance Cyclone Larry destroyed 80 percent of Queensland’s banana crop in 2006, resulting in large amounts of biomass without any use.

- The **Australian Bioenergy Roadmap** indicates some 2.8 million tonnes per year of sawmill and wood chip residues are produced. In the agricultural sector, this Roadmap indicates 5 million tonnes of bagasse are produced in the sugar processing industry.

- An almond industry briefing note indicates that this industry is in a rapid growth phase, with hull and shell residues set to increase from 99,333 tonnes in 2011 to over 201,000 tonnes in 2017. This production is centred on the Riverina area of western Victoria. Table 2-1 illustrates this growth trajectory.

[8] This logic assumes that the primary focus of the forestry or agricultural activity is the production of food or fibre, which represents a higher purpose and market value than simply providing biomass feedstocks for conversion into predominantly industrial products or services. However, there may be situations, for example, where a cereal crop has spoiled or been otherwise degraded so as to render it unsuitable for its respective primary food or fibre application, or maybe it is a surfeit, in an oversupplied market and worth more as an occasional source into the prevailing biomass market. In these circumstances, the available material will present with similar characteristics as the other materials in this category but would benefit from being able to access “receiver of last resort” facilities where a fair market price is available for the “spot” biomass supplies, within the locale, to avoid unnecessary transport or logistic complexity.

Table 2-1: Growth of Almond Hull and Shell Production

Harvest	Kernel Production (tonnes)	Hull & Shell Production (tonnes)
2011	40,000	93,333
2012	67,495	157,488
2013	75,714	176,666
2014	81,329	189,768
2015	84,426	196,994
2016	85,823	200,254
2017	86,257	201,266

These potential feedstocks into the emerging biomass value adding sector present as relatively homogeneous, reliably available in quantifiable volumes and often at a competitive price/gate fee, since they are not core products for the generator. Incrementally improved end uses can present as commercially attractive options where the basic core business is the focus of management time and resources, and where the value adding opportunity arises from particular specialisation and aggregation of multiple such sources.

2.3 Urban Waste Streams

These materials represent the **post consumer residues** that were **originally supplied by the agricultural and forestry industries** (food, fibre, pulp and paper products, wood/timber materials after various stages of conversion and complex transformation, even biosolids). The only new material presenting in these waste streams is domestically/locally generated green/garden/vegetative material for which council composting schemes often provide the most cost effective post consumer solution.

These materials are currently managed and handled as wastes, where the emphasis is on minimising the costs and impacts of collection and disposal, with some limited attempts at composting certain materials. This is mainly because composting is a least cost processing option, rather than because the highest value products have been systematically identified and the necessary production processes adopted.

These materials currently present as **costly waste disposal material flows**, and as such, could present with a positive gate fee for a properly established biomass value adding processing facility. These materials are also produced 365 days/yr and therefore could provide feedstock certainty for emerging biomass converting facilities.

To optimise the utility and quality of these materials, the **existing waste management sector** should be encouraged to adopt **"streaming and cascading"** strategies. In this way, waste generators are encouraged to source separate biomass material flows so that they can present with the least amount of contamination from other residual wastes as possible/practical, and simultaneously provide cascading or "next best" process options.

Recent estimates (2011 – EPHC Waste Policy), when extrapolated, indicate that the South East area of Australia (SA, VIC, NSW, ACT and SE Qld) generates:

Organic fractions of MSW (putrescible)	3,700 ktpa (db)
Garden/green waste (domestic/parks and gardens etc.)	900 ktpa (db)
Commercial and industrial (C&I)/Construction and demolition (C&D) biomass fraction (mostly wood waste)	1,350 ktpa (db)
Approx. Total	**6,000 ktpa (db)**

These materials are low/negatively valued and often putrescible, meaning that they need to be processed close to source and daily, to avoid public health issues or odour etc. This characteristic alone means that localised receival and primary processing facilities need to occur to directly address the specific issues related to these potential feedstocks.

2.4 Land Management and Development Sources

These materials present in at least three main categories:

a) Development/infrastructure clearing/maintenance operations

This occasional, project specific source of biomass occurs where vegetation is cleared to allow new (green field) development or infrastructure construction and/or the maintenance of such infrastructure installations such as maintaining clearance under powerlines, or along transport corridors etc.

These initial development sources **occur once only**, but often in substantial quantities and are often relatively homogeneous and of high quality. The production of regular maintenance volumes of biomass can occur to a regular schedule, but often in remote or inaccessible areas.

For these materials to be **reliable feedstocks** into a biomass economy, **the first point of receival facilities need to be readily accessible and conveniently located**, and able to realise fair value for the materials being presented, as and whenever they arise.

b) Bushfire – fuel reduction arisings

Another collateral benefit of harvesting excess forestry or agricultural harvest residues is the resultant reduction in potential fuel load in the event of bushfires e.g. current fuel load reduction initiatives in the plantations surrounding ACT being developed as part of revised forestry management plans to protect the plantations and adjacent communities.

Where bushfires have occurred, there are often stands of spoilt timber to be removed to facilitate replanting.

These biomass arisings are opportunistic and unquantifiable, but the respective management plans would benefit greatly from being able to access a local BioHub.

c) *Woody weed/land management sources*

Whether crown land, council land or private land, the management of invasive species, weeds or unwanted regrowth etc. has the **potential to generate significant volumes of sustainably yielded biomass supplies, as a by-product of the primary activity**. This optimises the utility, value and productivity of the affected lands (see Cobar Case Study – attached B 2).

Figure 2-1: Examples of woody weed/INS infestation

The most appropriate interface between the emerging biomass based economy and these three potentially sustainably yielded sources would appear to be the provision of dedicated harvesting/vegetative management contracting services, operating out of or for local fixed processing facilities, such as the national network of BioHub facilities which is the subject of this study. This source of biomass is the subject of the detailed BioHub case study "Dubbo Case Study," see attachment B 1.

This way the mobile collection/harvesting equipment can work to supply which ever fixed processing plant is the most convenient for any one contract opportunity.

2.5 Special Purpose/Industrial Farming, Plantations, Agroforestry or Intensive Algae Production etc.

These materials all have a common characteristic in that they have been **planted/grown for the primary or predominant objective of providing the emerging biomass economy with quality feedstocks for a fee**. As such, they may well present as the highest quality feedstocks available to the emerging biomass processing sector and be available as contractually assured. However, this high quality and assured supply will present at the highest price to the local processor. In essence, suppliers of such materials would do so as their primary activity, and so look to generate their primary return on investment from the sale of these materials. This contrasts with the commercial circumstances pertaining to the provision of the alternative sources described above (2.1-2.4) in that available biomass from these sectors will present as by-products.

a) *Agroforestry sources*

An existing agricultural enterprise may be considering **revegetation of portions of their property for a wide range of collateral benefits**, such as replanting ridge lines, riparian zones or as wind breaks etc. to achieve erosion mitigation benefits, river bank stabilization, shelter, biodiversity outcomes, or even native fauna migration corridors or a combination of all benefits. Eventual outcome is likely to be **surplus biomass** that needs to be considered in the overarching property management plant.

Such materials may well be produced on too sporadic a basis to justify dedicated downstream processing facilities in their own right, but **in aggregate, could present as a reliable baseline of biomass supply** into facilities that were established and capital justified on other (as above) available biomass sources in the first instance.

Land owners/managers may also choose to establish dedicated biomass plantings on the less productive portions of such properties where the return from select biomass production can demonstrate commercial benefits when compared with the primary activity (food, fibre) of the specific property.

Such plantings may well be undertaken only where assured off take arrangements can be contracted as a precondition of the planting in the first place.

b) *Dedicated plantings and plantations*

This source of biomass is a **common option for the existing forestry sector**, where the volume, location, species and harvesting schedules are determined by the requirements of the local pulp, paper, saw mill or export opportunity. In many cases this activity generates harvest residues (2.1 above) and value chain by-products (2.2 above), however with the emergence of a fossil resource replacement biomass processing sector, even the primary plantings could be produced for profit for biomass processing facilities. In these circumstances different species' harvesting schedules and collateral benefits may inform what is actually grown, where and how the plantings are managed, but the essential activity will be very similar to the plantation activity we currently recognise. Such sources of dedicated production will be essential if the emerging biomass processing sector is to reach its full commercial potential. **Nevertheless, whilst the prospective markets are being established and the conversion technologies are becoming more cost effective, this potential biomass supply source may well present initially as too expensive, even though the quality and reliability could be of a premium standard**.

This source of biomass **might become progressively more attractive to land holders needing to adjust to the regional and localised effects of climate change**. In these circumstances, marginal food and fibre production land may turn out to be best applied for biomass production where careful land use change management plans are developed to address the full range of sustainable land use issues and the sustainable provision of ecosystem services, whilst recognising the potential for simultaneous, selected mixed species biomass production as the basis for alternative local commerce.

A corollary of changing national land use could also include the development of previously marginal lands (in the heavier rainfall northern zones) such that selected development clearing would also produce a significant supply of biomass (2. 4 (a) and (b) above).

c) *Algae or other such highly industrialised methods of biomass production*

Such biomass production techniques hold **considerable promise** for large scale, highest value/quality assured and industrial levels of reliable supply; they also demonstrate the highest levels of solar conversion efficiency into biomass. However, such **technologies are developing and emerging**, and should be considered as medium to longer term prospects[9],[10].

Nevertheless, their eventual commercialisation pathway will benefit from being able to access convenient and existing markets and biomass conversion facilities, if not for their primary products, then at least for secondary or by-product outputs.

2.6 Generic Biomass Sources Summary

Table 2-2 (below) summarises the various types and sources of biomass that are, or could be, available to support Australia's apparent competitive advantage as a producer of high quality biomass based products and services. However, **future viability** for utilizing these materials will revolve around **efficient aggregation pathways**. At least two options present.

The first can utilize the **platforms created by existing industries**, such as sugar and/or pulp and paper, and the second requires a **completely new suite of systems and infrastructure** to provide the logistics framework common to most agricultural systems. For example, rail head silos as first-point-of-receival for cereal growers.

This need for a new suite of aggregation systems and infrastructure revisits the fact that biomass presents with low energy and bulk density, and high moisture content when compared to the fossil resource reserves.

[9] Current Status and Potential for Algal Biofuel Production, IEA Bioenergy Task 39 Report T39-T2, Al Darzins, Philip Pienkos and Les Edye, 6 August 2010. www.Task39.org.
[10] Algae as a Feedstock for Biofuels – An assessment of the current status and potential for algal biofuel production, IEA Bioenergy Task 39 and IEA Advanced Motor Fuels, July 2011. www.Task39.org.

Table 2-2: Essential Biomass Supply Characteristics

Biomass Source	[1] Sustainability of biomass yield	[2] $ Value/gate fees likely to be realised at the gate of the initial processing centre (or BioHub)		[3] Reliability/predictability of supply or availability			[4] Relative quality of material	
		Input materials that need to be paid for -$200	Input materials that pay a disposal fee to the facility operator 0 $200+	365 days/yr	Regular but seasonal	Sporadic, campaign based, unreliable	Homogeneous	Heterogeneous
2.1 Agricultural & forest residues	Essential prerequisite for all sources if the benefits over using fossil resources are to be fully achieved and monetized.		0-----------150			X	X	
2.2 Downstream processing of agricultural & forest materials		(30)------------100		X	X		X	
2.3 Urban wastes								
a) MSW organics		(100)----------0		X				X
b) Green/garden wastes		(50)----0		X		X	X	
c) C&D/C&I wood wastes		(60)-----0		X				X
2.4 Land management residues								
a) Development/infrastructure maintenance operations		(20)------50				X	X	
b) Woody weed/land management sources		(20)------50				X	X	
2.5 Special purpose plantings								
a) Agroforestry			0------80		X		X	
b) Dedicated plantations			50-------150	X	X		X	
c) Algae and similar			50-------150	X	X		X	

NOTES:

Column 1: A primary purpose of stimulating and then optimising biomass based activities to supplement or replace fossil resource sources of carbon/energy, in the economy, is to achieve ecological sustainability. Useful reference documents include:

General:
- Sustainability Guide for Bioenergy – A scoping study – RIRDC, (http://www.ecowaste.com.au/content/RIRDC_CSIRO.pdf)
- Sustainable Production of Bioenergy – RIRDC 09/167 (https://rirdc.infoservices.com.au/items/09-167)

Urban Wastes:
- Sustainability Guide for EfW Projects and Proposals – WMAA, 2004

Column 2: In the early stages of the development of the emerging biomass processing sector, the markets are nascent and the technology is in early stage commercialisation, so that for most first-of-type, initial processing facilities, commercial viability relies on the operator receiving a gate or receival fee, even if in time, such facilities will be able to afford to pay growers/suppliers for the higher quality biomass available.

Column 3: A fixed processing plant needs to operate as continuously as possible to ensure early stage viability and this will require reliable and continuous supplies of suitable feedstocks. Materials that are available all year, preferably under contract, are essential to establish an initial plant. However, when such a basic capability is established the same facility can proactively schedule receipt of materials (usually agricultural residues) only available on a seasonal basis (cropping cycles – bagasse, straw etc.) and also operate contract biomass harvesting operations to exploit sporadic or campaign based sources such as green field, development clearing activities, woody weed management or even power line and transport corridor maintenance contracts.

Column 4: Homogeneous materials provide a higher quality process feedstock and are best suited to the production of the highest quality end products. Mixed or indeterminate or heterogeneous materials tend to be only suitable as generic carbon sources for blending or for lower value product manufacture.

2.7 Key Message from Section 2

- **Five generic categories of biomass are discussed and the qualities and circumstances of their respective availability identified.**

3. Potential Biomass Available

3.1 Introduction and Context

In Section 2 the five generic sources of biomass were identified and illustrated with some actual examples. In this section the potential amounts of each of these categories that would be feasible to process in BioHubs are reviewed and quantified to provide a first order estimate of the short to medium term scale for this emerging sector.

As discussed in Section 2, BioHubs are intended to provide a first point of receival/receiver of last resort service. For many potential sources of biomass, it is the **availability** of a local BioHub that will stimulate non critical sources of biomass to be presented at the gate (the "merchant" service characteristic feature inherent in the BioHub concept). **To seek to contract defined quantities of such non critical sources of biomass will require both generator and receiver to define terms and outcomes**, which may be best agreed on a case by case basis, especially in the early stages when the opportunity has yet to be fully entrenched in the forward planning of both parties.

However, even the basic BioHub facility cannot be capital justified or established without having a basic minimum commercial operation, that whilst receiving biomass for a fee and making basic products to sell, can then provide the more discretionary services outlined in Section 1.

In terms of the potential sources of biomass arising in Australia, some can only be discussed in broad terms, as being potentially available, and therefore worth consideration only in the context of the BioHub existing and being a real time consideration for the generator. Other biomass sources that could support the minimum business model, and therefore support the establishment of a basic operation and capability, are described in Table 3-4, p. 32.

The Australian Energy Resource Assessment report[11] provides a summary based on the CEC Bioenergy Roadmap data of **biomass resources and the projections of electricity generation possible based on those projections for 2010, 2020 and 2050**. The resources covered are: agricultural related wastes, energy crops, woody weeds, forest residues, pulp and paper mills wastes and urban wastes.

Table 3-1 provides an extracted summary of the presented data:

[11] The Australian Energy Resource Assessment report, Geoscience Australia and ABARE, 2010

Table 3-1: Biomass Resources and Implied Generation Potentials to 2050

Biomass Source	Quantity tpa	2010 (GWh pa)	2020 (GWh pa)	2050 (GWh pa)
Poultry – manures	94 million	-	297	1055
Cattle – feedlots – manures	870 thousand	-	112	442
Pigs – manures	1.8 million	1	22	205
Dairy cows – manures	1.4 million	-	22	89
Abattoirs – wastes	1.3 million		337	1773
Stubble – grain and cotton crops	24 million			47000
Bagasse	5 million	1200	3000	4600
Sugar cane trash, tops and leaves	4 million	-	165	3200
Oil mallees	-	-	112	484
Camphor laurel	40 thousand		83	20
Forest residues (native forests, plantations, processing residues)	~ 9 million	79	2442	4554
Black liquor	-	285	365	365
Other pulp and paper wastes	-	74	141	141
Urban food Wastes	2.9 million	29	267	754
Garden organics	2.3 million	29	121	461
Urban paper and cardboard	2.3 million	-	38	1749
Urban wood/timber wastes	1.6 million	45	295	1366
Landfill gas		772	1880	3420
Sewage gas		57	901	929

The CSIRO Energy Transformed Flagship conducted a study[12] for the Australian Energy Market Operator (AEMO) to investigate the **potential for electricity generation in Australia from biomass in 2010, 2030 and 2050**. This study drew on previous CSIRO biomass resource assessment studies to estimate electricity generation potential at these three dates. The study noted that new tree plantings would grow the available forestry biomass from 68 million tonnes per annum in 2012 to approximately 96 million tonnes per annum in 2050. For the 42 AEMO regions (essentially in eastern and south eastern Australia) the total biomass resource available for power generation was **estimated as 67 million tonnes in 2010** and was **projected to grow to 84 million tonnes in 2030 and then to 96 million tonnes in 2050.**

Table 3-2 gives the various biomass sources identified in this study.

[12] AEMO 100% Renewable Energy Study, CSIRO Report EP-126969, Debbie Crawford et al. 4 September 2012

Table 3-2: Biomass Resources from the AEMO study

Biomass Source	Amount and Timeframe
Plantation biomass	8 – 10 Mtpa from 2010 to 2050
Native Forest biomass residues	7.3 Mtpa (constant over study period)
Short Rotation Trees	10 Mtpa 2020 growing to 20 Mtpa in 2050
Sugar Cane Bagasse	5.5 Mtpa (substantially constant)
Crop stubble	15-35 Mtpa Average 18 Mtpa in AEMO regions
Grasses	1-95 Mtpa (average 20 Mtpa)
Waste	9.2 Mtpa at present to 14.7 Mtpa in 2050

Some **discrepancies** are evident between the Clean Energy Council Roadmap figures and the more recent CSIRO AEMO figures. It is noted that the AEMO study figures only relate to the 42 AEMO regions of east and south-eastern Australia. The study methodologies were somewhat different, and both would need further investigation to refine the numbers. However, it is evident from both that there is a very large potential quantity of various types of biomass across Australia.

3.2 Forestry and Agricultural Harvesting Residues

3.2.1 Forestry

National estimates from the CEC Roadmap table are:

- Plantation harvesting and resultant residues – 3.8 million tonnes per annum
- Native forestry harvesting and resultant residues – 2.2 million tonnes per annum

While the above figures are national estimates, large concentrations of forestry biomass are in the forested areas of the 'Green Triangle' spanning western Victoria and eastern South Australia, Gippsland, and the NSW and Queensland coastal strips.

3.2.2 Agricultural

National estimates from the Roadmap are:

- Crop residues – 24 million tonnes from grain and cotton crops
- Animal husbandry
    - Feedlots – beef feedlot population approximately 870,000 tonnes
    - Dairy cows – 1.4 million tonnes
    - Poultry – approximately 94 million tonnes
    - Pigs – 1.8 million tonnes

3.3 Forestry and Agricultural Processing Residues

3.3.1 Forestry

- Pulp/paper/saw log sectors residues – See Table 3-2
- Engineered timber manufacturing residues

A major competitor for forestry residues is the fibre particle board industry.

3.3.2 Agriculture

- Crop processing residues – Bagasse – 5 million tonnes per annum
- Orchard residues (including wineries)
  - Potential wine industry wastes include prunings and wine marc.
  - Abattoir wastes – 1.285 million tonnes per annum produced from approximately 150 abattoirs
- Cotton trash – included in 24 million tonnes per annum for agricultural related wastes

3.4 Urban Waste Streams

3.4.1 MSW and C&I

The biomass fraction in residual MSW (EPHC report, 2010) is estimated at some 5 Mtpa (dry weight). This figure is somewhat less than the Urban Biomass category from the Bioenergy Roadmap which was reported as 9,080,000 tonnes per year, which may be a dry weight versus "as presented" data discrepancy.

BioHubs are ideally placed to **extract this material under contract to local councils** such that the putrescible load to landfill can be eliminated (saving considerable operating expenses and avoiding carbon liabilities).

The same EPHC report estimates urban waste biomass arisings at some 237kg/capita/pa as a useful guide to potential regional arisings. This is net of operating recycling/composting systems, or some 5Mtpa.

Residual green/garden wastes are estimated to occur on a national average of 150kg/capita/pa or 3.5 Mtpa. This is close to the Roadmap's figure of 3.8 Mtpa for garden organics.

Residual biomass arisings in C&I and C&D urban waste flows are reported in the same EPHC report at 4.5 Mtpa and 3.5 Mtpa respectively. This potential relationship provides the basis for negotiating a beneficial arrangement for both parties in that Council could see a progressively declining rate of gate fees in real terms over time, as the "merchant" services provided ever more of the assured income for the plant.[13]

These estimates are considered achievable over 5-10 years as the BioHub network is incrementally established.

[13] An advantage for receiving and processing urban wastes in any location where a BioHub is established is that the service provided to local councils all year round can provide a level of assured and contracted activity and gate fees for the BioHub facility as a "commercial" platform from which the other "merchant" services can be provided cost effectively.

Table 3-3: EPHC estimates – 2010 Report

Biomass Source National Estimates	Year 5	Year 10
MSW sourced biomass	1,000 ktpa	2.5 ktpa
Residual green/garden waste	500 ktpa	1.5 ktpa
Residual C&I/C&D biomass	2,000 ktpa	4,000 ktpa

3.4.2 Biosolids

Biosolids contain significant quantities of essential soil nutrients, trace elements and carbon, and are generated at the water treatment facilities servicing any population centre.

In any application, BioHubs are ideal for **converting biosolids into biochar** based fertilizers, but the availability of such materials can only be researched on a case by case basis.

3.5 Land Management/Development Biomass Arisings

3.5.1 Greenfield Clearance Arisings

Each time land is cleared for housing, roads, infrastructure or development of any kind, public or private vegetation is likely to be removed.

These materials are currently being handled by the proponents, and perhaps windrowed and burnt, or taken to landfill.

If a BioHub is established, it will provide a **convenient and cost effective first point of receival** for these biomass sources, however potential volumes cannot be defined for the purposes of this PFS, other than as a deemed estimate.

3.5.2 Vegetation Management Services

Biomass arisings from this activity include everything from parks and gardens maintenance, and roadside clearing, to under power lines clearing etc. In some instances, such as power line clearing, the biomass is left on site, being too difficult to recover, especially without a strong market for the material if extracted.

Again, these arisings **do not currently present as an assured input** into a proposed BioHub, but some will if a BioHub is available.

3.5.3 Fire Hazard Reduction Management

A considerable amount of biomass is burned to create fire breaks and to reduce the fuel loading in bushlands in periurban areas. It is likely that this source of biomass will be **investigated as a feedstock instead of being burned unproductively into the atmosphere**. This source of biomass has been used in the USA to obviate acquiring air emission permit, using the biomass for energy. This source of biomass is yet to be researched and quantified in Australia, but remains an unrealised opportunity.

3.6 Dedicated Biomass Generation

This source of biomass is characterised as being produced to provide oil seeds or lignocellulosic feedstocks as the primary activity, not as a by-product as 3.2-3.5 above.

As a primary activity, the product will tend to be of the highest quality and value but require basic return on investment from the primary activity. **The products are likely to be dedicated to a particular and pre-contracted end use, such as liquid fuels or platform chemicals**.

Such sources include dedicated plantations, algae, oil seed crops etc. Where such materials are processed for their primary yield, biomass residues will arise, and these may well be best processed at a local BioHub.

No estimations can be made at this stage, but they should be specifically researched and identified during the development of each respective BioHub facility.

3.7 First Order Estimate of Biomass Feedstocks

Table 3-4: First order estimates of biomass arisings by type

Biomass Source	Readily identified national arisings ktpa	Potentially available to BioHubs acting as receivers of last resort as a national network ktpa	Comments
3.2 Agricultural & forestry harvesting residues			
3.2.1 Forestry – plantations	3,800	3,000	High recovery rate assumed due to more predictable management regimes in plantations.
Forestry – native	2,200	1,000	Recovery rate assessed based on more difficult terrain in native forests.
3.2.2 Agricultural – crop residues	24,000	5,000	No till farming and higher order straw uses assumed to utilize most of the available material.
Agricultural – animal husbandry	–	–	These wastes could require on site AD facilities if raw and wet, but may find prior uses as composts and direct land applications.
Sugar cane trash	4,000	2,000	Assumes bagasse will be substantially diverted over time for specialist fermentation/digestion applications and so trash may assume a larger role in refinery heat generation.
3.3 Agricultural & forestry processing residues			
3.3.1 Pulp/paper/saw log residues	9,000	6,000	Quality materials that might be better value added in aggregate via BioHubs than individually for simple heat/drying on site.
Engineered timber residues	Inc	-	Included.
3.3.2 Bagasse	5,500	3,000	Likely to be appreciated for its higher order applications as a homogeneous and high quality feedstock.
Abattoirs	–	–	Paunch wastes and sludges ideal for BioHub processing, but usually already allocated to alternative uses.
3.4 Urban wastes			
– MSW sourced biomass	3,700 (db)	2,000 (db)	Wherever a BioHub is located, processing this material for highest value can be a core service to the local community.
– Green/garden wastes	900 (db)	400 (db)	Only available where local composting operations cannot beneficially process all the materials available.
– Residual wood waste	1,350 (db)	1,000 (db)	This is a problematic material for ambient temperatures sorting and processing and therefore ideal for BioHub processing for highest value recovery.
– Biosolids (based on 25 gms/p/day)	210 (db) 1,100 (wet)	50 (db)	Most communities have installed capabilities to beneficially process these materials, but the BioHub network could offer significant advantages over time.

Biomass Source	Readily identified national arisings ktpa	Potentially available to BioHubs acting as receivers of last resort as a national network ktpa	Comments
3.5 Land Management Arisings			
– Green field clearing	TBA	Approx. 2,000	This is only a subjective assessment assuming the optimisation of BioHubs "merchant" characteristic.
– Vegetation management services	TBA	Approx. 1,000	This is only a subjective assessment assuming the optimisation of BioHubs "merchant" characteristic.
– Fire hazard reduction	TBA	Approx. 1,000	This is only a subjective assessment assuming the optimisation of BioHubs "merchant" characteristic.
– Woody weeds	100,000	Approx. 10,000	The available woody weed/INS material from the NSW Peneplain area is confirmed as 37 Mt. Assuming 100Mt as a national amount on a 10 year rotation some 10 Mtpa as a sustainable resource if managed as a commercial resource.
Order of magnitude estimate Sub Total		**Say 40,000**	The order of magnitude estimate compares with the CEC estimate of 48 Mt.
Dedicated Biomass Generation			
– Mallees	TBA	TBA	Potential supply entirely dependent on individual decisions made in response to market conditions; such materials may usually be processed directly at initiating facilities but may generate sustainable arisings of process by-products.
– Oil seed crops	TBA	TBA	
– Algae	TBA	TBA	
– Plantations	TBA	TBA	
Order of magnitude estimate Sub Total		**50,000**	Extrapolated estimate.
Total		**90,000**	Extrapolated estimate.

TBA = To be assessed

A BioHub network receiving as a medium term objective some 40 Mtpa biomass as by-products of existing primary production (types 2.1-2.4) could produce some:

- 8 Mtpa quality feedstock to the liquid (jet) fuels sector;
- 3 Mtpa of metallurgical charcoals for local and export markets;
- 5 Mtpa of high ash biochar products for agricultural application and sequestration; and
- 2.5 GW bioenergy (as a major by-product).

Specifically grown biomass (type 2.5) could at least double these projections.

3.8 Key Message from Section 3

- **National estimates for readily accessible biomass supplies are discussed and then summarised in Table 3-4.**

4. Products and Outcomes

4.1 Product Philosophy

As described in Section 1, the proposed BioHubs will initially perform as a **"receivers of last resort"**. And in accordance with the "streaming/cascading" philosophy adopted, biomass generators will be able to stream their materials for highest and best use, only presenting materials to the BioHub if they are unable to derive a higher value outcome by themselves.

Options available to generators are related to the **biomass type**. B**iomass may be left on the ground at harvest time, or minimised during subsequent processing, or avoided from presenting in post-consumer waste streams**; and **when generated by households, the quality, source separated materials can be applied to sustain any local quality compost manufacturing operator**. The proposed BioHubs are intended to even support these higher order outcomes with brokering services for trading biomass for fair value to assist with feedstock security of supply issues where practical. However, after streaming materials for their highest use, the BioHubs provide the cascading alternative to extract full value from all such residual materials to avoid the binary outcome of waste and disposal as the alternative.

Materials presenting at a BioHub will be managed to **support highest order product outcomes starting with the assessment of every load of material presented** for quality, origin (sustainable yield assessment), type, quantity and regularity of supply and directed for subsequent management or processing cognisant of the prevailing demand for a full range of carbon based products. **Post assessment options** will include:

i) Trading/brokering to off-site composters/digesters if appropriate and cost effective;

ii) Aggregating materials like-with-like to generate critical mass both on site, and within a BioHub network if appropriate. If materials present as biologically unstable (e.g. manures, food waste/sludges, MSW organics etc.) they will be at least pre-treated and stabilized into recognised interim products immediately to eliminate potential odour/leachate issues;

iii) With accumulated quantities of stabilized biomass materials available, the full suite of products will be manufactured to the exact specifications established and tailored to achieve general market or specific customer requirements; and

iv) Different biomass categories finally processed to products such as:

- Low ash biomass channelled towards high value metallurgical grade charcoals and reductants;
- High/medium ash biomass channelled towards agricultural biomass based products, as a range of essential ingredients in specialty fertilizer products;
- Torrefied solid fuel products available if demand exists;
- Bioenergy as a by-product of all such product manufacturing activity; and
- Pre-processed materials for specialist third parties such as fuels manufacturers, eg. jet fuel.

Some background on the status of these potential markets follows.

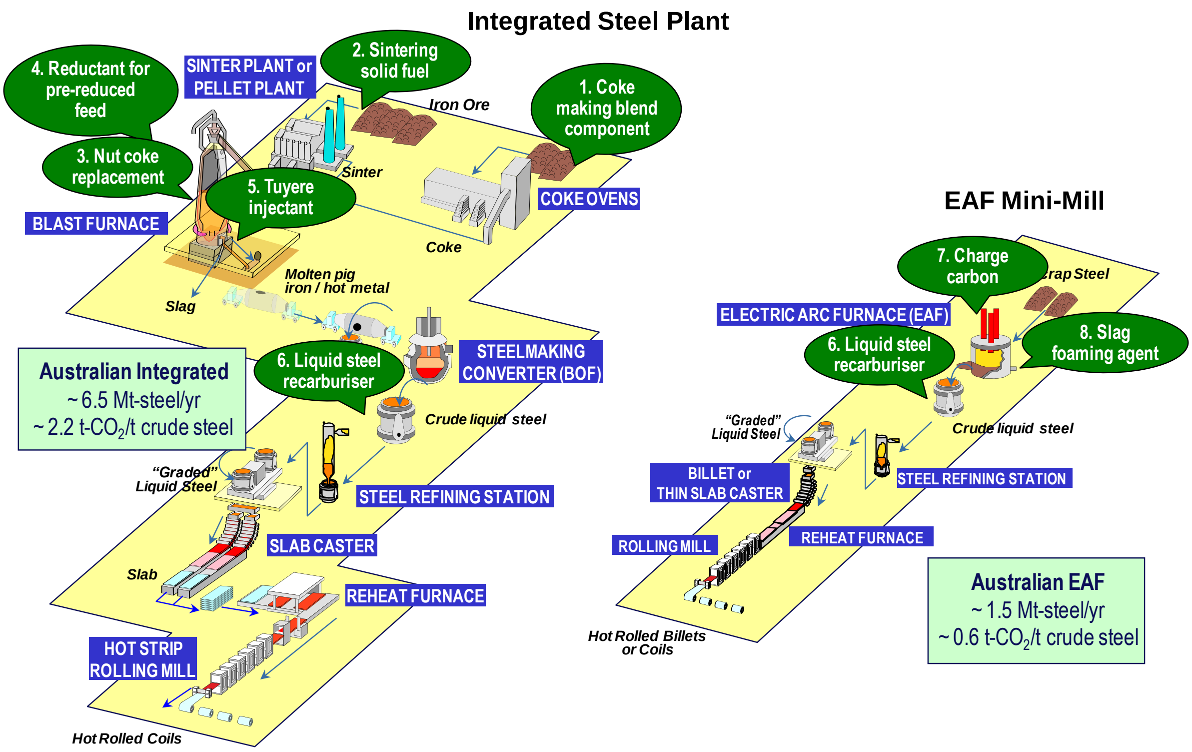
4.2 Metallurgical Charcoals and Reductants

Smelting metal ores (iron, lead, zinc, copper, magnesium, aluminium etc.) is achieved using cokes, coal and specialist carbon reductants to deoxygenate the basic ores.

This sector is **one of the major emitters of Greenhouse Gases** generally, and CO_2 in particular, due to the very nature and essential chemistry of the process.

For example, in the iron and steel making process in Australia which until 2011 manufactured some 8 Mt of steel/pa and generated approx. 15.2 Mt of CO_2-e (CO_2 equivalent) emissions. Research work since 2006 (attached C) has identified some eight separate points in both the integrated (steelmaking) and electric arc mini mill (EAF) process (using scrap metals) where specific charcoal products can be successfully applied as direct replacements for the current coke/coal products, Fig. 4-1. The comparison between fossil and biomass based emissions are presented in Figures 4-2 and 4-3.

Figure 4-1: Integrated Iron & Steel making value chain

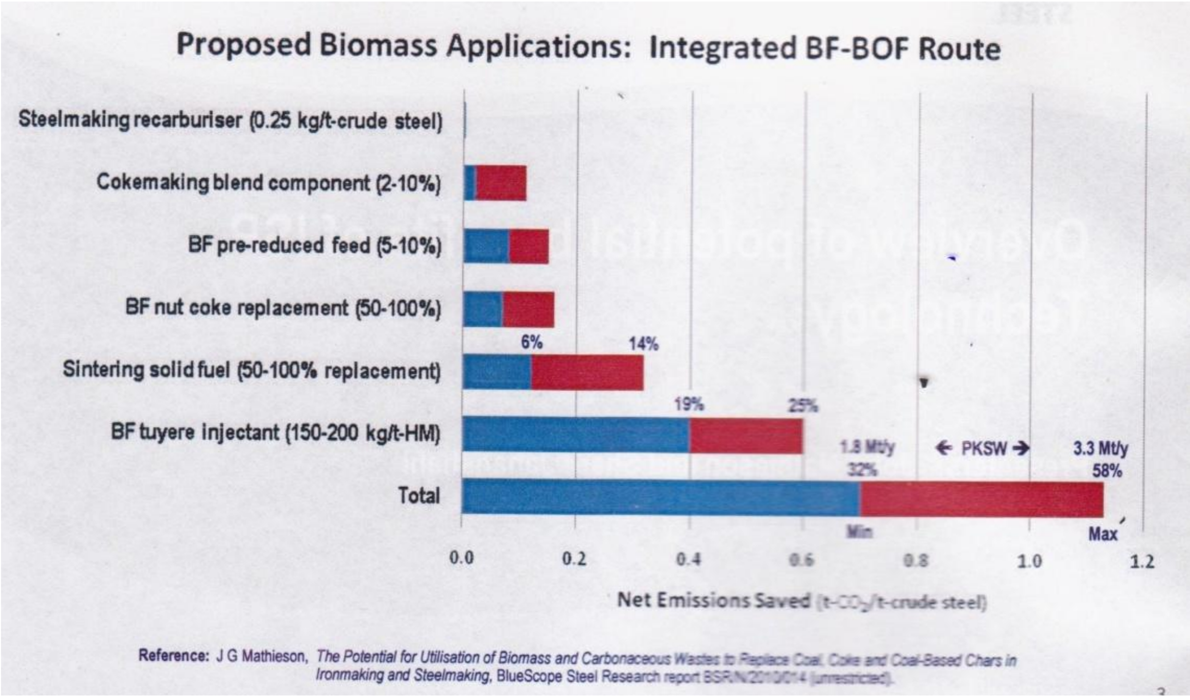


Key:

The points where biobased charcoal can be applied

Current estimates indicate that **total CO2-e emissions savings of some 60%** are possible if all the researched initiatives are fully implemented.

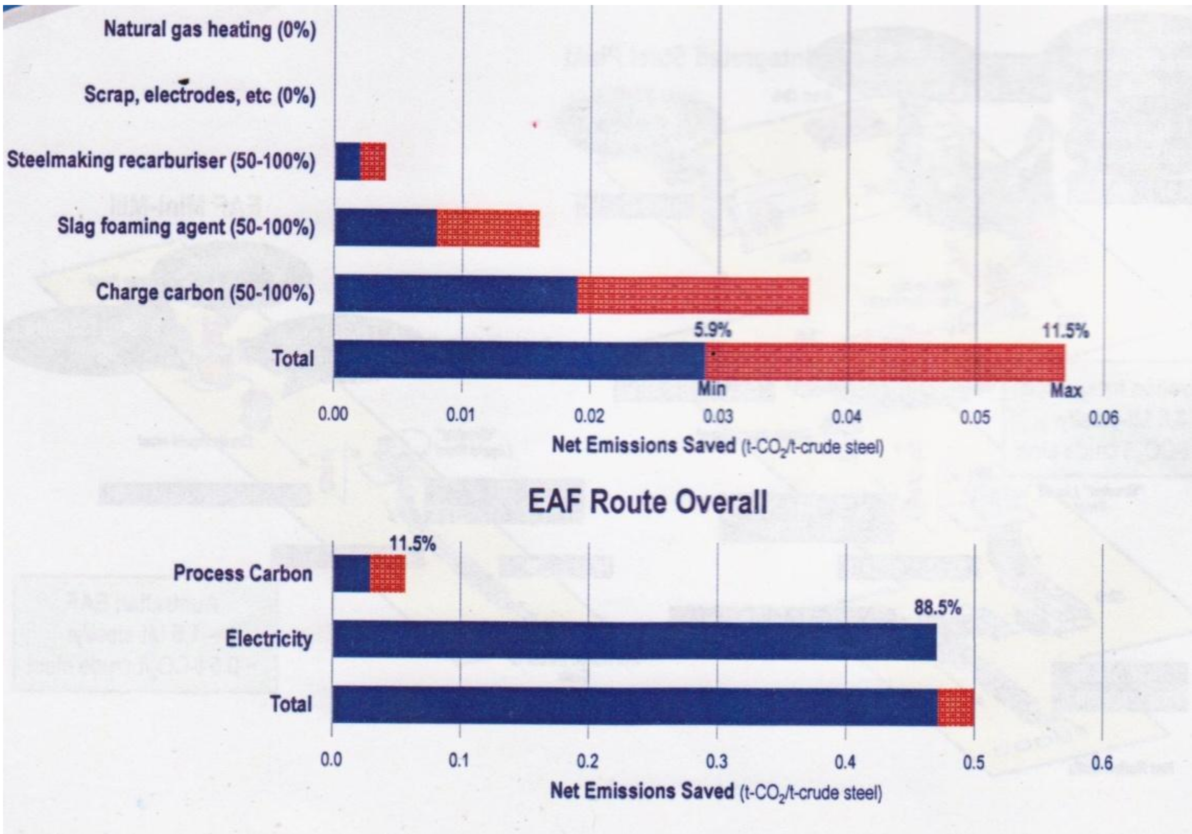
Figure 4-2: Integrated BF – BOF Route



Key:

Represents Min/Max range of net emissions that could potentially be saved (t-CO_2 per tonne of crude steel produced) depending on the actual extent of biomass applications adopted

Figure 4-3: EAF mini mill



The status of this work is summarised Attachment C and confirms that current demand for specific charcoal products in Australia alone, is some 1.5 Mtpa.

This is a very large market. Assuming that the charcoal yield is approx. 20-25% of the selected wood (biomass) processed, on a dry weight basis, and the processed wood will reflect some 50% of the "on the stump" weight of the as grown biomass, the **existing local demand for select low ash timber** is some 12-15 Mtpa. These numbers apply only to the Australian iron and steel making sector. Similar potential demand could be demonstrated from all the other metal smelting and foundry sectors. In addition, there is export, or import replacement, since many of the higher value reductant products are currently imported from EU and China.

Australian metals smelting represents only some 2-3% of such global metals manufacture and the same drivers for change (1.1, p. 1 above) are fully applicable to all other operations (subject to market conditions and the respective local political environment).

The production of high grade metallurgical charcoals could be an import replacement opportunity for Australia, since current anthracite based **materials** that are used as coking coal substitute are all imported (from China and EU) (eg. products such as steelmaking recarburiser or EAF charge carbon).

For example, the specific charcoal products identified (attachment C) are directly applicable to iron and steel making industries globally, and Australia has a market leading position as an exporter of the coal and raw materials to this sector and is thus in an ideal position to introduce a range of biomass based alternative products into these markets that appreciate the net profile benefits.

If the demand for low ash biomass based products in Australia is some 1.2-1.5 Mtpa, then the export potential is an order of magnitude greater. But this potential is unachievable to supply even the local market let alone the export market, due to the almost total lack of the systems and infrastructure to receive the various biomass arisings, as and when they are presented, and incrementally aggregate, value add and supply them to identified end users and generic markets cost effectively. This is the exact need and opportunity that the BioHub concept is proposed to address. Whilst the size of even the national market is greater than any particular region or facility can supply, the "network" concept for the BioHubs is proposed to address this issue; an approach currently replicated in many of Australia's forestry and agricultural sectors.

In summary, the market demand for these biomass based products is clearly identified, and Australia has the potential to be a global leader in the supply of the sustainably supplied biomass to address the market opportunity. However, as an emerging industry, the missing link is the provision of the standards, protocols, systems and infrastructure to facilities the emergence of this essential activity.

4.3 Biochar based, Tailor Made Fertilizer Products

Biochar is a term referred to in this PFS for all such **semi activated, usually high ash, char products manufactured for use on land as soil productivity improvers and soil structure amendments**.

Biochars manufactured by **slow pyrolysis** within the 450°-600°C temperature range (usually closer to 450°-500°C for optimum yield and effectiveness) provide a range of beneficial mechanical properties to soils, including:

– Improved water retention and penetration and thus reduced nutrient loss;

– Improved cation exchange capacity (CEC); and
– Support for elevated levels of soil microflora activity.[14]

Entrained mineral elements sourced as ash from the original biomass source, or added later can provide the essential nutrients nitrogen, phosphorus and potassium (NPK) as well as trace elements and modify pH.

Certain entrained clays and/or rock dusts can provide enhanced catalytic services for soil microflora to convert certain essential mineral plant nutrients from the mineral to the bioavailable form when added into tailored biochar products.

In its stable pyrolysed form, the biochar can present as a long term carbon bio-sequestration product whilst increasing net soil carbon with every kilogram so applied.

Biochar alone, or blended with other minerals and trace elements, can be **applied** for domestic/residential use, horticulture, and viticulture; and beneficial results can be achieved even in pasture and forestry applications.

To estimate the potential local demand for biochar, the cropping sector in Australia provides a sound starting point.

Cropping is taken to include the broad acre cultivation of cereals, oil seeds, lupins, sugar cane, legumes, hops, cotton, hay and silage.

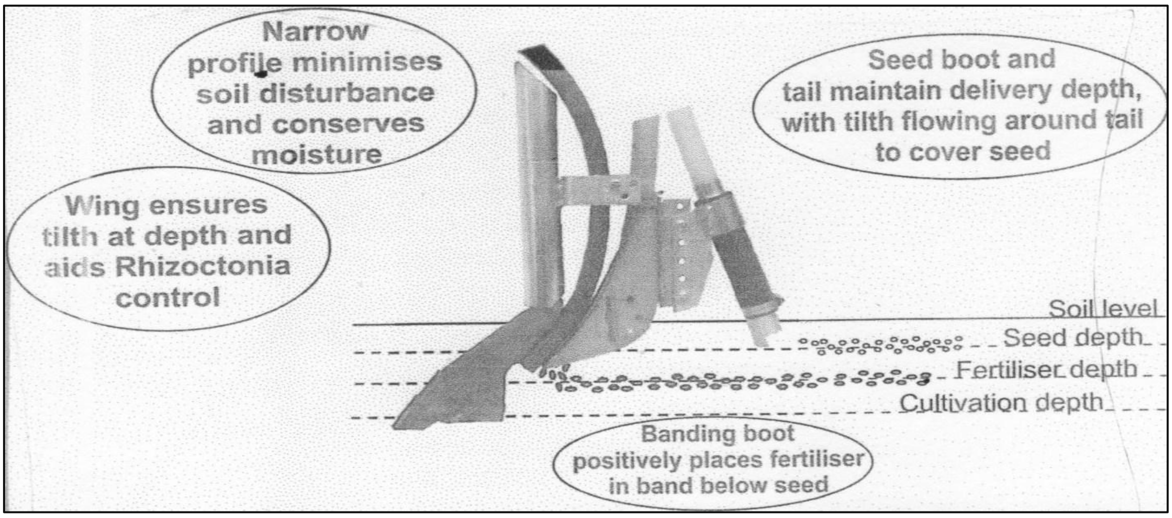
Currently some 35 million ha are dedicated to broad acre cropping in Australia (ABS 2011).

Most research work on the optimised use and application of biochar to cropping soils has been benchmarked around application rates of some 10 t/ha for biochar, to achieve the basic benefits in the literature[15]. However, since the production costs of quality biochars is some $150-$250/t, the broadcasting of such material uniformly over paddocks is not cost effective, since so much of the biochar remains on top of the soil, not directly in the root zone. Current research has focused on applications where the biochar can be delivered directly to the root zone of specific crops and thus deliver their benefits for most immediate realisation.

Recent trials in Central West NSW have focused on delivering **biochar pellets** directly to the crop root zone via the traditional air seeders as the new crop is being planted in minimum tillage applications (see Fig. 4-4).

[14] Lehmann, J, and Joseph, S (eds.), *Biochar for Environmental Management: Science and Technology*, http://www.biochar-international.org/projects/book
[15] Personal correspondence with Dr Lukas Van Zwieten, NSW DPI, http://www.dpi.nsw.gov.au/research/centres/wollongbar

Figure 4-4: Air seeder



(This application is discussed in greater detail in case study attached B 1).

Because the biochar is delivered to only the root zone, the full beneficial effects of biochar application, usually only achieved at application rates of 10 tonnes per hectare, can be realised with application rates of 150-200 kg/ha. Such applications become immediately cost effective within the previous cost structures for alternative methods of achieving such productivity and carbon sequestration benefits by any other currently commercially available method.

This also allows an order of magnitude extrapolation for **potential demand** for carefully tailor made biochar products.

- Approx. 35 million ha currently cropped in Australia;
- Application rate, approx. 150 kg/ha;
- ∴ Total demand for tailored biochars for cropping alone = > 5 Mtpa of finished product.

This would require some 40 Mtpa of suitable biomass nationally to present at the gates of the proposed BioHub network.

Whilst these figures for total national cropping need discounting to reflect alternative soil nutrient management techniques and the effects of only gradual market penetration, the national impact would not be limited to just cropping activities. This application for biochar would be directly compatible with existing Carbon Farming Initiative programs and should be equally supported by an alternative “direct action” policy if ever implemented.

4.4 Fine and Platform Chemicals and Plastics

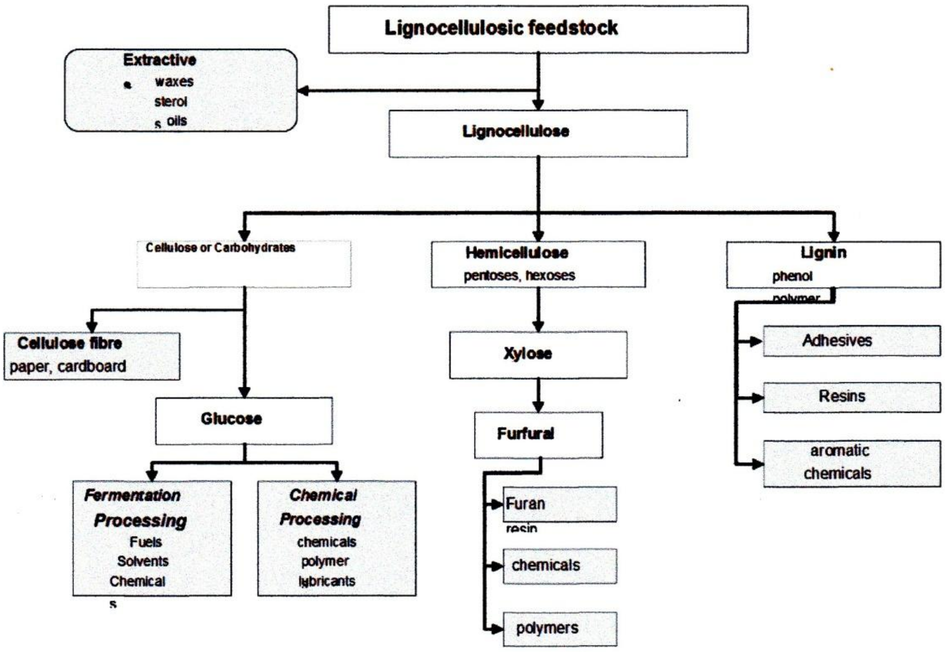
The global chemical industry, reported revenues (2007) of some $2,122 billion which is almost entirely based on fossil resources as the initial raw material (Corelli, 2010)[16].

In its greatly simplified form, the production of the similar range of chemicals and products could be based on **lignocellulosic (biomass) feedstocks**.

[16] Corelli Consulting, *Biorefinery Scoping Study: Tropical Biomass*, (prepared for DIISR), 2010

As an example of the potential to significantly value add basic lignocellulosic resources, the sort of fine or platform chemicals outlined are valued in the world market at some $1,000-$10,000/t when the raw sugar they can be made from is currently exported for some $250-$300/t (Corelli, 2010)[17].

Figure 4-5: Example of product streams potentially available from lignocelluloses processing



Source: Parratt & Associates, *Scoping Biorefineries: Temperate Biomass Value Chains, 2010 p. 67*

Parratt (2010), refers to one of the most significant challenges to Australia achieving even a fraction of the initial potential as being the need for the "development of the logistics systems to ensure efficient collection, delivery and storage of biomass", as well as "access to…biomass in sufficient quantities to ensure long term viability" for the emerging sector.

It is beyond the scope of this PFS to attempt to quantify the immediate actual demand for biomass sources to feed this potential market, other than to identify that this sector is currently constrained from reaching even a fraction of its potential by the lack of a systematic biomass generation sector, supported by the sort of integrated harvesting, aggregation, pretreatment and distribution systems proposed by the BioHub network concept.

4.5 Bioenergy

Whenever biomass is pyrolysed to produce for example biochar (see 4.2 and 4.3 above), **surplus heat and syngas (hydrogen plus carbon mono/dioxide)** are produced equivalent to some 50% of the calorific value of the dry weight of the biomass. For this PFS an assumption will be made that this energy source is converted to "green" power via gas engines and returned to the grid.

A subsequent full scale feasibility study will need to identify the most cost effective pathway to monetise this energy product, which could be applied simply as heat if a suitable application could be identified.

[17] Ibid.

4.6 Carry Forward Values

The specific requirement scoped by the focus on the four main products above will inform both the subsequent facility layout (Section 5) and financial assessments (Section 6).

For the **metallurgical/reductant opportunity**, the requirement is to identify and isolate the low ash and/or hardwood species for processing into the highest net value products.

The initial value of such products starts at some $200-$300/t and, with specialty processing product values of $300-$700/t can be achieved, most of which will present as import replacement products in Australia.

For the **biochar/agricultural products**, again the basic medium/high ash biochar products can find immediate markets in the $250-$350/t range.

For **petrochemical industry precursors**, again the existing benchmark is refined sugar, which is currently achieving export values of $250-$300/t.

With the prospective, **first order products of a Standard BioHub expected to be valued at some $200-$300/t**, the generation of bioenergy as a primary product looks marginal, and hence the starting proposition that bioenergy will usually present as a by-product of the primary product activity, except perhaps in those remote areas where the alternative supply of power is diesel generators.

This review also scopes the basic process capabilities that a Standard BioHub needs to have, to be able to supply all or any of these product lines from time to time:

1) To be located close to source to minimise collection/aggregation/transport costs and present as conveniently as practical to optimise occasional biomass supplies;

2) To be able to offer extension services in the form of temporary Feeder BioHub facilities to accommodate seasonal or opportunistic supply opportunities;

3) To provide receival/evaluation, sorting, screening, storage/aggregation and pretreatment capabilities efficiently, to sufficiently value add the myriad of highest value product/supply opportunities that are either contracted or emerge from time to time.

4.7 Key Message from Section 4

- **The main products that could be manufactured at individual BioHub facilities are identified and discussed:**

  i) Metallurgical charcoals and reductants;
  ii) Biochar based, tailor made fertilizers; and
  iii) Bioenergy,

  and that these products can support the establishment of individual BioHubs and hence an eventual network. The integrated facilities are then ideally placed to supply biobased feedstocks to more centralised and specialised liquid fuel/petrochemical end users, to provide supply certainty to such capital intensive value adding activities.

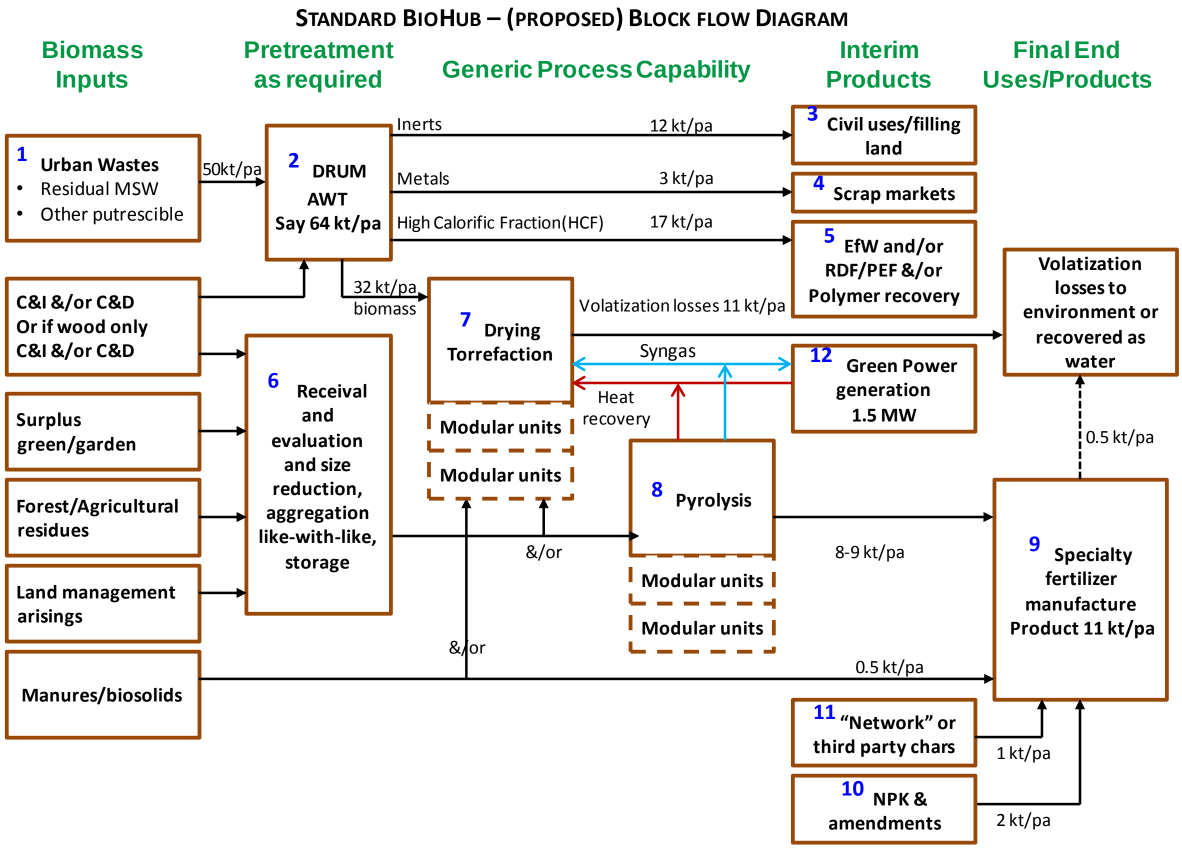
5. Technology and Process Flow Description

In this section we review the **operational capacity** for a Standard BioHub as proposed 1.2.6 (p. 9). It has the capacity to sort and pretreat biomass, and includes a basic pyrolysis capacity. As an example, this plant produces biochar based fertiliser.

A basic block flow diagram (BFD) for the BioHub has been developed to provide 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 5-1.

Figure 5-1: Standard BioHub – (proposed) Block Flow Diagram



* Mass flow numbers refer to the Dubbo BioHub Case Study (attached B 1) and represent proportions for "standard" BioHubs except that they might not include process nodes 10, 11 and 9.

<u>**Inputs**</u>

1. Urban wastes including residual Municipal Solid Waste and other putrescible wastes as described 3.4.1.

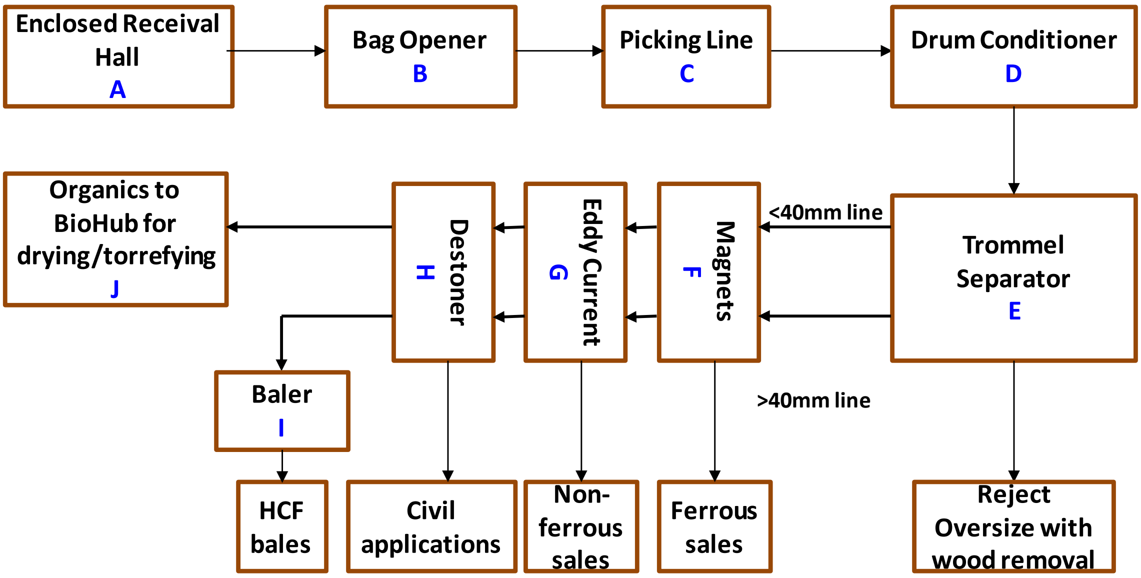
6. Other regional biomass arisings as described Table 2-1.

Pretreatment

2. The mixed waste is initially processed by a generic "drum" style **AWT (Alternative Waste Treatment**) plant. First, household hazardous wastes (such as chemicals, cleaners, electronic scrap etc.) and dry recyclables (paper, cardboard, glass, plastics and metals) are removed. Then organic materials (<40mm, including food waste and soiled paper and cardboard) are separated from non-organic (>40mm, mainly plastics) (the "blister pack" separation standard). Finally, the streams go through inerts/heavy particle removal and ferrous/non-ferrous metals recovery.

The generic Block Flow Diagram for this facility is shown in Figure 5-2.

Figure 5-2: Drum style AWT Block Flow Diagram



Key:

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 Household Hazardous Waste materials and recover any obvious dry recyclables that were not more correctly discarded via the kerbside "yellow bin" service or originated in the Commercial and Industrial (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.	

Interim products

3. Inert or non-putrescible materials will be suitable for select applications, for example blended with Construction and Demolition (C&D) masonry or crushed concrete for pavement sub-base applications.

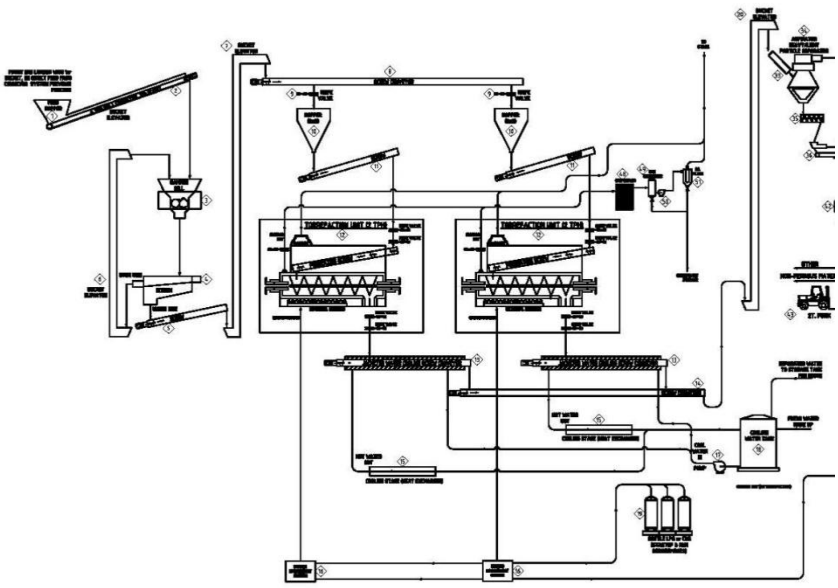
4. Recovered metals suitable for direct delivery to local scrap metals facilities.

5. The high calorific fraction (HCF) will present as a Refuse Derived Fuel (RDF) or Process Engineered Fuel (PEF) product for subsequent processing for kilns, foundries, Energy from Waste (EfW) facilities or more specialised secondary plastics processing to create petrochemical industry platform products such as Naphtha or (via Fischer-Tropsch) into liquid fuels[18].

Further processing of biomass and final product manufacture

7. The organic waste that has been separated and purified by the previous steps is put through **Drying/Torrefying** (approx. 280°-300°C). This is the initial step in the processing of raw, wet biomass into charcoal products.

Figure 5-3: Concept drying/torrefaction plant – typical plant configuration



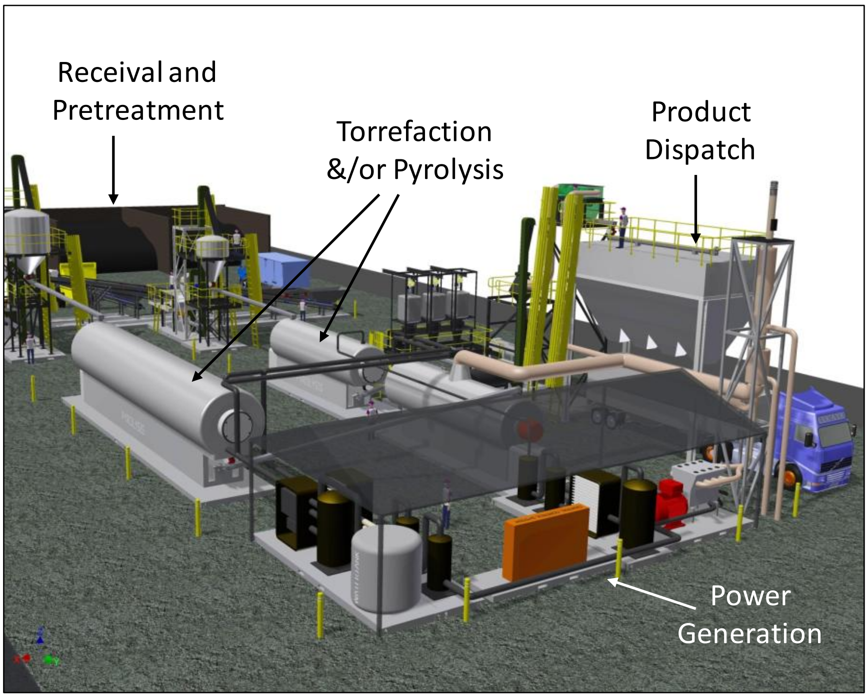
[18] Facilities to process these plastics for such high value outcomes don't exist in Australia at present. One reason is that systematic and assured supply of such HCF materials cannot be demonstrated at present. So wherever such drum AWT facilities are established to supply biomass to a BioHub, or 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

8. Pyrolysis Plant

This facility accepts the organic waste that has been prepared as described above. It makes a char product and syngas. It heats the biomass up to 450-500C, converting it into biochar.

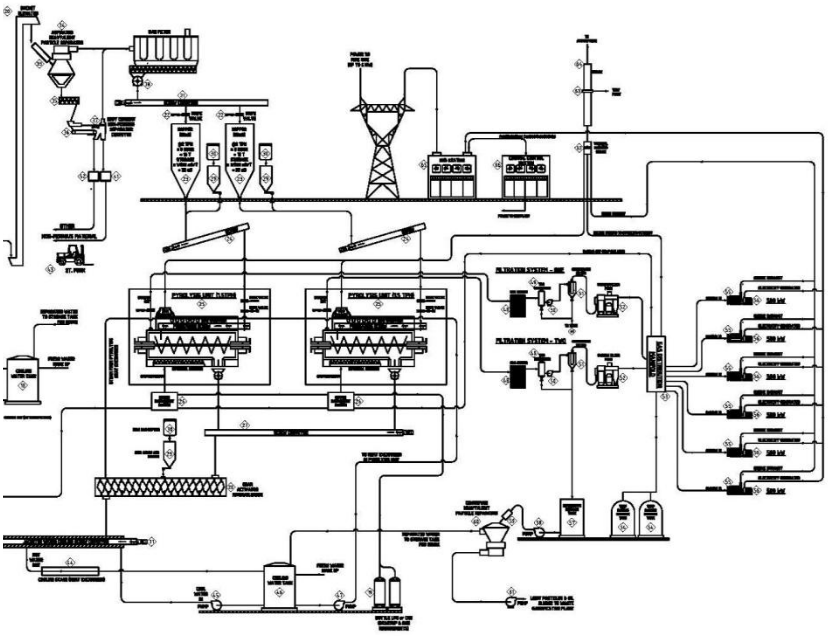
If supplied with quality low ash materials, the unit can produce metallurgical grade charcoal products. If supplied with high ash materials, the same unit can produce biochars for fertilizer manufacture. The proposed pyrolysis capability would be commissioned in discrete operational modules – usually 1, 2 and 4 t/h feed rates, such that parallel units could be processing different feed streams[19].

Figure 5-4: Typical pyrolysis plant concept



[19] 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 syngas supply system and all terminating in a single stack/emissions point to ensure better than EU Waste Incineration Directive minimum emissions standards and maximum waste heat recovery.

Figure 5-5: Pyrolysis processing – Typical plant configuration



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

9. Final fertilizer product manufacture (This "producer" capability is usually provided as an addition to "standard" BioHubs). 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.

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.

5.1 Key Message from Section 5

- **Describes core processing technologies and configurations to support the functional specifications for BioHubs as scoped in Section 1**.

6. First order Commercial Viability Assessment

6.1 Introduction

To test the commercial viability of the BioHub concept, two case studies have been undertaken.

The first, the "Dubbo" case study (attached B 1) has been developed in close consultation with Dubbo City Council and a group of interested local stakeholders who were initially brought together under the NSW EPA's "Sustainable Advantage" program and financially supported by the NSW Office of Environment and Heritage.

The second case study, the "Cobar" case study (attached B 2), focused on a more specific feedstock and value added product opportunity. The key information for this case study was collected with the generous involvement of:

- The Buckwaroon Catchment Landcare Group (BCLG) to collect data and information on potential feedstock data and information;
- The CSIRO "Minerals Down Under" National Research Flagship program (including BlueScope Steel and Arrium) for detailed information on specialty charcoals for steel making – the need, the opportunities and the specifications; and
- Renewed Carbon Pty Ltd who provided summarised information and data on the specific technologies under development to convert the Cobar Peneplain feedstocks into the exact products required by the Australian metal manufacturing sector in general, and BlueScope and Arrium in particular.

These two case studies, in effect represent an analysis of the three different types of BioHubs (described 1.2.6, p. 9).

The Cobar case study describes a "Feeder" BioHub arrangement to deliver biomass to a regional "Standard" BioHub. The Dubbo case study describes a "Producer" BioHub, where the volume of the potential local market for tailor made biochar based fertilizers could not be met from locally sourced biomass and will require biochar materials to be supplied from many other BioHub facilities to support the biochar based fertilizer manufacture proposed to service the regional cereal cropping sector.

From these two case studies a scenario is extrapolated to indicate what an integrated network of facilities to fully cover NSW might involve.

From this extrapolation, the potential for a national network of BioHubs is estimated to provide some high level information on the potential, impact, costs and benefits of the BioHub concept if a network was fully developed as proposed.

6.2 Summary of Dubbo Case Study (attached B 1)

6.2.1 Potential feedstocks

Table 2-2 (p. 24) summarised the five generic sources of biomass potentially available to be processed at BioHubs. Of these feedstock types, two important sub categories emerge:

1) Those biomass types that can be contracted to ensure year round supply and certainty, and thus capital justify establishing a BioHub facility to service the Dubbo region; and

2) Those biomass types that only become available on a sporadic, seasonal or campaign basis, and which will only be available to a pre-existing BioHub on a "merchant" basis.

The viability of a Dubbo BioHub was found to be dependent on negotiating a contract to receive and process the local residual urban waste streams, offering potentially some 90% landfill avoidance for Dubbo City Council, and simultaneously providing a sufficient level of supply assurance to establish a facility that would then be available to offer "merchant" services for all other occasional sources of forest, agricultural and land management biomass generated within the region.

This dependence on requiring one specific waste stream so as to be available to accept and value add a wide range of additional biomass materials will be a crucial project development complexity that must be overcome and negotiated with all the key stakeholders if the proposed Dubbo BioHub is to serve as a viable example for other similar facilities.

At its heart, the BioHub concept provides cost effective solutions to a wide range of stakeholders and generates sustainable opportunities across a range of sectors, all of which will be a strength of the concept when implemented, but which present as a considerable challenge as the first "demonstration" or proof of concept facilities are negotiated and developed.

6.2.2 Potential Products

The majority of locally available biomass materials in the Dubbo region are "high ash" which supports land application as biochar based fertilizers, for which local demand has been reviewed and assessed.

Currently the Central Western cereal cropping region applies high analysis (NPK) fertilizers to optimise crop yield. Renewed Carbon reports detailed product development programs (with UNSW and local farmers, agronomists and spreading contractors) for a specific biochar based fertilizer that would not only deliver all the mineral fertilization essential for optimised crop yield, but also sequester carbon in the soil and improve the soil quality. The Dubbo case study is predicated on manufacturing some 11 ktpa of this product, which is only a fraction of the total amount of traditional NPK fertilizer currently applied. However, as this is a new product offered to a conservative cropping community, an extensive program of product development and field testing will be required to fully explore this opportunity.

6.2.3 The Facility

The facility layout and functional capability (as summarised Fig. 5-1 and Fig. 5-2) features:

i) The MSW pretreatment section, employing established and proven technologies, to recover the (50-60%) biomass content for subsequent processing through the BioHub with the other biomass materials available. (Residual metals and plastics sold into existing scrap markets and the inert residues used locally for miscellaneous civil functions);

ii) The integrated drying, torrefying and pyrolysis to create the basic char products with bioenergy as a by-product; and

iii) The dedicated biochar based all-in-one fertilizer product manufacturing process.

6.2.4 Commercial Viability

Table 6-1 summarises the key performance statistics.

Table 6-1: Analysis Summary of Concept Financial Model – attached B 1

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.

The key features of this case study that support the projected profitability indicated by the 20% internal rate of return (IRR) include:

i) Initial sustaining gate fee income is directly related to providing a systematic urban waste processing service for the local community (the Council).

   This essential service is presented as a cost effective alternative to Business As Usual (BAU) (landfill) approach and securing the service at less than the current actual "true cost of landfill".

   For initial BioHub facility development this income producing function is crucial to justifying the construction of the facilities. But once established, the facility is then able to offer a wide range of "merchant" services that when fully commercialised, will provide a framework where the dependence on the MSW processing fees will be reduced. In addition, the community will be in a position to negotiate lower waste processing fees as the installed capabilities derive supplementary revenue by receiving and value adding these third party biomass materials.

ii) The highest value products will be manufactured from the "non urban waste" biomass materials, but this potential will not be realised without the urban waste processing function securing the initial investment to create the BioHub in the first place.

iii) The "Dubbo" case study demonstrates that productive, strategic and commercial synergies are created where the organic, or biomass fraction of urban wastes are processed for highest product value as an integral part of a wider biomass processing approach. This approach presents in stark contrast with the alternative approach where urban waste biomass and the more general third party arisings operate as separate sectors.

6.2.5 Proposed Ownership/Operational Models

As currently conceived, the BioHub network is proposed to operate under a central BioHub brand management organisation. Whilst the central BioHub brand management company might own and operate the individual facilities, the preference would be for local interests to own and operate each respective facility within a whole of network commercial framework, whereby:

Central BioHub Brand Management (CBBM) functions:

- Develop each facility opportunity to financial close;
- Design and construct each facility to successful commissioning and hand over;
- Provide each facility with ongoing technical support;
- Provide each facility with "off take" certainty at financial close and retain marketing and product sales responsibility for individual facilities and the network as a whole on a local, regional, national and international scale.

The BioHub concept is strengthened when a network of such facilities arises. At that stage, value is created by managing inventories of raw biomass types, semi processed chars, bioenergy and the full range of finished products so that higher order end users (i.e. liquid fuels refiners or the petrochemical sector and potential export markets) can be provided with supply security, which only a network can achieve.

Respective BioHub Owner/Operator (RBOO) functions:

- Raise the funding for each facility at either financial close (i.e. engage Engineering, Procurement, Construction and Management Contractor (EPC(m)) or at completion hand over;
- Operate the facility to produce the products for CBBM;
- Proactively secure the full range of biomass materials available in the facility catchment to optimise return on investment (ROI).

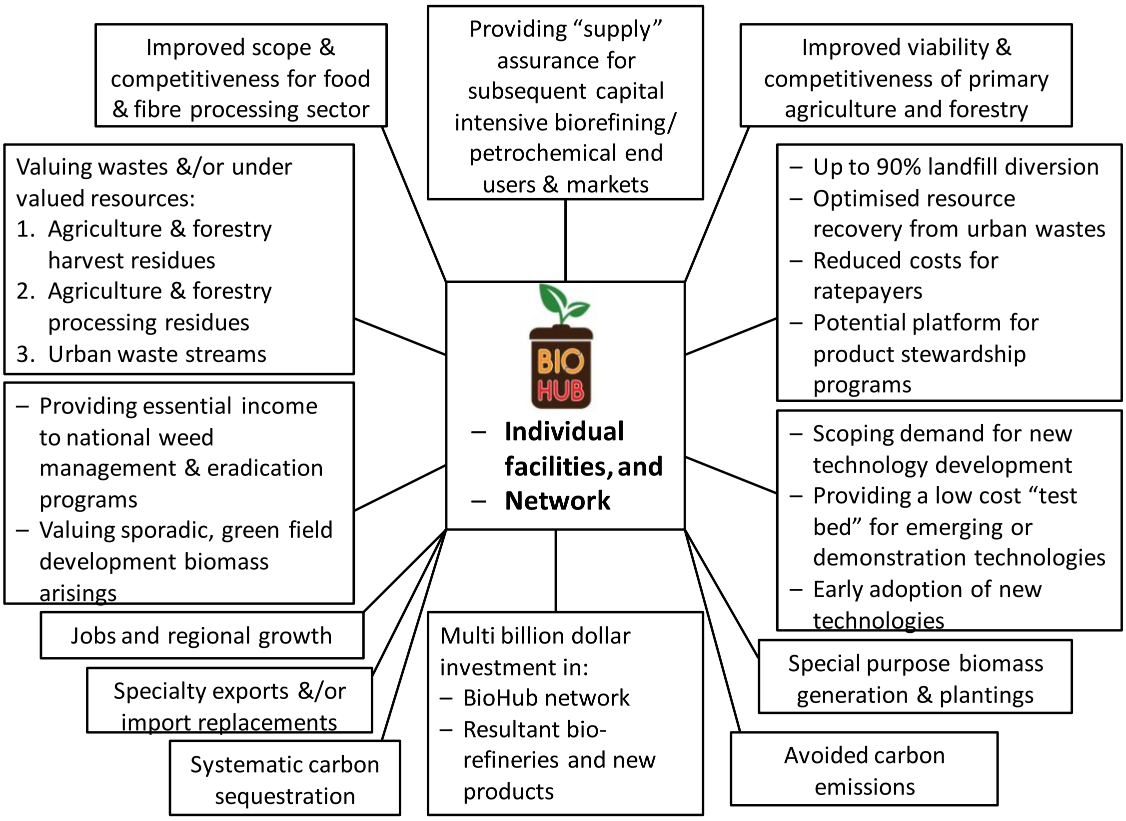
In this model, CBBM could provide assistance to secure project funding and even take a carried or cash equity interest. And under such an arrangement, RBOO may well select to sell products and services directly into the local market if in accordance with the agreed off take arrangements negotiated at financial close.

Whatever the final ownership/operational models agreed for each respective BioHub development, one key intention is to optimise the local expertise and knowledge for each facility within a framework structure that optimises the broader opportunities for mutual benefit.

6.2.6 Summary of Risks and Sensitivities

Development Risk – The major commercial and economic strength of the BioHub concept is the integration of many needs and opportunities, and the achievement of multi benefits from multi inputs and multi service delivery, as reflected in Fig. 6-1.

Figure 6-1: BioHubs creating an integrated "Industrial Ecology" contribution to support "Circular Economy" outcomes



However this same integration and multi benefit delivery presents as the major area of development risk until the first facilities are established and proven.

Early demonstration, or first-of-kind BioHubs will be able to reduce this development or completion risk by focusing on assured feedstocks, that can present with contractible gate fees (i.e. urban waste streams), processed through proven and fully vendor guaranteed technologies where the market or end use is still nascent (i.e. new fertilizer products).

Alternatively, where the end use or market can present with contractual certainty (i.e. metallurgical charcoals) the feedstocks might need to be paid for, for processing also through proven and fully vendor supported technology. This approach has been adopted in suggesting the projects that could be supported to overcome inertia and address the complexity of the proposed business model for fully developed BioHubs (7.3 below).

Supply Risk – When fully established as community facilities, or as a network, it is anticipated that considerable reliance on receiving biomass in a "merchant" capacity will be possible, much as occurs now at scrap metal facilities. However, initially, only assured contracted supplies from urban waste streams or perhaps selected animal husbandry operations, or even certain food or fibre processing operations could offer the required level of supply assurance.

Process Risk – This issue will need to be addressed for early projects by adopting proven, fully vendor supported technologies.

Market Risk – The science and potential of using specialty biochar is well established in the literature and in demonstration trials, but no full scale commercial operation has yet been commissioned.

The testing of metallurgical charcoals is well established for some products but yet to be fully commercialised for others.

The generation and use of bioenergy is well proven and established.

And finally, the Biorefinery/petrochemical potential end users of biomass are currently constrained in part, by a lack of secure supplies of suitable biomass. This market would need to be negotiated when a BioHub actual commissioning date could be assured.

6.2 7 Proposed Development Pathway

Step 1 – Raise initial funding to:

- Undertake detailed cost/benefit analysis for or on behalf of Dubbo City Council to demonstrate that direct and proactive participation in the proposed regional BioHub proposal will be in their short, medium and long term best interests and include a review of the proposed garden/food waste processing strategy proposed by NetWaste[20] (approx. $30K); and

- Contribute to the ongoing UNSW ARC Linkage program (LP120200418) to expedite the confirmation of the specific biochar based all-in-one fertilizer product, to confirm the initial project off take market (approx $30K).

Step 2 – Undertake full scale project feasibility study (approx. $800k).

[20] NetWaste & Impact, *Organics Management Options for the NetWaste Region: An investigation of the potential to enhance kerbside organics collection and organics processing*, May 2013, http://www.netwaste.org.au/

Step 3 – Secure committed private equity to proceed with the project in an owner/operator role as a basis to apply for matching grant funding on a dollar for dollar basis from an appropriate funding body.

Step 4 – Secure project funding and a suitable Engineering, Procurement, Construction and Management Contractor (EPC(m)) contractor.

Step 5 – Construct and commission the plant.

Step 6 – Refinance completed project with suitable debt and equity structure.

6.3 Summary of Cobar Case Study (attached B 2)

6.3.1 Proposed Feedstocks

The woody weed/INS material is a specialist biomass that can be provided as an assured supply source, but for a harvesting cost, rather than a receival gate fee (as opposed to the Dubbo BioHub proposal).

This material is currently available from those properties where the owners are prepared to pay the full cost of land clearing in accordance with their Catchment Management Authority approved Property Vegetation Plans.

But where landholders currently wish to offset the cost of the direct harvesting by channelling the material for "green" energy production, the NSW Native Vegetation Act prohibits such an end use. The NVA is silent on using the harvest material to manufacture metallurgical charcoals. These issues, amongst others, are the subject of a current review of the prevailing legislation, which would need to be resolved before investment in either a Feeder or a Standard BioHub for the area could be justified. However, this issue is in train, and could come to a productive conclusion in a timely fashion.

6.3.2 Potential Products

The products described in attachment C have been specified and confirmed by the local steel makers to a point that now justifies pre-production trials. This work is currently progressing under a Clean Technology Investment Program (CTIP) application. When concluded, if successful, the capital expenditure to adapt and upgrade existing process plant and furnaces to utilize charcoals on a continuous basis will, in large measure, be dependent on assured and commercial supply of the required charcoal products being reliably available.

Preparatory work at the steel works can be progressed substantially in parallel with the establishment of the charcoal production facilities at Cobar if both projects are directly linked and coordinated under the appropriate contractual conditions.

6.3.3 Specialty Metallurgical Charcoal Technology

The current global status of such a specialised and dedicated charcoal plant is only available at a pilot or demonstration scale. Renewed Carbon has partnered with specialised technology developers and vendors and is ready to construct and commission a best-of-type metallurgical charcoal plant when funding of some $2.75M is secured.

This plant would then be able to produce quantities of select charcoal products, in collaboration with the steel mills, whilst the then proven designs are upgraded to full scale production, that would not only meet all national demand, but also create export opportunities and provide import replacement benefits.

6.3.4 Commercial Viability

Table 6-2 summarises the first order commercial model, attached B 2.

Table 6-2: Analysis summary of first order commercial model

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 model is still sensitive to a final determination of harvesting costs, final plant Capex/Opex, transport costs to market, and confirmation of genuine sustainability standards (Fig. 1-2). Certification of sustainable biomass yield will be crucial to the success of these products which will need appropriate certification to ensure the full market value of the “carbon lite” steel products can be recognised, and carbon liabilities mitigated.

6.3.5 Ownership/Operational Models

As for Dubbo case study or very similar.

6.3.6 Summary of Risks and Sensitivities

Development Risk – This specific project will be dependent on the current Native Vegetation Act (NVA) review not resulting in project prohibiting legislation and a subsequent full scale feasibility study confirming the initial commercial viability assessment.

Supply Risk – Dependent only on the above.

Process Risk – Appropriate funding (approx. $2.75M) for the construction of a semi commercial demonstration plant will be crucial to ensuring that the eventually constructed full scale production plant (Fig. 3-1 Cobar Case Study) will fully meet the projected performance requirements.

Market Risk – Subject to successful production trials currently in progress, secure contractual off take arrangements will be available to anchor this proposed project.

6.3.7 Proposed Project Development Pathway

Step 1

- Make detailed submissions to NSW Government in support of a constructive review of the NVA.
- Secure funding for the construction of a semi commercial demonstration plant (approx. $2.75M).

Step 2 – Secure committed private equity to proceed with the project in an owner/operator role as a basis to apply for matching grant funding on a dollar for dollar basis from an appropriate funding body.

Step 3 – Undertake a full scale feasibility study.

Step 4 – Secure project funding and a suitable EPC(m) contractor.

Step 5 – Construct and commission the plant.

Step 6 – Refinance completed project with suitable debt and equity structure.

6.4 Extrapolation to State (NSW) Scale Network

The Dubbo and Cobar case studies reflect the circumstances in the Dubbo region with reinforcement from a specialist application. BioHub proposals for other communities will need to be based on their own respective circumstances, constraints, opportunities and markets.

If this "Dubbo" scenario is accepted as a reasonable proposition that could be replicated, then Table 1-3 presents a possible "roll out" scenario, if the BioHub concept was delivered as a network across NSW to address all such "last resort" biomass arisings.

BioHub Type	Approx. No./530 km² of suitable land for NSW	Receival, sorting, screening, pretreatment & torrefaction	Pyrolysis & energy recovery	Final Product manufacturing and wholesale	Approx. Capex $M each
"Mobile" Feeder BioHub	14	✓			$5
Standard BioHub	35	✓	✓		$19
Producer BioHub	5	✓	✓	✓	$34
Totals	**54**				**$905M**
Facilities processing: min. 70 ktpa (Capex $19M), max. 250 ktpa (Capex $34M)					
Processing estimate 6,500 ktpa ∴ 54 facilities processing an average of 120 ktpa biomass each					
Average Capex/BioHub - $16.75M					

This "NSW" scenario is based on the prospect of the 54 facilities processing some 6,500 ktpa supplied from generic biomass sources 2.1-2.4 above.

For assessment purposes, the NSW model can be extrapolated for all other states (Table 6-3).

Table 6-3: Extrapolated BioHub network Capex based on NSW model (Table 1-3)

State	Total/ serviced area km² '000	Population/% '000	#Producer BioHubs	#Standard BioHubs	#Feeder BioHubs	Totals #
NSW	800/530	7350/32	5	35	14	54
VIC	227/200	5680/25	4	18	10	32
QLD	1730/700	4610/20	5	20	15	40
WA	2530/350	2472/11	3	7	13	25
SA	983/200	1662/7	2	7	12	21
TAS	68/30	512/2	1	3	7	11
NT	1350/300	236/1	1	3	7	11
ACT	2.5/2.5	380/2	–	1	1	2
			Medium term expectation of facilities rollout			**196**
			average Capex $16.75M ∴ basic Network Capex			**$3,283M**

Such a medium term national BioHub network is proposed based on a core focus to realise full value from the "by-product" biomass sources 2.1, 2.2, 2.3 and 2.4 in Table 2-2.

All specially grown biomass sources (2.5, Table 2-2) would be entirely extra or additional to the already available biomass sources 2.1-2.4 (Table 2-2). However, once established and capital justified on existing biomass supplies, the same BioHub network would greatly assist and enhance the proactive biomass creation activities described 2.5 (Table 2-2). In fact, it might be anticipated that a strong level of parallel development would occur once early BioHub facilities demonstrated strategic and commercial viability.

Table 3-4 projects that even the initial, medium term BioHub network implementation could beneficially receive, convert and value add some 40-50 Mtpa of readily available biomass to produce a possible suite of primary products including:

- 8 Mtpa quality feedstock to the liquid (jet) fuels sector[21];
- 3 Mtpa of metallurgical charcoals for local and export markets;
- 5 Mtpa of high ash biochar products for agricultural application and sequestration; and
- 2.5 GW bioenergy (as a major by-product).

whilst simultaneously delivery the collateral and economic benefits listed in Table 1-3 including:

- Assessment and certification of the sustainability status of the materials presenting at the BioHub;
- Platform to trade or broker biomass resources, as presented or partially processed, to third parties (eg. local compost operations) or between other BioHub facilities in the emerging network;
- Value adding various primary activities (forestry, cropping, grazing, waste management or land management) by placing a market value on current by-products or residues;
- Providing "supply" assurance to high value product manufacturers (eg. liquid fuels, reductants, petrochemical precursor chemicals etc.) to enable them to justify capital expenditure and specialist operations secure in the knowledge that the necessary and appropriate biomass feedstocks will be available;
- Providing receiver of last resort facilities for biomass materials recovered from urban waste streams; and
- Support for specialist technology developers and vendors by:
  - Providing functional specification information direct from the supply chains to inform their respective research and design development activities; and
  - Offering approved sites for pilot and demonstration activities, where inputs and off takes are readily available.

6.5 Key Messages from Section 6

- **In summary, there is reason to consider that BioHubs, either as individual sites or operating collectively, can be inherently profitable, whilst delivering a range of important economic benefits.**
- **This outcome is based on a basic business model where services are delivered locally and products are manufactured for local, national and even international markets.**
- **The independently viable network is then able to provide "supply" security to the highest value applications in the liquid biofuel sector (especially jet fuel).**

[21] To suit fermentation and digestion of fast pyrolysis technologies where one or all are adopted.

7. Summary and Conclusions

7.1 Key Findings

The objective of this PFS was to outline the detail of the BioHub concept and to determine if the proposal was worthy of the considerable investment in a subsequent detailed Feasibility Study.

In the event, much of this report has needed to focus on describing and developing the BioHub concept in terms of strategic need (Section 1), understanding potential biomass categories (Section 2) and their potential availability (Section 3).

A **philosophical framework** for evaluating the potential role of currently produced biomass (<100yrs) has been set out in a series of Discussion Papers (attached A) to this Study.

The **key products and their commercial demand** were explored in Section 4. This section discussed how biomass was a logical replacement raw material to manufacture an entire range of "drop in" products that could supplement and/or replace nearly all applications currently supplied by fossil resources (gas, oil, coal). However, since the recurring availability of biomass is inherently limited by space, soils, sunlight and competing uses[22], this study has focused on those "drop in" products that can optimise the inherent properties and values of sustainably yielded biomass. The BioHub concept, implemented as a systematic and enabling network, has been explored in light of high level goals, and the achievement of considerable general or economic benefit, supported and capital justified by meeting specific local demand at each facility in the network, and so providing a cost effective platform to deliver the higher level products, services and economic benefits.

The **higher level product range** includes partially processed products and materials to supply and support the establishment of a specialised liquid fuel sector, such as jet fuel, and /or specific petrochemical industry precursors or platform chemicals. To meet this objective the BioHub facilities and linking network are proposed to act as aggregators, accumulators and partial/pre-processors so as to provide "supply" security to the final conversion/bio-refinery facilities. To support this higher level product manufacturing objective, the individual BioHubs and the integrated network, is proposed to manufacture and supply:

– A range of highly specialised charcoal products for industry generally, and the metals smelting/manufacturing sector (local and export) in particular;

– Biochar based fertilizer and carbon sequestration products for land/agricultural application; and

– Bioenergy (as an optimised by-product at each facility).

A **collateral "service" product** available to any community hosting a BioHub will be the ability to process all residual urban wastes to eliminate the need to use landfill as a treatment option for such materials.

[22] Pearman, G., "Limits to the potential of bio-fuels and bio-sequestration of carbon", *Energy Policy*, 59 (2013), 523-535

The **installed capacities and resultant functional description** has been addressed in Section 5 and the **capital and operation costs** of operating a regionally tailored BioHub is assessed in Section 6, demonstrating that:

- Individual BioHubs can be established to be inherently profitable on an individual site basis (the **"Dubbo" and "Cobar/Charcoal" case studies** – attached B 1 and B 2);

- As a **network** of such facilities, established in the short to medium term to process currently available biomass arisings:

    i) Some 40 Mtpa of sustainably yielded biomass could be available;

    ii) Some 8 Mtpa of quality assured biomass, pretreated if required, could be available to provide assured supply to an emerging liquid fuels or petrochemical demand;

    iii) Some 3 Mtpa of dense, specialised charcoal products could be available for the local and export markets;

    iv) Some 5 Mtpa of biochar based fertilizers could be available for the land application, broad acre and carbon sequestration sector; and

    v) Some 2.5 GW of bioenergy could be available in aggregate from the network of individual facilities.

In the **longer term** (>10 years), if and when dedicated plantations, oil seed/sugar crops or algae production become viable to supply the higher order liquid fuels and petrochemical market, the BioHub could be available to optimise all/any biomass by-products of such a sector. It could provide the "first point of receival" convenience to such an emerging sector, in much the same way that railhead silos provide such services to the existing cropping sector.

However, even before a BioHub network is contemplated to service this expanded and optimised national need, in the **short (<5 years) to medium term (>5 years)**, the proposed BioHub network could represent:

- Capital investment of some $3,283M;

- At an investment grade IRR 20% ±25% accuracy;

- The sequestration of some 60 Mt CO_2-e;

- Employment – construction approx. 3,000 FTE jobs, operations approx. 1600 FTE jobs;

- 25% substitution for the import of specialty anthracite based reductants;

- 75% for metallurgical coal substitution in steelmaking – if fully optimised; and

- A national aggregation, consolidation, and biomass pre-processing network to offer secure supply to the capital intensive liquid fuels (jet fuel) and petrochemical alternatives sectors.

7.2 Implementation Risks and Issues

7.2.1 Biomass Supply Security

Each BioHub is proposed as a **"first point of receival"** to provide convenience and minimised delivery costs so as to optimise the potential receipt of "merchant" biomass arisings. The BioHubs are also proposed as **"receivers of last resort"** in commercial terms, (or "we're here when you need us") as a service offering. Within this context, if any expected supplies do not eventuate due to fire, flood, drought or the availability of alternative biomass use options, the BioHub will just need to rely on core/contracted business, and continue to offer the receival option as circumstances change.

As with the scrap metal business, customers can't be forced or contracted to generate scrap metal. But when it is generated from some unrelated primary activity, the scrap industry is always there to offer fair value. To maintain this option, every available source of scrap metal is accepted, and, in aggregate, sufficient receipts of scrap from the full range of diverse sources supports the basic service. So too would be the case with BioHubs, but to ensure viability, especially in the early stages, the ability to contract to service certain problematic locally sourced waste streams can secure the basic operational viability.

Such contractible waste processing services might include locally sourced residual MSW processing, or perhaps a local animal husbandry waste stream. The "Dubbo" case study amply demonstrates this feature within a framework that provides lasting and synergistic benefits to both parties.

7.2.2 Technology Development

BioHubs are proposed to be technology "agnostic", as described 1.4.4. When more efficient or targeted technologies emerge, the individual BioHubs will be keen to **adopt the latest "mousetrap"** and to support such technological development as it occurs.

The fundamental technological driver for the BioHub proposal is to supply sustainable biomass sourced products and services to supplement and replace existing fossil resource applications, and that core demand is immutable. Many of these alternative biobased products will be adopted for use and application in a globally competitive pricing framework. The BioHub concept could be at risk **or even "stranded"** if less efficient or less developed technologies and processing techniques were persisted with in the face of better alternatives.

The proposed technology and process risk mitigation strategy is to provide advice and support to the technology development specialists (1.4.4 above) in return for being able to adopt the latest mousetrap as it becomes commercially available. This approach is seen as crucial in this nascent, but rapidly developing sector.

7.2.3 Development Inertia

The BioHub concept has industrial precedent in many agriculturally based sectors such as the railhead silo example in the cereal cropping sector. However, whereas in the cereal sector the end uses and markets are established, well understood and highly developed, in the generic biomass sector it is only recent developments in response to the climate change agenda that have crystallised the current need.

The BioHub concept is a direct and reasoned response to a now clearly articulated need. There is inherent risk in the BioHub concept being the first systematic response of its kind to the herein expressed needs of the emerging biomass processing sector, and this first-of-type issue could attract a reticent response from the private investment community, which in turn could manifest in inertia to implement the BioHub network concept to its full potential.

Whilst each facility is proposed to be independently profitable, as shown with the “Dubbo” and “Cobar” case studies respectively, the greater community benefit will be achieved once the basic network framework is implemented, and hence an initial level of Government support is recommended, all outlined 7.4 below. During an initial Government supported rollout phase for the first few projects, the service model would be refined and the operational arrangements streamlined to greatly expedite private sector investment. This strategy is proposed to overcome initial development inertia and expedite the achievement of the BioHub benefits and delivery of the integrated service offerings and economic benefits.

7.2.4 Regulated/Legislated Framework

The BioHub concept reviewed herein has been proposed **to address the complete lack of existing receival, aggregation, processing and logistics systems and infrastructure, seen as vital to enable the biomass processing sector to progress.** The essential need for such a biomass processing sector to achieve its full potential is in response to both the climate change agenda and the need to develop specialised fossil resource replacement products. These drivers are immutable, but development and implementation of the BioHub concept is likely to be greatly influenced in the timeliness and policy settings of the Government of the day.

The BioHub concept is not commercially dependent on any particular Government program or initiative. However, the BioHub concept rollout will be greatly enhanced and facilitated where a price on carbon is recognised either in the market or as legislated. And where specific programs exist to promote the supplementation or replacement of fossil fuels with sustainably sourced biomass based alternatives, any assistance towards the initial capitalisation of the program would hasten the achievement of all the commercial and economic benefits identified in this study.

7.3 Proposed Project Implementation Pathway

To progress this initiative, it is proposed that at least one BioHub project, but preferably three, be iteratively developed as a partnership between a group of potential plant owner operators and Government in discrete stages, in a gates and milestones format.

Project 1 – for example Dubbo “Producer” BioHub – focused on producing biobased fertilizer products tailor made for the local cropping sector.

Project 2 – for example a “Feeder” BioHub linked with a “Standard” BioHub – based at Cobar, NSW (or Hughenden, Qld) to support the local catchment management, wood weed/INS management programs and simultaneously provide high value charcoals and reductants to the national and international metals smelting sector.

Project 3 – a metropolitan based, fixed “Feeder” BioHub that processed biomass recovered from urban waste streams for pretreatment and transfer to a “Producer” BioHub, probably Dubbo, to support the end product manufacturing activity with volumes of interim processed chars, which also provide essential trace elements for blending into finished products.

These three projects could be initiated in parallel, and alternative sites could be identified if necessary. (Projects at Western Sydney, New England, Lithgow, Ballarat, Latrobe Valley (Vic) and Hughenden (Qld) are just some that have been identified in the course of this study and that could be quickly actioned).

The suggested staged or gates and milestones approach to progressing either one or all three projects could be as follows:

Stage 1 – A prospective local investor group be established for each project who are attracted by the concept described herein and who would commit to the provision of equity up to 25% of the projected capital cost of the respective projects to be matched with grant funding from an appropriate source.

NB: A level of preliminary work may be required for each project to secure this proposed commitment.

Stage 2 – The accumulated budget then be drawn down against a pre-agreed gates and milestones schedule of works. This would include detailed work to:

- Confirm and describe all committed biomass supply arrangements;
- Make submissions to NSW NVA review process to ensure productive outcomes;
- Process design to progress from current concept to completed F.E.E.D.;
- Complete biochar product development with UNSW and then made up trial batches for broad acre trials;
- Construct demonstration plant to manufacture metallurgical charcoals;
- Secure off take agreements for finally confirmed biochar based fertilizer products;
- Secure long term purchase agreements in Australia and overseas for metallurgical charcoals; and
- Complete licencing and approvals process.

Stage 3 – Achieve financial close for each project and approach CEFC for a debt and equity package for the final 50% of the project value.

7.4 Potential Roles for Government – Local, State and Commonwealth

At a local level – BioHubs can provide an entirely sustainable processing option for urban waste streams. BioHubs can not only deliver benefits at a lower cost than the "true cost of landfill" but can also provide forward service cost certainty at a time when urban waste management charges are escalating at a rate greater than C.P.I. as a result of disposal levies, carbon levies and ever increasing levels of service demanded by the respective communities.

By engaging proactively with the BioHub concept, local councils can resolve many of their most problematic putrescible waste treatment and disposal issues, but simultaneously provide the momentum for sustainable biomass value adding to occur in their region.

To achieve these benefits, individual councils or regional groupings will need to develop respective urban waste strategies that look past the existing collect and dispose-of approaches and instead look to integrate with the providers of service offerings such as BioHubs. Such service providers would accept process risk and provide councils with an assured receival service for such urban wastes so as to access the materials as valuable inputs into their integrated solution (Fig. 5-1, p. 43).

Some early collaborations (as 7.3 above) with such councils or council groupings would instil confidence in this sector generally and put urban waste management on a new and sustainable footing for the future.

At a State level – BioHubs provide a sustainable commercial platform to:

- Inform State waste management strategies for which State Governments have jurisdictional responsibility;
- Inform State forestry policy and operations for immediate value creation and longer term economic development;
- Inform State agricultural policy and operations for immediate value creation and longer term economic development;
- Inform State Government climate change and sustainability policy responses;
- Inform catchment management activities and initiatives and land management policy generally; and
- Provide focus of select business development and grant funding schemes to assist the early BioHub projects achieve full commercial status.

To achieve these benefits, **State Governments need to be made aware of this BioHub concept** and proactively explore the wide range of benefits available to inform and improve exiting policy settings and program frameworks in each of these identified sectors. This study, commissioned by the Commonwealth, now needs **dissemination to the respective State jurisdictions through the appropriate intergovernmental structure**.

At a Commonwealth level – The BioHub concept, if implemented substantially as proposed herein, could inform and/or support a number of important policy areas including:

- Clean Energy Future, by:
  - Providing an integrated and cost effective platform to deliver supply certainty to the emerging liquid biofuels sector, especially jet fuels;
  - Helping the essential metals manufacturing/smelting sector to reduce Greenhouse Gas emissions and liabilities and transition to the production of "smart" or "carbon lite" products;
  - Providing tailor made biochar based soil productivity improvers and fertilizer systems to not only improve agricultural productivity, but also improve cropping soils quality and sequester fixed carbon in support of the Carbon Farming Initiative;
  - Direct production of bioenergy;
  - Reduction/elimination of GHG emissions from municipal landfills where the local community is fully engaged with their local BioHub;

- Generally removing the main barrier to biomass/bioenergy achieving its optimum and sustainable role in achieving a Clean Energy Future as a targeted contributor with all other renewable/non fossil techniques for generating power.

- National Forestry Policy, by providing a sustainable platform for the realisation of the full economic and environmental benefits from plantation and native forestry operations.

- National Agricultural Policy, by:

  - Providing full and fair value for currently undervalued residues and by-products;

  - Improving soil fertility and productivity; and

  - Sequestering carbon and elevating organic carbon in treated soils.

- Land Management policy, by:

  - Providing an important enabling option for catchment management, (woody) weed/INS management, farm forestry initiatives and general revegetation initiatives.

- Industry Policy, by creating an eventual investment opportunity of some $3-$4Billion, the creation of some 1,000-2,000 new jobs and providing the bio-based products to support the metals manufacturing sector and provide supply certainty to the emerging liquid (jet) fuels sector and generate options for the local petrochemical sector to transition from fossil resources as their primary inputs.

As with State jurisdictions, an initial barrier to immediate progress is disseminating the full potential of the BioHub concept to all the relevant departments. From a position of informed interest, the potential benefits then need to be explored within each of these specialist areas, and full scale feasibility studies scoped and commissioned for the selected projects.

In the event that the Commonwealth Industry Innovation Precincts initiative is implemented, this BioHub concept could be an ideal initiative in the event that a biomass focused precinct is adopted. Such a precinct would be ideal to coordinate individual State participation.

In the very short term, the Commonwealth could assist with the funding of some of the essential immediate steps that need to be undertaken to ensure the market pulled focus of the entire BioHub concept, such as:

1) The construction of a demonstration metallurgical charcoal plant (6.3.7, Step 1); and

2) Field testing of biochar/fertilizer products (6.2.6, Step 1).

Attachments:

A i) Discussion Paper EWDP 13/012: Biomass ain't Biomass

ii) Discussion Paper EWDP 13/013: Making Products from Urban Wastes

iv) Discussion Paper EWDP 13/011: The Business of Sustainability

iv) Discussion Paper EWDP 13/014: Highest Net Resource Value (HNRV)

B 1) Dubbo BioHub Case Study

2) Cobar BioHub Case Study

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

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

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