SPECIAL REPORT

SUSTAIN Northern Rivers

New South Wales North Coast Bioenergy Scoping Study

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Sustain Northern Rivers is a collaboration of 27 regional organisations, which aims to empower local communities to become self-sustaining. Our focus areas are food, transport, energy and behaviour change.

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This project is funded by the NSW Office of Environment and Heritage. The project was initiated and developed by the members of the Sustain Northern Rivers (SNR) Energy Working Group. As a member of SNR, the funding has been auspiced by Regional Development Australia – Northern Rivers (RDA-NR). RDA–Northern Rivers would like to acknowledge the contributions of industry stakeholders who participated in interviews and reviewing data in this report; Craig Jenkins of NSW Trade and Investment and Paul Cruickshank of NSW Office of Environment and Heritage for research and data to finalise this report; and Robyn Fitzroy, Geof Webb and Katrina Luckie of RDA-NR for project management and coordination.

The Institute for Sustainable Futures (ISF) were the lead researchers on this project. ISF was established by the University of Technology, Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human well-being and social equity. We seek to adopt an inter-disciplinary approach to our work and engage our partner organisations in a collaborative process that emphasises strategic decision-making.

For further information visit: www.isf.uts.edu.au

Citation:

Ison, N., Wynne, L., Rutovitz, J., Jenkins, C., Cruickshank, P. and Luckie, K. (2013) *NSW North Coast Bioenergy Scoping Study,* Report by the Institute for Sustainable Futures to RDA-Northern Rivers on behalf of Sustain Northern Rivers.

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LIST OF ACRONYMS

GWh	Gigawatt hours
ISF	Institute for Sustainable Futures
kWh	Kilowatt hours
LGC	Large Scale Generating Certificates
MSW	Municipal solid waste
MW	Megawatts
MWh(e)	Megawatt hours (of electrical energy)
OEH	Office of Environment and Heritage
RDA-NR	Regional Development Australia – Northern Rivers
REC	Renewable Energy Certificate
SNR	Sustain Northern Rivers
t/yr	tonnes per year

EXECUTIVE SUMMARY

The North Coast of New South Wales has significant scope for bioenergy and the key factors to develop a vibrant bioenergy sector. The region has a strong commitment to transitioning to local sustainable energy, and a range of industry sectors that produce waste suitable for bioenergy plant feedstock such as agriculture, food processing and forestry.

Two of Australia's largest bioenergy facilities, Condong and Broadwater, are already located at sugar mills in the region. While these facilities have had financial difficulties they represent a major opportunity for bioenergy in the region.

The North Coast has one of Australia's pioneering councils with respect to bioenergy. Ballina Council has secured funding to build one of Australia's first pyrolysis plants that will generate energy and biochar from municipal green waste.

The scoping study examines the main bioenergy feedstocks in the region and quantifies their high-level energy potential where possible. Annual energy generation of approximately 1,100 GWh per year was estimated for those feedstocks with available data, equivalent to approximately 28% of the region's annual electricity consumption.[1] As the energy potential of many feedstocks could not be quantified within the scope of this study, the importance of the sector and the need for additional research is clear.

Plantation forestry residues, sugar cane and municipal solid waste in the region have been identified as having significant energy generation potential. Camphor laurel also represents an important feedstock. Further investigation into the energy potential of food processing wastes, dairies and woody energy crops such as coppicing is also recommended.

This scoping study provides a brief overview of the main bioenergy technologies – direct combustion, pyrolysis and anaerobic digestion, as well as the main development models – site specific, regional and by industry or sector.

The key opportunities for bioenergy in the North Coast identified in this scoping study are:

Opportunity 1. Condong and Broadwater Cogeneration revitalisation

Opportunity 2. The Ballina biochar project, and potential replication

Opportunity 3. Forestry industry opportunities in the Grafton area

Opportunity 4. Food processing industry opportunities (including meat and livestock, and poultry)

Opportunity 5. Council landfill site gas collection and/or MSW gasification and pyrolysis

Opportunity 6. Energy crops/coppicing

Opportunity 7. Co-locating bioenergy facilities with large energy users

It is recommended that this important sector is developed by pursuing the key bioenergy opportunities identified in this report, and by undertaking a comprehensive Bioenergy Resource Assessment to address key knowledge gaps as part of a wider Sustainable Energy Strategy for the North Coast.

1. INTRODUCTION

Bioenergy is a significant source of renewable energy in Australia, and supplied 2% of all electricity in 2002. The sector offers a diverse range of opportunities for the North Coast. Already, two of Australia's largest bioenergy facilities are located in the region, and the climate and agricultural base position the North Coast well to develop a significant bioenergy sector.

The *Future Energy Skills for the North Coast* report identified many opportunities for the North Coast to address skills gaps to develop and support a sustainable energy future. A key recommendation of the report was to develop a Bioenergy Strategy for the North Coast, bringing together a range of relevant stakeholders.

Building upon the *Future Energy Skills* report, this scoping study serves as a precursor to a Bioenergy Strategy, and will help Sustain Northern Rivers (SNR) understand the current opportunities that exist for bioenergy in the North Coast region.

The study summarises the results of initial desktop research and stakeholder interviews. A list of the stakeholders interviewed is provided in the Appendix (p. 33).

1.1. Purpose

This study aims to quantify the potential contribution of bioenergy to sustainable energy in the North Coast and identify priority areas for action. To do this, the study:

- identifies current and emerging bioenergy activities;
- provides a high-level indication of the North Coast's bioenergy resource;
- outlines the range of applicable bioenergy development models (for example, regional, sectoral, or based around individual businesses) and associated challenges and opportunities; and
- identifies a range of priority opportunities for bioenergy in the North Coast region.

Additionally, the Institute of Sustainable Futures (ISF) hopes that the tables developed through this research will provide a framework for SNR to collate further information as work on bioenergy in the North Coast continues.

Note that this report does not consider bioenergy for conversion to biofuels, as the main focus of the stakeholder group is the potential for bioenergy to play a part in the transition to sustainable stationary energy.

2. CURRENT AND EMERGING NORTH COAST BIOENERGY ACTIVITIES

This section of the report outlines existing activities in the North Coast region. The map in Figure 1 shows locations of existing bioenergy activities and potential future feedstocks.

Figure 1: Existing bioenergy activities and potential future feedstocks

Table 1 (over) provides details on current and emerging activities, including location, size and feedstock type.

Table 1: Current bioenergy activities in the North Coast region

Name/ Location/ Owner	Status	Feedstock type	Size (MW)	Electrical Energy (MWh_e/yr)	Electric onsite	Heat onsite	Export to grid	Notes
Ballina Biochar, Near sewage treatment works **BALLINA SHIRE COUNCIL**	In development, expected to be operating by 2015	Municipal green waste	0.75	6,000	?	N	Y	Estimated cost $8.5 m Ballina Shire Council developing in cooperation with Pacific Pyrolysis. Plan to sell to sewage treatment works/depot/and export to grid
Broadwater Sugar Mill NSW SUGAR/ DELTA ELECTRICITY	In receivership	Bagasse, wood waste	38	262,000 at 100% capacity	Y	Y	Y	The receiver in recent years has been operating the plant during the cane 'crush season (five or six months of the year). The factors that led Broadwater to go into receivership are discussed in Section 4.3
Condong NSW SUGAR/ DELTA ELECTRICITY	In receivership	Bagasse, wood waste (including native wood sawmill waste), camphor laurel	30	260,000 at 100% capacity	Y	Y	Y	The receiver in recent years has been operating the plant during the cane 'crush season (five or six months of the year). The factors that led Condong to go into receivership are discussed in Section 4.3
Harwood Sugar Mill, (Near Yamba) , **NSW Sugar**	In development	Bagasse/other (plans to use sawmill residues).						Low pressure boiler and cogeneration plant supplying heat and electricity for sugar milling (seasonal) and refining process (year round) and some export to grid. There is also a pilot bioethanol facility.
BIG RIVER TIMBERS	Operating	Timber waste, saw dust			Y	Y	N	
NORTHERN COOPERATIVE MEAT COMPANY & OTHERS	Biomass-fired boilers operating	Timber waste, meat processing waste, macadamia shells			N	Y	N	Some industrial sites using biomass. Opportunities to switch to cogeneration.

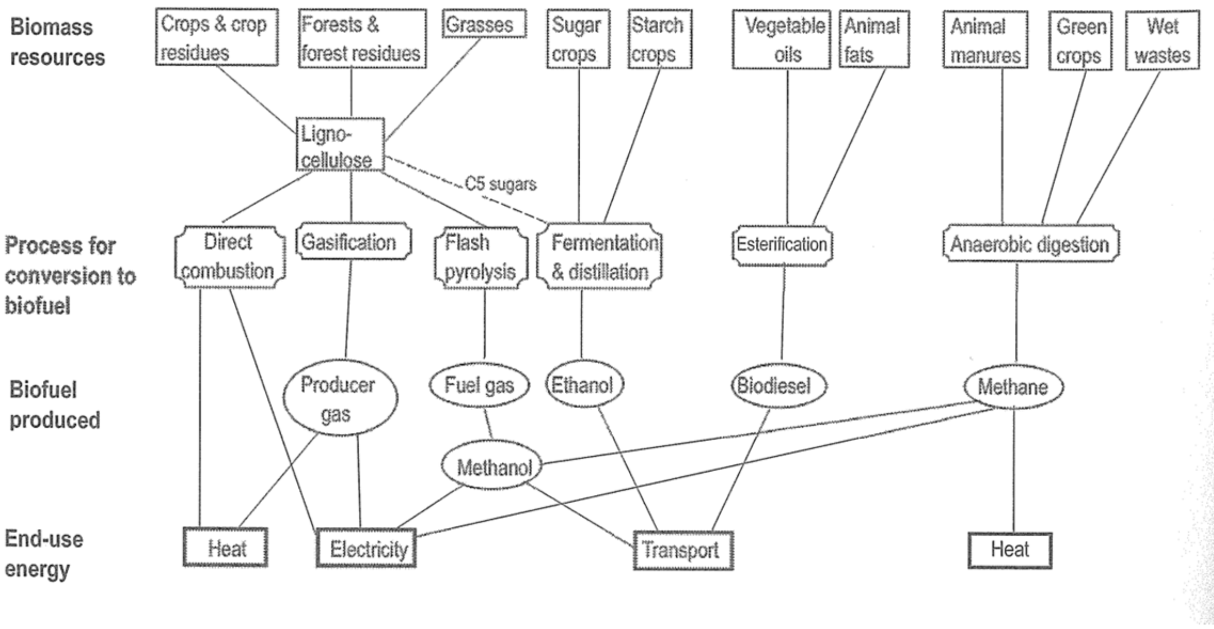
3. BIOENERGY DEVELOPMENT MODELS

There are three main development models that could be pursued in the North Coast region. These are:

- **Onsite** – a company with a large bioenergy resource installs a bioenergy conversion plant onsite to turn this resource into useful energy (heat or electricity) or fuel for sale (e.g. gas or briquettes).
- **Sector based** – organisations from the same industry sector (e.g. saw mills or chicken farms) in close proximity to one another jointly develop a bioenergy facility, and send all of their bioenergy resource to that facility.
- **Regional** – a bioenergy facility is developed in a region, fuelled by a range of compatible but different bioenergy feedstocks (e.g. plantation thinnings, camphor laurel and macadamia shells) found in that region.

In order to understand the benefits and challenges associated with each model, it is useful to have an understanding of the range of technical processes involved. One of the features of bioenergy is that there are a huge variety of **feedstocks** (bioenergy fuels or resource types), **processes** for converting feedstocks into useful energy, and **energy use** (for example, heat, electricity, transport). Figure 2 provides an overview of the range of feedstock and processing combinations possible.

Figure 2: Some pathways for converting biomass into useful energy[2]



The models of bioenergy development outlined in this section apply to technologies that may be fuelled from a range of feedstocks. However not every type of bioenergy feedstock can be used with a particular bioenergy technology. Facilities may also be very specific regarding the parameters of fuels they can use.

The appropriate technology is determined by a combination of the available feedstock and the end use energy required. Some industries produce feedstocks that are only suitable for particular technologies, for example wet wastes are generally only suitable for anaerobic digesters or anaerobic ponds.

This report focuses on three main processes (and associated technologies) for converting feedstocks into useful energy:

- **Anaerobic digestion** – this involves the decomposition of organic material in an environment without oxygen - usually a tank (digester) or a covered pond. Bacterial process break down biomass to form methane. The methane rises to the top of the tank or pond and is drawn off and burnt to produce heat and/or electricity. A liquid fertilizer is one of the side products of this process.

- **Combustion –** this involves direct burning of biomass material to produce heat and/or electricity. Heat can be produced via a simple boiler, or be used to produce steam to drive a conventional steam turbine to generate electricity.

- **Pyrolysis –** this involves heating biomass in a deoxygenated environment to produce methane and biochar. The methane is drawn off and burnt to produce heat and/or electricity.

The rationale for focusing on these three processes in this report is that they are the commercially available and the most common bioenergy technologies in use in the industrial world. Table 2 provides a summary of these conversion processes and the main characteristics of suitable feedstocks. “Appropriate for cogeneration” means that a useful energy output of the specified technology can be heat as well as electricity. For more information please refer to Section 3 of the *NSW Bioenergy Handbook*[3].

Table 2: Conversion processes for bioenergy considered in this report

Technology	Cogen	Biochar	Biogas	Feedstock characteristics	Feedstock examples
Anaerobic digestion	✓		✓	Wet, low lignin content	Manure, liquid waste
Pyrolysis	✓	✓		Large range (not liquid), high nutrient content preferable	Wood waste, greenwaste poultry manure
Combustion	✓			Relatively dry (maximum approx. 55% moisture), relatively high calorific value	Wood waste, Energy crops, sugar cane

Information sources on the different bioenergy technologies can be found in the OEH Bioenergy Resource List[4].

An overview of the potentials of the main bioenergy resources (feedstocks) in the Northern Rivers region is given in Section 4.

Approach: Onsite	
How it works	A farm or processing facility (timber, waste, food, etc.) installs a bioenergy plant and uses the onsite waste product to generate energy (heat, electricity, cooling, gas) for their operations. They may use both electricity and heat onsite, or they may use the heat and export all or part of the electricity
Requires	A large (unused) biomass waste feedstock and significant onsite energy use. In order to use cogeneration, which is frequently the most efficient energy conversion, there must be either onsite heat or cooling demand. The bioenergy facility should be scaled to use the waste stream(s), and ideally the onsite energy need as well. Electricity export under current pricing arrangements has considerably lower returns than onsite use, so the plant should generally not be oversized relative to energy use, unless there is clear expectation of expansion. Further, the plant should be scaled to the feedstock available, unless alternative feedstocks have been identified, otherwise it will be difficult to get the return on capital as the plant will be operating only part time.
Pros/Opportunities	This approach to bioenergy has several advantages: it has minimal transport costs (and emissions). Further, it offsets retail energy (electricity and gas) prices, thus making the business case more favourable. It can make use of a waste-stream that may have been problematic to remove, and which is in the control of the operator. Lastly, the main stakeholder generally has the power to make the decision, and location of the plant is likely to be straightforward.
Cons/Challenges	This approach requires one organisation to make a significant capital outlay for the plant equipment. Payback periods for such plants may be longer than the hurdle rate for some companies. Small units may not be efficient e.g. combusting wood residue – boiler low pressure, high labour cost/MWh.
Appropriate Technologies	All technologies – determined by the feedstock.

Approach: By Sector	
How it works	Organisations from one industry (e.g. poultry, sugar cane or timber mills) group together for example in a cooperative and jointly develop a bioenergy facility that takes the waste from the whole sector. They may alternatively group together to supply the fuel only, with a third party operating the power station.
Requires	Organisations from the specific industry need to be located in fairly close proximity to minimise transport costs. A history of cooperation in the industry also increases the likelihood that such a venture will get off the ground. The bioenergy facility should be ideally be located at a fairly central site and co-located with one business that has a high electricity and/or heat demand.
Pros/Opportunities	Many bioenergy technologies require a standardised or regular feedstock. If the feedstock comes primarily from one industry, this will be the case, thus increasing the range of technologies available. If the feedstock does not have a current use, conversion to bioenergy may save disposal costs throughout the industry. If the facility is co-located with a large energy user, some of the advantages of the onsite model apply, particularly the opportunity to offset retail electricity prices thereby making it more economically viable. It shares the cost of capital outlay over a range of stakeholders. It could also increase the collaboration within and thus potentially economic viability of the whole industry.
Cons/Challenges	Collecting and transporting some waste streams can be logistically challenging. Transport costs can also be expensive.
Appropriate Technologies	All

Approach: Regional	
How it works	A bioenergy facility is built within a region and takes a range of technically appropriate biomass feedstocks from the area and converts it to useful energy. Even facilities taking a variety of feedstocks will generally be geared to wastes with similar attributes (for example woody wastes OR wet wastes).
Requires	A range of bioenergy resources in the region with similar characteristics e.g. woody or wet. The bioenergy facility should be located at a central site and co-located with either one of the bioenergy feedstock providers or a business that has a high electricity and/or heat demand. The technology for the facility should be chosen very carefully, to ensure that sufficient bioenergy feedstocks in the region can be processed.
Pros/Opportunities	The viability of the bioenergy plant is not reliant on one organisation or industry, and can draw on a range of feedstocks and organisations within a particular region. Can address the issue of multiple waste streams. Multiple biomass feedstocks may ameliorate seasonal fluctuations of fuel for the facility. Could increase cooperation in the region. A regional approach suits the full range of possible business models, from a community owned cooperative to a council facility to a privately owned venture. If the facility is co-located with a large energy user, it can offset retail electricity prices thereby making it more economically viable.
Cons/Challenges	There are a more limited range of technologies that work efficiently with multiple feedstocks. Transport costs can be expensive and some feedstocks are logistically challenging to collect and transport (e.g. some manure). The range of possibilities and number of potential partners could be challenging to coordinate. Different fuel types are likely to require blending and hence require a holding /stockpile area.
Appropriate Technologies	All

4. NORTH COAST ESTIMATED BIOENERGY POTENTIAL

This section outlines the potential, opportunities and challenges of various sectors or industries in the North Coast region of NSW that have biomass or biogas resources (feedstocks) that could potentially be used for stationary bioenergy.

It should be noted that this report provides only a high level estimate to identify areas of potential and key knowledge gaps and does not replace the need for a detailed bioenergy resource assessment in the North Coast Region. It demonstrates rather the need for such an assessment and will hopefully help focus the efforts of further research.

The specific sectors considered are:

1. Plantation forestry residues
2. Saw mill waste
3. Sugar cane
4. Camphor laurel
5. Woody energy crops/coppicing
6. Macadamia
7. Coffee
8. Poultry
9. Piggeries
10. Dairy cattle
11. Meat processing/Abattoirs
12. Food processing
13. Landfill gas
14. Municipal solid waste

Table 3 provides a summary of these feedstocks, their locations and the estimated energy potential per year. The assumptions behind the energy potential figures are outlined in Sections 4.1-4.14. The combined annual energy generation estimated in this report is 1,100 GWh per year for those feedstocks with available data. This is equivalent to approximately 28% of the region's annual electricity consumption.[5] As the energy potential of many feedstocks could not be quantified within the scope of this study, the importance of the sector and the need for additional research is clear.

Only plantation forests residues (thinnings) are considered, as residues from native forests (other than sawmill wastes) are prohibited from being burnt for electricity generation in any generator over 200 kW[6]. Opportunities for electricity from bioenergy facilities will therefore only arise from plantation forest residues. Plantation forestry residues refer to wood taken directly from the plantation, whereas saw mill waste refers to wood residues from processing (saw mill) facilities. Saw mill waste both from plantation and native forest are discussed in this report.

The use of perennial woody energy crops for bioenergy, including coppice plantings integrated into broadacre or dairy farming, has not been quantified for the Northern Rivers regions, although it is likely to have significant potential. While general characteristics are described below, it was not possible to calculate the potential resource within the scope of this project. It is recommended that this research is undertaken as part of a more comprehensive bioenergy or renewable energy strategy for the Northern Coast.

Crop residues from broadacre crops have not been explored here. This is firstly because the practice of no-till farming has been increasing due to crop residues being important soil improvers. As such, there is a need to leave a high proportion of crop residue on the field. The economics of broadacre agricultural residue collection are marginal at best, and are further compromised if only a proportion are collected. Lastly, there is limited broadacre farming in the region.

Table 3: Summary of bioenergy resource energy potential on the North Coast of NSW

Sector (feedstock type)	Location	Estimated Energy potential MWh/year	Complementary feedstocks
1. Forest residues (plantation only)	Casino, Grafton	162,500	Saw mill waste, sugar cane, camphor laurel, coppicing, macadamia residue
2. Saw mill waste (plantation only at current plantation harvesting rates)	Casino, Grafton, Richmond Valley, Clarence Valley, Kempsey, Hastings	2,332	Sugar cane, forestry residue, camphor laurel, coppicing, macadamia residue
3. Sugar cane	Region wide	420,000	Forestry residue, camphor laurel, saw mill waste, coppicing, macadamia residue
4. Camphor laurel	Tweed area, Richmond Valley	4,200,000 (total, not annual)	Forestry residue, saw mill waste, sugar cane
5. Coppicing	Region wide	Not known (large)	Forestry residues, sawmill waste, sugar cane, camphor laurel
6. Macadamia	Ballina Shire, Byron Shire	Not calculated	Coffee, forestry residue, saw mill waste, coppicing, camphor laurel
7. Coffee	Ballina Shire, Byron Shire	Not known	Macadamia, forestry residue, saw mill waste
8. Poultry	Byron Bay, Lismore, Casino	Not known	Crop waste, dairy waste
9. Piggeries	Region wide	2,157	Poultry manure
10. Dairy cattle	Region wide	Not known (small)	Meat processing wastes
11. Meat processing/ Abattoirs	Casino, Booyong,	Not known	Woodwaste, piggery and dairy manure
12. Food processing	Region wide	Not known	Dairy, poultry and piggery wastes
13/14. Municipal solid waste, landfill gas	Region wide	340,000	

4.1. Sector – Plantation forestry residues

Location	**Grafton and Casino**
Types of feedstock	Wood waste – thinnings and forest residues occurring in the forest
Estimated recoverable feedstock size	32,500 t/yr (2008)[7] Note that thinnings residues from native forests (other than sawmill wastes) are prohibited from being burnt for electricity generation in any generator over 200 kW[8], so opportunities for electricity from bioenergy facilities will only arise from plantation forest residues. This figure only includes plantation residues.
Energy potential	39,000 MWh[9] (2008)
Best fit technology	Combustion
Most appropriate business model	Industry based or regional
Complementary feedstocks	Sugar, saw mill waste, camphor laurel
Key Players	Boral, Clarence Valley Council
Challenges	While there is a significant plantation residue resource available, currently, only 5% of the timber harvested in the North Coast is from plantation forests. Many of the companies that owned, harvested and maintained the plantations on the North Coast have gone out of business, making this a significant challenge. An additional challenge is the cost of collecting and transporting plantation forest residues (thinnings), which is currently more than bioenergy plants in the region can afford to pay for feedstock (see Section 4.3 for further discussion).
Opportunities	The price of woodchip is currently low, making it uneconomic for businesses to chip plantation forest residues for export. As such, plantations are not being thinned or timber is left at the plantation to decompose. The development of bioenergy generation could provide a more productive end-use for this timber. Condong and Broadwater bioenergy cogeneration plants may provide an opportunity to utilise plantation forest thinnings and residues. While there are economic and legal issues to resolve, the possibility of this resource providing an additional feedstock for the Condong and Broadwater plants, which have a smaller feedstock from the sugar industry than anticipated, is worth further investigation.

4.2. Sector – Saw mill waste

Location	Casino, Grafton, Richmond Valley, Clarence Valley, Kempsey, Hastings
Types of feedstock	Wood chip, saw dust, shavings and fines from plantation timber
Estimated recoverable feedstock size	**Grafton**: 135,500t/yr 50kms, 58,4430t/yr within 200kms. **Casino**: 98,200t/yr 50km, 274,180t/yr 200km radius.[10] Only around 5% of currently milled timber in the area is from plantations, so only 5% of this resource would be eligible for Renewable Energy Certificates.[11]
Energy potential	46,640 MWh[12] (2,332 MWh potential from plantation-sourced wastes)[13]
Best fit technology	Combustion
Most appropriate business model	Industry-based or regional
Complementary feedstocks	Sugar – bagasse, forestry thinnings and residues, macadamia shells (if available)
Key Players	Big River Timbers, Boral, Australian Solar Timber and the 80 saw mills in the Clarence Valley and Hastings regions
Challenges	New bioenergy projects utilising sawmill wastes from native forests wood are ineligible for Renewable Energy Certificates (RECs). However currently 95% of the timber processed in saw mills on the North Coast is from native forest. Thus, new bioenergy projects using native forest saw mill residues are unlikely to be economically viable. Further, where plantation timber is milled it is often mixed with native forest timber, thus representing an accounting challenge to determine whether and to what extent a bioenergy facility is eligible for RECs if saw mill waste is used as a feedstock. Saw mills residues have a range of possible commercial markets; energy from wood-waste thus has to compete with these other end-use markets.
Opportunities	The price of woodchip is currently quite low, making it uneconomical for businesses to chip their wastes for export. Waste is becoming a problem for many players across the region. The development of bioenergy generation could provide a solution to this waste problem. Already some saw mills are selling their wood waste for the firing of industrial boilers, there could be potential for more of this in the area.

4.3. Sector – Sugar cane

Location	Region wide
Types of feedstock	Bagasse, tops and trash
Estimated recoverable feedstock size	830,000 wet tonnes/year (Broadwater – 300,000 tonnes of bagasse, Condong – 180,000 tonnes of bagasse, 350,000 tonnes of trash which is currently burnt on the fields)[14]
Energy potential	420 GWh/year (including trash)[15]
Best fit technology	Combustion with cogeneration
Most appropriate business model	Industry based or regional
Complementary feedstocks	Wood wastes, timber processing wastes
Key Players	NSW Sugar
Challenges	Condong and Broadwater, two 30MW cogeneration plants, co-located at two of NSW Sugar's sugar processing mills are currently in receivership and for various reasons have only been operating for five or six months of the year (during the cane 'crush season') in recent years. These plants were developed to use sugar cane waste, with heat and electricity used in sugar processing, with excess electricity exported to the grid. The key factors that led to Condong and Broadwater going into receivership were: • Low cane crop volumes; • Availability of supplementary fuel at an economically viable price; • Only 12.5% of Broadwater's 38MWs of capacity is used by the sugar mill on site (during the crushing season) and for Condong only 11.1% is used onsite (also during the crushing season), the majority of the electricity generated is exported to the grid and thus its economic viability relies on the wholesale electricity market. The wholesale electricity price has been lower than forecast in the modelling for the plants[16]; and • Large Generating Certificate (LGC, previously known as REC) prices, the second income stream for the Condong and Broadwater plants, were also lower than forecast. These factors represent challenges specifically for these plants and more

	generally for the economic viability of sugar based bioenergy systems in the region. The main challenge for Condong and Broadwater currently is to deal with the plants' debt problems, presently in the hands of its receivers. A second challenge is how to utilise 25% of the sugar cane bioenergy resource – 'the trash' – which is currently burnt in the field. Previous attempts have encountered technical harvesting difficulties and increased transport costs. Transport costs increased significantly due to the increase in volume of cane product being transported from the field to the mill.
Opportunities	The presence of two large bioenergy generators at sugar processing facilities is a significant opportunity. The capital is already sunk, all of the pre-feasibility, feasibility, planning approval and construction processes have been undertaken, and the supply chain for additional feedstocks has functioned previously. Once the plants' debt problems have been resolved there may exist opportunities to partner with the local timber industry to secure year-round feedstock, and ideally to co-locate a facility with the sugar mill which has a year-round heat and electricity demand to ensure demand for heat outside the crush season and to reduce the amount of electricity exported to the grid. Opportunities for this sector are discussed further in Section 5.1.

4.4. Sector – Camphor laurel

Location	Richmond Valley, Tweed region
Types of feedstock	Wood waste
Estimated recoverable feedstock size	3.5 million dry tonnes in the North East NSW region[17]
Energy potential	4,200,000 MWh18 total potential. Annual potential is unclear as it is dependent on the harvesting rate.
Best fit technology	Combustion
Most appropriate business model	A regional approach, specifically Camphor laurel removal companies sell on to existing generators (e.g. Condong).
Complementary feedstocks	Wood wastes, timber processing wastes, woody energy crops
Key Players	Eco-clearing
Challenges	Many camphor laurel harvesters left the business when Condong went into receivership. There will need to be a higher degree of certainty provided for these businesses to be re-established. There is also a question of how economically viable camphor laurel is as a bioenergy feedstock given the transport costs. Further research is required to answer this question.
Opportunities	Condong provides an end-use for the removal of an extremely well-spread pest species. Camphor laurel is eligible for RECs. This has already been done, in the North Coast region as such the skills and experience already exists. Camphor laurel harvesting requires similar equipment and business models to coppice harvesting, and there may be opportunities for the same players to establish a supply chain for coppice harvesting alongside their current business.

4.5. Sector – Woody energy crops/coppicing

Location	Region wide
Types of feedstock	Mallee species have been successfully coppiced in WA and are currently being trialled in NSW in a partnership between Greenline Sustainable Biomass and Delta electricity
Estimated recoverable feedstock size	Currently none, ultimate potential large. The NSW Bioenergy handbook estimated that NSW as a whole could potentially supply 550 MW from purpose grown woody energy crops[19].
Energy potential	Unknown, but likely to be significant
Best fit technology	Combustion or pyrolysis
Most appropriate business model	The NSW trials around Forbes use a business model where a supply company plants and harvests the trees on a lease arrangement with the farmer, and supplies wood chip to a power station. The farmer keeps the below-ground biomass and may in the future receive carbon credits for the mallee root system. The supply company will harvest the trees, chips and supply to the power station.
Complementary feedstocks	Wood wastes, timber processing wastes
Key Players	Greenline Sustainable Biomass (currently carrying out trials in the Forbes area of NSW, have developed harvesting equipment).
Challenges	The coppicing industry does not currently exist in the North Coast of NSW.
Opportunities	Perennial woody energy crops, if planted in appropriate areas, can have significant co-benefits for dryland salinity control. It is most suited to broadacre farming or grazing, where there is need for shelter belts.

4.6. Sector – Macadamia

Location	Ballina shire, Byron Shire
Types of feedstock	Nut shells
Estimated recoverable feedstock size	In 2008 macadamia production was approximately 27,000t/yr of nut in shell. Approximately 17,000 tonnes of this material is waste shell & reject nut.[20] Macadamia shells are a high value fuel because of their high oil content.
Energy potential	Not yet calculated
Best fit technology	Combustion or pyrolysis
Most appropriate business model	Regional
Complementary feedstocks	Wood waste, saw dust, coffee
Key Players	Macadamia processing plant
Challenges	Macadamia shells are likely to have alternative uses which are higher value, and are already used to fire boilers in the region. There are a number of other uses, including as a mulch or fertiliser and mixing with a polymer to form a “green plastic”. If co-firing with wood wastes, generators would need to ensure plantation-only so as to be eligible for Renewable Energy Certificates (RECs) saw mill waste from native forests is not eligible for RECs and native forest residues may not be used for electricity generation in NSW.
Opportunities	Opportunities to expand the use of macadamia shells for bioenergy are likely to be limited due to much of the resource being used already. Transport of macadamia shells is economically viable as evidenced by their use in boilers across the region.

4.7. Sector – Coffee

Location	Ballina, Byron Shire
Types of feedstock	Coffee bean husks, waste from roasting.
Estimated recoverable feedstock size	500 hectares coffee production. At least 50% of the harvested weight will end up being discarded at the processing stage.
Energy potential	Not known
Best fit technology	Pyrolysis or Combustion
Most appropriate business model	Regional
Complementary feedstocks	Wood waste, saw dust, macadamia (if the resource is available).
Key Players	Small coffee growers around Byron Bay.
Challenges	Coffee within the Northern Rivers region is on a relatively small scale. There is a need to combine with complementary feedstocks as most producers have insufficient feedstock to supply a generator.
Opportunities	There is a high heat demand associated with the coffee processing industry (i.e. roasting beans). As such, a coffee processing facility could be suitable site to host a regional bioenergy cogeneration facility.

4.8. Sector – Poultry

Location	Byron Shire, Lismore, Casino
Types of feedstock	Poultry manure, hatchery wastes
Estimated recoverable feedstock size	411,295 chickens (feedstock quantity not known) 2, 792 tonnes of litter/year[21].
Energy potential	Not known
Best fit technology	Pyrolysis or Combustion
Most appropriate business model	Regional[22]
Complementary feedstocks	Crop waste, dairy waste
Key Players	Inghams (hatcheries and breeders) and some smaller growers around Byron Bay and Lismore.
Challenges	The individual sites which make up the growing and processing industry are not big enough to make this viable, however the cost of transporting waste between sites is extremely high. Feedstocks from breeders and hatcheries are patchy and relatively small.
Opportunities	There is a great deal of interest from Inghams in supporting the development of a bioenergy generator through a regional approach in the Northern Rivers region (and elsewhere).

4.9. Sector – Piggeries

Location	Region wide
Types of feedstock	Manure (slurry)
Estimated recoverable feedstock size	29,550 pigs[23]
Energy potential	827,400 m^3 methane/year, 2,157 MWh/year[24]
Best fit technology	Anaerobic Digestion (tanks or ponds)
Most appropriate business model	If a piggery is large enough, an onsite facility is most likely to be successful. Otherwise a regional approach with other industries producing wet wastes may be most appropriate, as there is not a sufficient clustering of piggeries in one area which could make a sectoral approach viable.
Complementary feedstocks	Poultry manure, dairy wastes
Key Players	Unknown
Challenges	If individual piggeries are not large enough to support an onsite facility, transport costs to the plant will be a significant factor in economic viability.
Opportunities	Methane capture and energy recovery from piggeries is the first approved methodology under the national Carbon Farming Initiative to receive carbon credits. Already one farm has implemented this in NSW, so there is experience in NSW that piggeries on the North Coast can draw on. Anaerobic digestion of manure slurries can provide an effective waste management strategy, and may both assist piggeries in meeting any environmental consent requirements, and reduce disposal costs.

4.10. Sector – Dairy cattle

Location	Region wide
Types of feedstock	Manure (slurry)
Estimated recoverable feedstock size	There are 79,000 cattle in the region, however none appear to be in feedlot arrangements. Where cattle are on pasture, manure recovery is not practicable, and in any case acts as fertiliser. Thus the only accessible resource is manure and slurry from the dairies – where cattle spend a maximum of around 15% of their time.
Energy potential	Assuming that cattle spend a maximum of 15% of time in the dairy[25], the maximum energy potential will be around 14,514MWh/year for the region.
Best fit technology	Anaerobic Digestion (tanks or ponds) or Pyrolysis.
Most appropriate business model	Regional – the lack of concentration of cattle in a particular area suggests that if manure can be recovered it is best done as part of a regional bioenergy plant for wet wastes.
Complementary feedstocks	Meat processing wastes.
Key Players	Unknown
Challenges	The optimal size of a dairy for the generation of bioenergy onsite is minimum 500 head[26]. Most of the dairy farms in the Northern Rivers region are smaller, with around 200-300 head. The cost of transporting a primarily wet waste is significant (high volume/low value). However, the majority of dairy farms in the region are in clusters and relatively close to larger towns. This provides an opportunity for dairy waste to become a valuable bio waste feed stock.
Opportunities	There may not be viable opportunities in the North Coast region due to the relatively small size of dairy farms. The cost of the technology is likely to prohibit on-farm investment, and the costs of transporting a primarily wet waste may be prohibitive. Quantification of transport costs is a key knowledge gap before this opportunity can be properly assessed.

4.11. Sector – Meat processing

Location	Casino, Booyong (near Lismore), Kempsey
Types of feedstock	Meat processing effluent, manure, paunch (waste from stomachs of cows), hair from tanning process.
Estimated recoverable feedstock size	Not known
Energy potential	8.2 - 31.3 kWh/tonne of carcass (without/ with rendering)[27]
Best fit technology	Anaerobic digestion (tanks).
Most appropriate business model	Onsite
Complementary feedstocks	Woodwaste from plantations for firing boilers/cogeneration Other wet wastes: piggery and dairy manure
Key Players	Northern Meat Cooperative, Macleay Rivers Meats.
Challenges	Many sites may not be able to create the economies of scale necessary to make bioenergy generation viable. There will need to be further investigation to determine whether other feedstock sources can be co-located or whether feedstocks could be transported.
Opportunities	There are opportunities to develop the bioenergy sector within the meat processing industry in the region. Many of these sites have a high heat or steam demand and are large consumers of electricity. Many sites may need support to understand the opportunities available and to develop their business case.

4.12. Sector – Food processing

Location	Region-wide
Types of feedstock	Food processing wastes – coffee, dairy, meat, poultry, waste water sludges.
Estimated recoverable feedstock size	Not known.
Energy potential	Not known.
Best fit technology	Anaerobic Digestion (ponds or tanks).
Most appropriate business model	Regional
Complementary feedstocks	Poultry, piggery and dairy wastes.
Key Players	Inghams, Nestle
Challenges	Transport costs may make a regional approach prohibitively expensive. Many of the wastes are up to 90% water – high volumes of waste with low energy content.
Opportunities	A regional approach is considered appropriate by several players in the food processing industry, and could bring together a range of feedstocks.

4.13. Sector – Landfill gas

Location	There are at least 12 landfills of reasonable size in the Northern Rivers region of NSW[28].
Types of feedstock	Existing landfill sites in the region may be used to collect methane (landfill gas).
Estimated recoverable feedstock size	There have been no onsite measurements to determine gas volumes available from Grafton Landfill[29], further research is warranted.
Energy potential	Not known.
Best fit technology	Gas collection from landfill, followed by use in a combined cycle gas turbine used as a peaking plant or in a cogeneration plant if in a gas fired cogeneration plant if the landfill site is close to suitable facilities with heat demand. If a processing site for waste including a gasifier is co-located with the landfill site, landfill gas can be used in whatever generator is used for the MSW.
Most appropriate business model	Onsite facility operated by Council or third party.
Complementary feedstocks	Not applicable.
Key Players	All local governments in the region and their waste contractors.
Challenges	While landfill gas is usually economic, working out arrangements that would make a landfill recovery viable could be challenging, given the small size of many of the landfills in the North Coast area.
Opportunities	Landfill sites emitting more than 25,000 tonne CO_2 /yr net of collection and use or flaring will have carbon liabilities under the Clean Energy legislation. Some landfills (including Grafton, at 40,000 tonnes MSW per year) are likely to exceed this threshold. Collection and use of the methane generated would avoid this liability and produce income. SNR could play a role in supporting councils in the region to reduce their landfill gas emissions, see Section 5.1 for more discussion.

4.14. Sector – Municipal solid waste

Location	In each of the council areas in the region.
Types of feedstock	Municipal solid waste, which may be diverted from landfill to energy recovery and recycling plant.
Estimated recoverable feedstock size	Total regional landfill in 2012 was approximately 170,000 tonnes of mixed MSW.[30] In 2005 the estimated recoverable feedstock size for the region was as follows: Drop-Off Greenwaste 23,098 tonnes; Kerbside Collected Organics 10,519 tonnes; and Biosolids 33,549 tonnes.[31] In 2011/12 Clarence Valley Council received 8,000 tonnes of mixed recyclables and 8,000 tonnes of organics which did not enter landfill. If these figures are reflective of the region as a whole then this represents a substantial feedstock asset. [32]
Energy potential	340,000 MWh/year[33] from landfill.
Best fit technology	Pyrolysis or combustion for greenwaste and MSW diverted from landfill. Gasification and pyrolysis or gas generation for sorted MSW. If the processing site is co-located with the landfill site landfill gas can be used in whatever generator is used for the MSW.
Most appropriate business model	Regional facility located adjacent to landfill site or another council waste processing site.
Complementary feedstocks	MSW is a complex feedstock, so most feedstocks other than wet wastes may be suitable to increase the throughput of the plant.
Key Players	All local governments in the region and their waste contractors.
Challenges	Energy extraction from waste fits within a broader waste management strategy, and is relatively low down the value chain (although above disposal to landfill). Materials should be reused, recycled back into the same item, reprocessed into other items, or the energy recovered. The interaction with other waste diversion strategies such as composting or paper recycling should be considered. Indeed, many Councils in the North Coast region already have composting facilities, which means the potential resource for energy recovery is lower. Energy recovery from waste will generally require a gasification process as direct burn of waste is unlikely to get planning permission in NSW.
Opportunities	Ballina Shire Council is developing a biochar facility. Other local governments could divert waste to this facility to produce energy or look into developing a similar facility in their area. There could be opportunities for councils located near each other to develop a joint bioenergy facility e.g. Clarence Valley and Coffs Harbour Councils.

5. RECOMMENDATIONS

Bioenergy could be a major source of sustainable energy in the NSW North Coast region. This report has two main recommendations to progress bioenergy in the North Coast:

1. Pursue a range of key bioenergy opportunities for the North Coast
2. Address knowledge gaps identified in this report by undertaking a comprehensive North Coast Bioenergy Resource Assessment and a wider Sustainable Energy Strategy for the North Coast.

These two recommendations are discussed in detail in the following sub-sections.

5.1. Pursue key bioenergy opportunities for the North Coast

Seven key opportunities for SNR to support bioenergy development in the NSW North Coast region have emerged from this research:

Opportunity 1.	Condong and Broadwater Cogeneration revitalisation
Opportunity 2.	The Ballina biochar project, and potential replication
Opportunity 3.	Forestry industry opportunities in the Grafton area
Opportunity 4.	Food processing industry opportunities (including meat and livestock, and poultry)
Opportunity 5.	Council landfill site gas collection and / or MSW gasification and pyrolysis
Opportunity 6.	Energy crops/coppicing
Opportunity 7.	Co-locating bioenergy facilities with large energy users

OPPORTUNITY 1 – CONDONG & BROADWATER REVITALISATION

A major priority for the bioenergy sector in the Northern Rivers Region should be to support the revitalisation of the Condong and Broadwater Cogeneration plants. The partnership between Delta Electricity and NSW Sugar that developed, owned and operated these plants is now in receivership. The receiver has continued to operate the plants although for various reasons, including the historically low cane crops of recent years, operations have been limited to the cane crushing season (5-6 months per year).

As such, the first priority for the bioenergy sector in the North Coast should be to engage with the receiver to determine whether any assistance can be given to resolve the debt problems of the plants. Once Condong and Broadwater are out of receivership, there are a number of strategies which should be investigated to ensure that they are fully utilised so that generation at the plants is significantly increased.

If/when the receivership issue is resolved, Condong and Broadwater represent a significant opportunity for the North Coast. As existing assets, the development and capital cost is already sunk, and they are likely to offer the most immediate and cost effective bioenergy opportunities. In addition, a number of industries including camphor laurel removal were developed based on supplying feedstock to the Condong and Broadwater bioenergy plants, so the effects of reduced operation go beyond NSW Sugar and Delta Electricity.

A number of strategies are suggested below which may support increased generation at the plants.

1. Strengthening the links between Condong and Broadwater and the local forestry industry. There is a need to foster ongoing collaboration between the forestry industry in the region and the cogeneration plants. The forestry industry is relying on these plants to provide an end use for timber waste, and to support businesses established to transport wood waste to the plants.
2. Co-locating a facility with a year-round heat and electricity demand: The lack of demand for heat in the non-crushing season is a significant inefficiency for both of the generation plants. Co-locating a facility that has a demand for heat (and a potential feedstock stream) would provide an additional end-use and hence additional revenue for this heat output.[34] A useful next step would be a broad (quantitative) assessment of energy intensive opportunities that could be aligned with the off-season for cane.
3. Talk with existing and former camphor laurel collection businesses about what it would take for them to start operating again.
4. Continue R&D into overcoming problems associated with green cane harvesting.

OPPORTUNITY 2 – BALLINA (AND OTHER) BIOCHAR PROJECTS

After Condong and Broadwater the next significant bioenergy project in the North Coast region is the Ballina biochar project. This project provides an opportunity to showcase emerging technology that has the potential to be not only greenhouse neutral but greenhouse negative, and is likely to play an increasing role in climate mitigation. If this project can demonstrate economic viability it is likely to be replicated in the region, as it can be used with many of the regional resources.

SNR could play a role in identifying complementary feedstocks for the Ballina project, as there appears to be capacity for expansion, and perhaps assist with testing the inclusion of electricity generation. SNR could also play a role promoting this project as a learning opportunity for other Councils and industries in the area.

OPPORTUNITY 3 – GRAFTON AREA FORESTRY

There is a large forestry industry on the North Coast, particularly in the Grafton area. This includes more than 80 saw mills in the Grafton region alone as well as an extensive area under plantation. The plantation resource (see Section 4.1 for details), particularly thinnings, is not currently being utilised. The size of the plantation and saw mill wood waste/residue resource is greater than required to operate Condong and Broadwater, so there may be a significant opportunity for the development of a regional bioenergy facility based on plantation residues. All wastes from plantations (thinnings and sawmill wastes) are eligible for LGC creation.

The generation of electricity from native forestry thinnings is disallowed in NSW. However although electricity from native forest saw mill residues is not currently eligible for RECs, the one exception is sawmill waste from native forest that was established as a fuel before July 2011, so that Condong and Broadwater facilities can burn native forest sawmill wastes from and still be eligible for RECs until 2020.

The legal situation means different approaches are required for plantation forest bioenergy resource and the native forest bioenergy resource, and the emphasis should be on developing bioenergy projects with the plantation forest resource.

It should be noted that the majority of the timber currently processed in saw mills in the area come from native forests rather than plantations. This is a complex and controversial area and Sustain Northern Rivers should carefully consider under what conditions they would support for the use of native forestry residues as a bioenergy resource.

OPPORTUNITY 4 – FOOD PROCESSING INDUSTRY (INCLUDING MEAT AND LIVESTOCK, POULTRY)

The meat and livestock and poultry industries in the region have expressed interest in participating in bioenergy. This report recommends that SNR support the meat and livestock industry in the Casino area to investigate regional or site-based bioenergy project/s. This would require a feasibility study, and it may be appropriate to include the wider food processing sector in a scoping study as a first stage.

OPPORTUNITY 5 – COUNCIL LANDFILL WASTES

Landfill gas emissions become a carbon liability for Councils where they exceed 25,000 tonnes, and in any case require management to protect from explosion risk. Collection and use of landfill gas reduces these liabilities as well as generating its own income. As such, SNR could play a role in supporting councils in the region to reduce their landfill gas emissions. Strategies could include:

- Diverting biomass waste from landfill to be used in another bioenergy facility. Existing examples include the Condong and Broadwater cogeneration plants and the Ballina biochar project (in development).
- Collecting landfill gas and using it in a gas generator. Where the quantities of landfill gas are not sufficient to make a stand alone gas generator economically viable, they could co-locate with an industry with a compatible waste-stream, or an industry with a large energy and heat demand year round.

SNR could play a role in coordinating and facilitating information sharing and cooperation between councils to move towards best practice landfill management and utilisation of landfill gas.

OPPORTUNITY 6 – ENERGY CROPS/COPPICING

Integration of coppice plantings into livestock and broadacre crops can provide both a bioenergy resource and co-benefits such as salinity control and shelter belts. It is recommended that SNR quantify this resource and investigate the potential to extend or replicate the central NSW trials to the Northern Rivers region.

OPPORTUNITY 7 – CO-LOCATING BIOENERGY FACILITIES WITH LARGE ENERGY USING FACILITIES

In the current energy policy environment, renewable energy projects such as bioenergy plants are more likely to be economically viable if they can offset retail electricity prices rather than export electricity to the grid and rely on the wholesale electricity spot market. For all three business models identified in this report – on-site, sectoral or regional, a bioenergy facility represents an opportunity to attract new industry to the region and/or increase the viability of existing industry in the region. Specifically, if a bioenergy facility is co-located with a large energy user, particularly a company or industry that has a high heating and/or cooling demand, the large energy user reduces the risk of unknown future energy prices and the bioenergy facility can sell their electricity at higher than the average wholesale price, thus creating a win-win situation.

This represents an industry development opportunity for the region, if SNR can identify appropriate locations and pull together an information package to attract suitable industry to the region. NSW Trade and Investment's involvement in SNR could be particularly useful here.

5.2. Address knowledge gaps identified in this report

Undertake a Bioenergy Resource assessment and a wider Sustainable Energy Strategy for the North Coast. This will ensure that SNR targets their resources to best effect and outline the role that bioenergy will play in the wider transition to a sustainable energy North Coast.

The Bioenergy Resource Assessment and/or Sustainable Energy Strategy should address the key knowledge gaps identified by this research, and should have a particular focus on technical and economic viability, including high level of rigor and consistency regarding assumptions for energy content, conversion efficiencies for the different processes, cost estimates, cost of capital and more.

The key knowledge gaps from this research are:

1. **The energy potential** of the following feedstocks in the North Coast region:
    a. Woody energy crops, and in particular, coppiced crops integrated into broadacre and /or dairy farms
    b. Poultry litter and hatchery wastes
    c. Food processing wastes, including:
        - Meat processing/abattoir wastes
        - Coffee
        - Macadamia
    d. Dairy cattle – manures and slurries
2. Whether the legal and economic complexities of plantation forest residues, camphor laurel and saw mill residues as a feedstock for the Condong and Broadwater can be resolved beneficially for all parties.
3. **Forest residues, woody energy crops, and camphor laurel**: transport and collection costs are key factors in the economic viability of these feedstocks. It would be useful to provide data on collection and transport costs per km as well as an indicative measure of where transport distances become prohibitive.
4. Barriers and opportunities to restarting the **camphor laurel sector**.

5. **Livestock industries**: the following questions should be answered in order to assess the viability of projects in this sector:
    a. The minimum size of a piggery (number of pigs), dairy or poultry farm that would make an onsite biodigester project economically viable.
    b. The transport costs associated with wet wastes from dairy farms, and an indicative measure of where transport distances preclude using wastes at a shared facility.
    c. The transport costs associated with poultry litter and hatchery wastes, and an indicative measure of where transport distances preclude using wastes at a shared facility.
6. Whether new or existing bioenergy facilities in the region could be considered a non-network solution to increasing demand in the area and thus eligible for a network support payment from Transgrid or Essential Energy. For this to be the case, such a bioenergy facility (or series of bioenergy facilities) would need to reliably defer or remove the need for transmission and/or distribution network investment.

6. APPENDIX – LIST OF INTERVIEWEES

1. Ken Davey: Australian Development Manager at MT Energie
2. John Truman: Group Manager Civil Services Group at Ballina Shire Council
3. Des Schroeder: DGM (Environmental and Economic) at Clarence Valley Council
4. Ray Loy: Owner of Hardwood Residual Solutions
5. Todd Westgate: Environmental Officer at Northern Cooperative Meat Company
6. Julia Seddon: Group Environment Manager at Inghams Enterprises
7. David Thompson: RDA Northern Inland
8. David Maylor: Farmer interested in bioenergy/biodiesel
9. Rex Farrell: NSW Sugar

7. ENDNOTES

[1] Based on Northern Rivers Catchment Management Authority (2012) *Regional State of the Environment Report 2012, p12.* This report quantifies total electricity consumption across the North Coast local government areas as 4,058GWh in 2011/12. The calculation also assumes that the camphor laural resource will be used over a 20 year time period.

[2] Diesendorf, M. (2007) Greenhouse Solutions with Sustainable Energy, UNSW Press

[3] Rutovitz, J., & Passey, R. (2004). *NSW Bioenergy Handbook*.

[4] NSW Office of Environment and Heritage Bioenergy Resource List (in prep). The updated List will be published on the RDA–Northern Rivers web site when finalised.

[5] Op cit 1

[6] The Protection of the Environment Operations (General) Amendment (Burning of Bio-material) Regulation 2003

[7] 5% of forestry in the region is plantation from Northern NSW Forestry Services (2008) *Commercial development of native forest, plantation and processing residues in Northern NSW,* for Northern Rivers Private Forestry.

[8] Op cit 6

[9] Uses 1.2 MWh_e/dry tonne forestry residue from Op cit 3.

[10] Wood Processing Investment Brief, Northern Rivers Private Forestry Development Committee

[11] Northern NSW Forestry Services (2005) *A Profile of the Northern NSW Private Forestry Resource and the Private Native Forest Industry,* prepared for Northern Rivers Private Forestry

[12] Assuming 5MWh/tonne for forestry residue from Op cit 3

[13] 5% of total energy potential

[14] From interview with Rex Farrell, NSW Sugar, assuming bagasse is 30% of cane.

[15] Assuming an energy content of bagasse and trash of 2.5MWh/tonne and a 20% conversion efficiency, from Op cit 3, p37

[16] Interview with Rex Farrell, NSW Sugar

[17] http://www.ecoclearing.com.au/camphor-laurel-removal.html

[18] Uses 1.2 MWh_e/dry tonne forestry residue from Op cit 3

[19] Op cit 3

[20] BEST Energies Australia (2008) *Northern Rivers Pyrolysis Unit – Scoping Study,* Prepared for Ballina Shire Council, NSW Department of Primary Industries, p13

[21] Assumes 18.6g litter/day/chicken (FAO), multiplied by number of chickens by 365 (number of days per annum). This does not account for the bedding material (e.g. straw) that is collected with the litter.

[22] Inghams have done investigations and found that a vertically-integrated bioenergy generator is unlikely be financially viable for them. A regional approach is needed to ensure financial viability. Interview with Julia Seddon, Inghams.

[23] *Northern Rivers Food – An Appetising Investment Decision* (2011) Regional Development Australia – Northern Rivers.

[24] Conversion rate of 73kWh/pig/year from Op cit 3

[25] www.dpi.vic.gov.au/agriculture/dairy/managing-waste/minimising-dairy-shed-effluent-stream

[26] Personal communication - Julian Fyfe, Research Consultant at the Institute for Sustainable Futures.

[27] Op cit 3

[28] www.environment.nsw.gov.au/waste/asbestos/ncasbestos.htm

[29] Personal Communications – Ken Wilson, Sustainable Service Coordinator, Clarence Valley Council

[30] Based on North East Waste Forum (2012) North East Waste Forum Annual Report 2012, which identified 150,012 tonnes of MSW in 2011-12 from all councils in the region excepting Lismore and Kyogle. This was rounded to 170,000 based on a conservative population based scaling factor for the remaining two councils.

[31] Op Cit20

[32] Op Cit 31

[33] Assumes the MSW figure using a conversion factor of 2MWh/tonne mixed municipal waste with a 25% conversion factor which would be appropriate for a mixed waste gasification plant, from Op cit 3. These would not be appropriate assumptions for landfill gas generation or anaerobic digestion of only food waste.

[34] Note this is dependent on land availability at the Condong and Broadwater sites, which is unknown to the research team