Venture Southland

Consultant/specifier practice paper

for Wood Fuelled Industrial and Commercial Heating Systems

15 June 2015

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Glossary

B(g)	Bars(gauge)
BANZ	Bioenergy Association of New Zealand
BD	Bone Dry
BMS	Boiler management system
dT	Differential (delta) Temperature
EECA	Energy Efficiency and Conservation Authority
EMANZ	Energy Management Association of New Zealand
EPC	Engineer, Procure and Construct
FPA	Fuel Purchase Agreement (or FSA, Fuel supply agreement)
GCV	Gross Calorific Value (Also known as Higher Heating Value, HHV
HMB	Heat and Mass Balance
HPHW	High pressure Hot Water
IBL/OBL	Inside battery limits/Outside battery limits
LCCA	Life Cycle Cost Analysis
LFO	Light Fuel Oil
LPG	Liquefied Petroleum Gas
LTSA	Long Term Service Agreement
mc	Moisture content (dry or wet basis)
MCR	Maximum Continuous Rating
MW(th)	MegaWatt (Thermal)
NCV	Net Calorific Value (also known as Lower Heating Value, LHV
O&M Agreement	Operation and Maintenance agreement
PECPR	Pressure Equipment, Cranes and Passenger Ropeways
PPE	Personal Protective Equipment
PSA	Power Supply Agreement

Executive summary

This practice paper seeks to provide broad guidance, primarily for Consultants and Specifiers, on evaluating and carrying out wood fuelled industrial and commercial heating system projects.

The paper covers hot water and saturated steam plant for a size range typical of small to medium commercial and industrial plant, and common wood fuel types.

The paper considers initial project evaluation to establish business criteria and basic economic viability, system and project design (heat loads, fuel supplies, plant design), and contracting.

The paper does not (and cannot) provide detailed design information for the full range of plant and issues involved, but it does seek to identify and discuss the issues that must be resolved, and proposes good-practice approaches for achieving these resolutions. For many project aspects, checklists are provided with the aim of assisting the Consultant/Specifier in ensuring that all relevant issues are addressed.

For many aspects of biomass projects, responsibility can only rest with one party, and so it is it is important that all parties are clearly aware of what is required of them. This paper outlines the responsibilities that are commonly associated with the various project roles. For all cases, it is assumed that parties will clarify their own competence to undertake their roles and responsibilities.

1. Scope and applicability

1.1 Background

This report has been prepared in accordance with the scope of work/services as agreed with Venture Southland. It is designed to support the work of Wood Energy South, promoting the development of successful wood-fuelled heating projects.

1.2 Scope (coverage and exclusions)

Coverage

Biomass heat projects can offer very significant rewards, but also involve a number of technical and contractual challenges that have not always been well-understood. Biomass heat projects also commonly involve a range of parties, and in some historical cases there have been misunderstandings between parties resulting in projects of sub-optimal performance.

This paper is intended to promote understanding of the issues that are commonly relevant to biomass (pellets, chips or hog fuel) fuelled heating projects in the 500kW to 10MW range, and proposed good-practice approaches to addressing these issues.

The paper will cover initial scoping and concept development, understanding of biomass fuels, refinement of project parameters, technical specification, commercial evaluation, and a very brief introduction to contracting approaches to project execution.

This paper discusses good practice for biomass heat projects. Such projects almost certainly include aspects which are either regulated (seismic design of structures, electrical codes, discharges to air/water, fire safety requirements plus others) or are the subject of other good-practice documentation. This guideline must not be considered in any way to relieve parties of either statutory or professional responsibilities for specific aspects of a biomass heat project.

Every project requires specific design; this paper covers design approaches and lists issues to be considered, however it is not possible to provide detailed design processes for the complete scope and variety of projects that could be considered.

Exclusions

“Wood fuelled industrial and commercial heating systems” could potentially cover a very wide range of fuels and plant types – and it is not possible for this paper to adequately cover all possible current and future combinations.

Issues and items that are NOT covered adequately by this paper are listed below. These fuels / plants / circumstances may offer very good project opportunities, but require a bespoke investigation by persons who are familiar with the specific issues involved. They cannot be adequately covered in a general-purpose paper. Specifically, the issues not addressed in this paper, and requiring specialist input, are:

- The growing and harvesting of biomass: Cases may occur in which biomass fuel is grown as a fuel crop by the heat-user, however the issues involved are silvicultural/horticultural and related to biomass harvesting and post-harvest processing. The skill sets and conditions are entirely different from those addressed in this paper.
- Post-harvest treatment of biomass might include chipping, sizing and removal of contaminants.
- Any other special treatment of biomass including drying. While even modest levels of biomass drying offer significant gains in calorific value, drying is considered to be outside the scope of this paper. Drying is generally carried out by the fuel vendor since significant volumes of stored (moist and dried) fuel are involved.
- Other fuels (e.g. harvesting residue from crops, wet sawdust) are sources of biomass fuel, but may require special materials handling and combustion provisions, and are generally not sufficiently common as to warrant treatment in this practice note.
- Municipal waste. Such waste is typically a combination of biomass (food waste, paper, cardboard, garden clippings, natural textiles) and fossil (plastics, rubber, synthetic textiles) components so could be considered as potential biomass fuel, but is not covered in this paper
- Biomass-derived fuels. Several biomass-derived fuels are known; these include (but are not limited to) torrefied pellets or chips, pyrolysis oil, low-CV gas and ethanol derived from enzymatic or other breakdown of cellulose. In some cases these derived fuels have significant advantages (e.g. torrefied biomass is non-hygroscopic and has a higher energy density) over more common forms of biomass. However, the production infrastructure for these fuels is not yet mature (and so supplies cannot be guaranteed) and in some cases the production technologies cannot be considered mature either.
- The development of experimental fuels or experimental plant: This note is only relevant for plant that has a proven record and can be purchased commercially and operated/maintained using skills, consumables and tools that are commonly available.
- For plant over 10MW thermal output, this note is not sufficiently detailed, and specialist input must be sought.
- For plant with thermal output less than 500kW, it may be preferable to purchase a packaged unit from a supplier, and work to the constraints of the available packaged unit (e.g. limits on fuel form, moisture etc.) – a leaner approach to overall project development may also be adopted
- For boilers generating steam at higher pressure than 10bar(g) and/or at temperature above saturation, this note is not sufficiently detailed and specialist input must be sought.
- Contractual aspects of cases in which multiple heat users are served by a single heat-supplier
- Cases in which biomass combustors are to be used to heat air directly, or to heat “Thermal oil” as a heat transfer fluid. These are specialist fields and not covered in this document.
- Cogeneration/tri-generation. The generation of electricity (or electricity plus refrigeration) from steam is possible, but this paper does not cover power generation plant, nor the evaluation of power generation or refrigeration projects.

1.3 Document structure and guide to usage

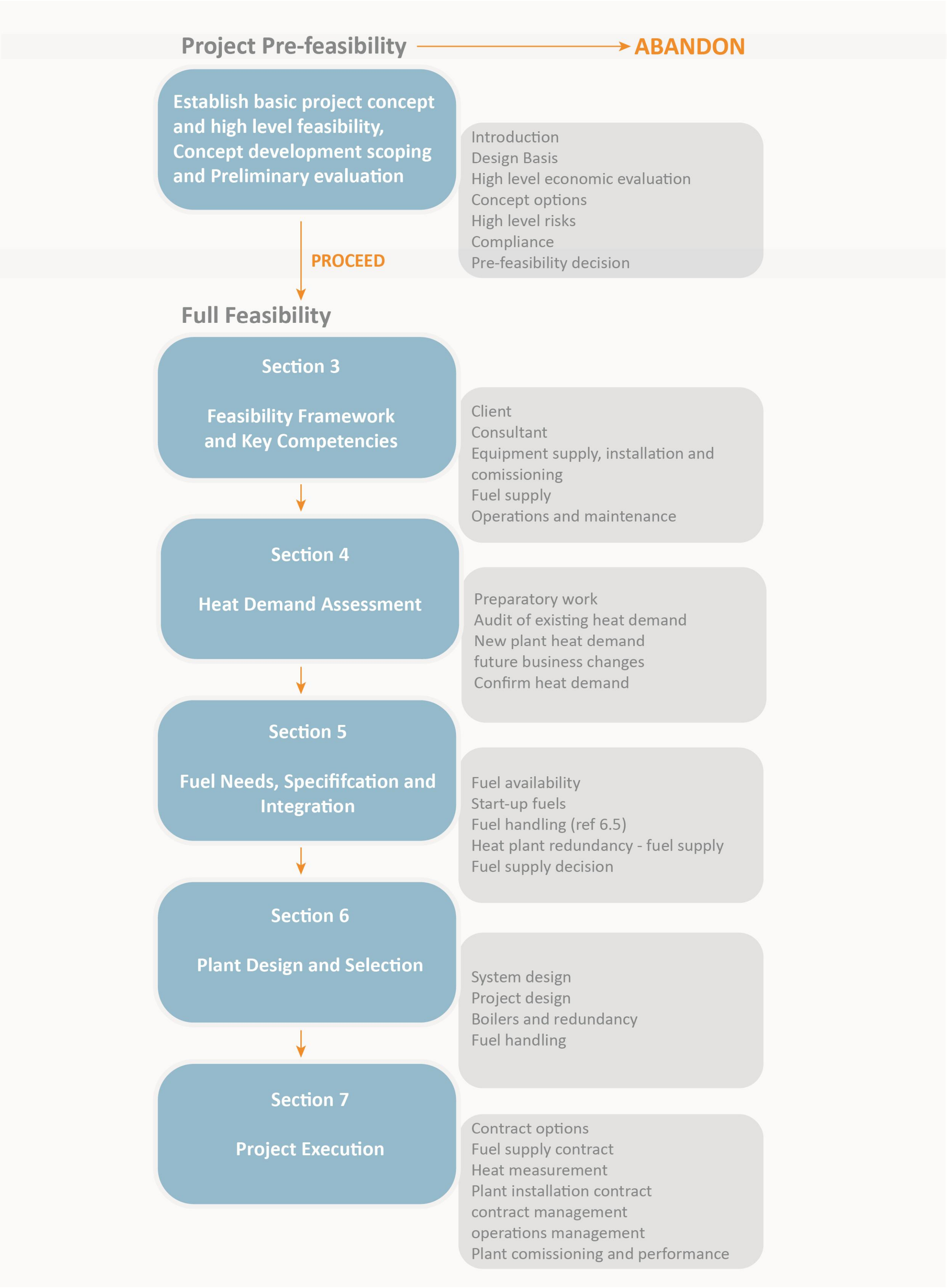


Figure 1: Document structure

This paper has four major parts:

- The first part (Section 1) sets out the scope of the paper
- The second part (Section 2) covers project concept development and preliminary evaluation: material covered in this section will allow the parties to determine whether the project is likely to be viable, and to determine critical project issues before proceeding further
- The third part (Sections 3, 4, 5, and 6) covers the detailed definition and final feasibility assessment of the project, and provide guidance and checklists to assist the Consultant to confirm project system design, and to specify plant requirements
- The fourth part (Section 7) briefly covers the issues to be addressed in the contracting of the project

The Concept and the Feasibility stages of biomass heating projects commonly involve some iteration of steps.

This paper should be considered in its entirety when a biomass project is proposed: for example, although fuel types are discussed in section 5.2, an appreciation of the fuel options and characteristics is also required during the “concept” stage.

Many (if not most) specific aspects of a biomass heating project (e.g. boiler design, combustion, contract management, control systems) are specialist fields in their own right: this paper does not cover specialist fields individually. The intention of this paper is to ensure that the Consultant/Specifier understands the issues to be specified/ achieved, and understands the skills and expertise areas required to achieve this.

Deficiencies in communication between the parties involved in biomass projects are a common source of difficulties: This paper proposed a number of documents that can be developed cooperatively and agreed-to by relevant parties – ensuring an improvement in mutual understanding of plant requirements and performance.

1.4 Who should use this document?

This document is intended primarily as a guide for the Consultant who is advising a Client regarding a proposed biomass fired heat plant, and wishes to ensure that the project is viable, and to carry out the system design and specification functions. This paper proposes checklists of issues to be addressed, and hence will assist a project champion to develop confidence in the viability of a designed project that is to be presented to the Client’s decision-making body.

The concepts covered in the document should be used as discussion topics between parties, and selected output documents should (as appropriate) be formally agreed to by interfacing parties.

1.5 Summary – paper scope

This paper considers the design and specification of medium-sized steam and hot water projects using common types of biomass fuel, and summarises contractual aspects of tendering/construction.

It is designed to assist Consultant/Specifiers, plus other parties, with the evaluation, high-level design, and tendering of such projects.

This paper is not intended as a detailed design guide, but does reference significant publications. It is expected that Consultants operating in this field will ensure that projects undertaken are within their competence and experience. It is also expected that Consultants operating in this field will be fully aware of statutory requirements.

2. Concept development, scoping and preliminary evaluation

2.1 Introduction

Establish business goals and essential aspects

Project concepts should be clarified at an early stage: the objectives of this early review and clarification are to establish:

- Business goals of the project, and codify non-negotiable requirements
- The scope of project (boundaries, and responsibilities beyond the boundaries)
- High-level project decisions (type of project, fuel, scope, etc.).
- The likely viability of the project, and the high-sensitivity issues

Ensure that only viable projects proceed to more detailed analysis

Early clarification of issues will ensure that projects carried-forward for more detailed analysis, have a high probability of viability. Early clarification of issues will also assist with preventing “scope creep”, and will ensure that focus on basic business requirements is maintained throughout the project.

2.2 Basis of design

A “basis of design” document should be prepared: This document should establish quite clearly the high level goals and the non-negotiable parameters of the project. As a minimum, the “basis of design” document should address:

- A clear statement of project purpose
- Critical business requirements – if heat supply is critical (e.g. if major costs or environmental effects will occur if there is an interruption), then there may be a need to assume dual boilers or redundant systems design. Such issues have major effect on project design and economics. Similarly, if there is a requirement for food-grade steam, or particularly tight temperature controls, or fast boiler response, these should be established and documented.
- Proposals for future business expansion, contraction, or change
- Project scope should be agreed:

  - "Terminal points" should be agreed – i.e. the physical and contractual points of interface, between the proposed wood-fired plant and other site infrastructure (existing or new) – power supply, steam/ hot water piping, pilot fuel supply piping, wood fuel transport vehicle access etc.
  - Specific work intended to be undertaken by client staff should be identified and clearly distinguished from work required of other parties.
  - Establish what permissions are required (planning, environmental, and known conditions such as noise, air-emission limits)
  - Services available to the project (i.e. made available by the Client)
- Specific times during which construction work can be done (e.g. a brief interval during an off-season)
- Non-negotiable constraints on fuel supplier or fuel type
- Specific Health, Safety and Environment issues

The "Basis of design" document should be signed off by a Client representative, who has sufficient authority and knowledge to do so. The "basis of design" document should be referenced as the project proceeds, to ensure that key project goals are achieved, or that re-evaluation takes place should it become clear that initial project goals are unachievable. Should the "basis of design" document itself need to be significantly changed in the course of the project, this should trigger a quite fundamental review of the project.

2.3 Initial economic evaluation

An initial economic evaluation is strongly recommended. A detailed evaluation is NOT required at this stage; what is needed is a sufficient indication of viability to justify the effort of a detailed project evaluation.

The initial economic evaluation will require an initial estimate of heat demand, noting that this will be an estimate only, and will lack the detail, rigour or contractual significance of the confirmed heat demand document described in section 4.

While boiler efficiency will need to be considered in much more detail later, a figure of 75% (on a fuel GCV basis) will probably be sufficiently accurate for this stage of the project, and will allow at least initial estimates of total fuel requirement to be made, and will allow discussion of fuel supply adequacy and security.

A "Whole of life" evaluation should be carried out to compare the existing or baseline approach with the proposed project (ensuring common project scopes).

The major cost components are likely to be:

- The cost of fuel (processed, quality-controlled, and delivered to site), expressed in NZD/GJ. If a fuel conversion project is contemplated, comparative fuel costs should be obtained.
- Cost of removal of old plant, if applicable
- Capital cost of installed plant (roadworks, civil and structural, boiler, balance-of-plant, fuel storage).
- Operating costs (other than fuel). These are likely to be primarily staff costs, maintenance and boiler survey-related costs.

Various approaches to cost estimating are used; a common approach is to itemise all major components, allocate estimated percentages of total project cost to each, and then build up a project cost by acquiring "budgetary costs" for key components and using the estimated percentages to assess other component costs. It is very important that all parties realise that full project cost estimates are generally not finalised until quite late in the project's development life: estimates made at the concept stage, commonly have uncertainty margins of up to ±50% and even at the stage when firm quotations are received, large uncertainty will still exist in regard to final, total project cost.

Different businesses and organisations may apply different approaches to preliminary financial assessment, ranging from calculation of a simple payback period to development of a more detailed discounted cash flow model.

It may be necessary to conduct the concept study before the initial economic evaluation, if multiple options for plant design appear equally feasible.

The initial economic evaluation should carefully check and document any assumptions. Much time and effort has been wasted in the past, because parties made “guesses” on key items such as fuel price or heat demand, and then later found these guesses to have been significantly in error.

2.4 Concept study

Assuming that the initial evaluation indicates a viable project, a concept study should be prepared. A concept study should start with the “basis of design” document. The concept development task can be undertaken within the Client organisation, or can be undertaken by a Consultant based on interviews and other data collected from the Client.

Establish project boundaries

The concept study should clarify and define the project boundaries, describing in detail the “terminal points” (sometimes called “battery limits”) where interfaces will exist between the proposed project and other parties/equipment. Each such terminal point should also identify the party “on the other side”, and the corresponding responsibilities.

Establish high-level parameters

- Establish very high level parameters (possibly with significant levels of uncertainty) such as heat demand (MWh/yr), fuel price ($/GJ), annual fuel requirements, allowable ranges of heat/water supply temperatures and minimum return temperatures.
- Document basic technical assumptions and high level plant performance (boiler efficiency, process fluid temperatures and pressures and flows).

Consider conceptual project options

Document (at a high level and with minimal detail) the broadest possible range of acceptable plant types or project approaches, investigate and document the key issues for each. The project conceptual approach may be very clear, but equally the need for further investigation may become apparent. Well-researched, high level investigation of options is almost guaranteed to be more cost effective than detailed effort on a single option without considering alternatives.

Each concept should have the same terminal points (overall scope), to ensure an equal basis of comparison. Care should be taken to ensure that the widest reasonable range of options/concepts is considered.

For biomass projects, it is common to need to make a decision between a higher-quality and higher cost fuel (e.g. pellets) with wide availability and low handling costs, and a lower quality, lower cost fuel with higher handling costs. Such basic considerations need to be investigated, documented and agreed at an early stage.

Establish that, within tolerance limits, a fuel supply that is adequate (in volume, specification and security of supply) for the project is available at the project location.

Consider changes arising from fuel conversion

Biomass fuel has a very significantly lower energy density than (for example) coal: Where a fuel conversion is considered, this will result in very much increased fuel delivery traffic, and will be likely to require increased storage volume on site. Conversely a lower volume of ash removal will be required.

2.5 Project risk review

A high level project risk review should be carried out, even at this early stage. Project risks should be identified; their probability and possible consequences documented, and possible mitigation approaches should also be documented.

The discipline of carrying out a project risk review will ensure that major “show stoppers” are not neglected as the project proceeds. As a minimum, the project risk review should identify and assess:

- Economic risks (e.g. “critical dependence on long term fuel price remaining below xx$/GJ” or “project is only viable if installed plant cost is below $yy” etc.)
- Technical risks and contractual risks (feasibility of an adequate long term fuel supply agreement).
- Regulatory risks (e.g. feasibility of obtaining resource consent within an acceptable time and on technically acceptable terms).
- Scheduling risks (long lead-time issues, seasonal demands).

The risk review need not be lengthy. The identification of risks allows attention to be focusses on critical items, and will minimise wasted effort in future.

2.6 Compliance requirements

Statutory requirements

All statutory requirements must be complied with. These should be identified, and are likely to include:

- Plant safety requirements (AS/NZS 1200:2000 Pressure equipment, and other national and international standards related to fired and unfired pressure equipment, PECPR, building code). Specific responsibility for identifying relevant codes must be clear.
- Safety of personnel engaged on the project (all phases).

Regionally dependent requirements

In addition to the above, some regionally specific requirements are likely to include:

- Environmental Impact Reports
- Resource consenting (construction, operation, noise, air-discharges, water discharge, fuel etc.)
- Seismic design requirements

2.7 Summary and prefeasibility decision

At the conclusion of the concept stage, the following documents should exist:

- **A basis of design document,**

- **A concept study,**
- **An initial economic evaluation,**
- **A list of regulatory requirements and**
- **A risk review document.**

None of these documents need be long or detailed. The important issue is the discipline of establishing base data, clarifying objectives, identifying major issues, and agreeing these with the Client organisation.

These documents should form that basis for a decision to either proceed to detailed design and specification of the project, or to abandon the project. Even if a project does not proceed, the results of this work should be retained: It is possible that the documents will reveal a trigger price (e.g. coal price exceeds $x/GJ) at which the project should be reactivated.

These documents should be accepted (signed) by the Client as forming the basis upon which the project can move to the next stage. As noted previously, none of these documents need be large or detailed, but the issues should be able to stand scrutiny or risk time wasted on subsequent stages.

3. Feasibility framework and project team

3.1 Introduction - what is covered in this section

Following the decision to proceed beyond concept phase with further project development, it is important that the Client and the Consultant/Specifier agree on a preferred project team structure. This structure can evolve as the project develops, but a clear starting position will enable orderly progression through more detailed project design and feasibility assessment.

This section notes the general responsibilities of parties to a biomass heat project. Commonly a Client may proceed with a project structure and division of responsibility very similar to that outlined in 3.2 through 3.6. Alternatively they may have a distinct preferred approach based on past experience with the implementation of similar projects, or based on skills available within their organisation. Practical considerations of availabilities of skill and time will contribute to decisions on the level and type of input that can be made by Client staff (permanent or contract) and Consultants.

Even if a Consultant is to carry out a large portion of the work, the Client cannot avoid significant effort, and significant responsibility for confirming project data.

3.2 Owner/Client

Responsibilities

- Establish and sign-off the “agreed heat demand” document (the Consultant will have only limited means to determine Client heat demand profile, unless specifically engaged for that scope). While portions of this task may be contracted, the Client must take a high level of responsibility for the outcomes, or risk the Consultant carrying out design work on an incorrect basis.

- Gain permissions such as resource consent (some aspects can be subcontracted, but Client input will be needed).

3.3 Consultant

The Consultant should be able to demonstrate:

- Resource levels (total staff and availability net of pre-existing commitments) that are adequate for the project. The Consultant should also be able to demonstrate contingency plans for unexpected loss of resources.
- Competence to carry out system design,
- Competence to determine plant types, plant configuration and parameters,
- Ability to ensure that plant configuration and parameters are practical and optimised within agreed performance parameters.
- Competence to develop purchasing specifications,
- Competence to ensure that solutions proposed by suppliers/constructors are practical.
- The ability to ensure that scope is clear and clearly understood by Client and suppliers.
- Experience to clarify project interfaces (terminal points for fuel delivery, for heat delivery, foundations, power, water, discharges.
- The ability to manage Consultant staff and maintain internal quality controls on outputs and to ensure that safe working practices are used at all times.
- Appropriate insurances.

Commonly, Consultants are engaged using the IPENZ/ACENZ “Short form conditions of contract for the engagement of consultants”, with or without additional clauses. Pro-forma versions of this document are available for download from the IPENZ website. Other conditions of engagement are also available and quite acceptable.
The Consultant’s engagement contract should list the project objectives, the specific tasks to be undertaken by the consultant, the inputs required for each task, the deliverables arising from each task, and include a detailed schedule of milestone dates and fee structure as a minimum.

3.4 Equipment suppliers, installers and commissioners

Depending on precise scope of contract developed, the equipment supplier(s) will be required to take responsibility for many of the following duties, and should be able to demonstrate their capability to do so:

- Carry out detailed system design.
- Select plant items (make and model).
- Carry out or subcontract foundation design and structural design.
- Mobilise staff and transport to achieve the safe and professional installation and commissioning of plant.
- On site assembly, installation and commissioning of plant.
- Troubleshoot plant (which may require parent company or specialist backup).
- Ensure/demonstrate that each item of plant and the assembled plant meets purchasing specification.

- Provide training, develop and supply adequate documentation.
- Provide agreed initial spares and consumables.

3.5 Fuel supplier

Depending on precise scope of the fuel supply contract developed, the fuel supplier will be required to take responsibility for the following duties, and should be able to demonstrate the capability to do so:

- Undertake commitment to make minimum and maximum quantities of fuel available within a specified term: Refer to section 5 of this document for additional information.
- Ensure that delivered fuel remains within defined specifications.
- Arrange sampling and testing to demonstrate fuel quality.
- Achieve defined delivery times (from the time of receipt of advice that fuel is required).
- Maintain agreed stockpiles to ensure continuity – or maintaining agreed alternative sources.
- Achieve “Certified supplier” status if required.
- Make available contract renewal options on an agreed basis.
- Accept penalties for contractual failures.

3.6 Operation and maintenance (O&M) staff

General

New plant will require effort and skills to operate and to maintain. Specific skills and resource levels for operation and maintenance should be determined at feasibility study stage. O&M costs can be a significant proportion of lifetime costs, and details of resource levels and costs should be clarified during the feasibility study stage

Issues

Client staff may or may not possess the skills necessary to operate and maintain the bioenergy plant. Additional training may- or may-not be feasible, and staff may- or may-not have time to undertake any additional duties. Using Client staff may allow better communication of priorities and control, but also incurs burdens of recruitment and retention, and of risk management.

The option of using a Long Term Service Agreement (LTSA) and/or O&M contract with a third party should at least be considered. If the supply of O&M capabilities is contracted, responsibility for sourcing skilled staff devolves to the O&M Contractor, and Client costs are more controllable.

Decision

At an early stage in the project considerations, the Client should reach a decision on the approach to resourcing O&M requirements

3.7 Summary - checklist - got the right team?

- **The preferred allocation of responsibilities and sources of expertise should be documented.**

- **A basic assessment of resources required by each party should be documented.**
- **Note should be made of the evidence that each party has the skills and resources to carry out the assigned tasks.**

4. Confirming heat demand

4.1 Introduction: coverage of this section

A preliminary assessment of heat demand will have been developed as part of the project concept development, but only in sufficient detail to give confidence in likely project economics. The magnitude and characteristics of the proposed heat demand must now be defined in detail as an authoritative basis for the design of the biomass fuelled plant. Failure to accurately clarify the patterns and quanta of heat demand is one of the more common causes of biomass project problems.

This section describes good practice with regards to heat demand confirmation, and issues for consideration.

4.2 Detailed heat requirement

4.2.1 Preparatory work

If existing heat-using plant is poorly maintained or has obvious energy-wasting faults, these should be corrected before the project heat demand is assessed. Failure to correct pre-existing faults first will not only waste everyone's time, but may result in an oversized heat-generating plant and ongoing economic loss.

Poorly insulated pipework, leaking valves and steam traps, inadequate fan and vent controls etc. should be fixed before any further work is done to characterise energy demand.

Careful consideration should also be given to the possibility of revising the design, configuration and operation of existing Client's plant. It may be possible to reduce the size of a new boiler (or even avoid the need for one) if significant energy savings can be made at the site.

4.2.2 Audit of existing heat demand

Once maintenance and system improvements are complete, an energy audit of existing plant should be carried out, preferably to the standard of the latest edition of AS/NZS 3598.2 (2000) "Energy audits – Industrial and related activities".

4.2.3 Characterisation of new client heat demand

For the situation where heat load does not currently exist (i.e. new heat-using plant is planned), an energy audit is impossible, however the future heat demand must be characterised carefully and at the same level of scope and detail as for an existing heat load. This is likely to be possibly by using data from the designers of the new plant, or from the performance of similar plant installed elsewhere. Suitable margins of tolerance should be applied.

4.2.4 Assessment of proposed business changes

Proposals (including scope, and timing, and contingencies) for business expansion, change, or retraction should have been established in the course of preparing the "basis of design" documents.

System design and plant selection is difficult when business changes are likely: a boiler selected for a future major load may not be capable of stable operation at a current load. There is no point in specifying a boiler plant for current load if the business intends to expand by 100% in the next few years (or conversely if it intends to downsize or move away from existing markets). Contingency options may also be required, in case planned changes to business do not materialise.

Options for changes to existing systems, that will "smooth" heat demand, should also be considered: Such options may be significantly less costly than design and selection of plant for a very "peaky" heat demand. Options may include operation of older boiler plant for peak loads, and/or the use of various heat storage options.

4.2.5 Confirm agreed project heat demand

Following investigation of above issues, an "agreed heat demand" description should be drawn up; this document should address:

- Absolute maximum project heat demand (note, if this demand only occurs over short periods and/or infrequently, then plant design options may allow this to be met without incurring the cost of an oversized boiler)
- The detailed pattern of demand (seasonal, weekly, diurnal, and any batch-mode fluctuations) that is expected: The variability of the heat demand will be a key consideration in the selection of the boiler and related equipment.
- Any business expansion provisions. Any heat project should include a careful consideration of likely future changes, whether expansions of contractions of plant, likely adoption of new processing technologies or retirement plant that will reach end-of life.
- Specific issues that will affect plant design, for example the possibility of periodic significant reduction in temperature of returning circulating water.
- Appropriate margins of uncertainty, based upon the quality of data available.

4.3 Summary: confirmed demand

The agreed heat demand document is key to the whole project; It must we well-founded (using audits that are carried out to an agreed standard or other reliable data), must address detailed usage patterns as well as maximum and minimum usages, and it must also take account of feasible improvements to existing processes, and planned expansions/contractions.

When the agreed heat demand document is completed, it should be signed-off by all relevant parties. This document then becomes a key contractual document, to be relied upon by all parties.

5. Confirming fuel needs and specification

5.1 Introduction

A preliminary assessment of fuel options and associated costs will have been undertaken as part of concept phase project assessment.

Based on the project's "agreed heat demand" and expected heat plant performance, reliable fuel needs must be established and agreed, and fuel options must be further investigated and evaluated, including assessment of fuel suppliers. This work will lead to the development of a fuel purchase contract.

This section discusses the characteristics of biomass fuels and notes key issues to be considered with regards to the project's fuel supply chain.

5.2 Biomass fuel types, and characteristics

Common biomass fuel types

The common wood fuel types considered by this paper include:

- Pellets
- Wood chips
- Hog fuel

Table 1: Typical fuel types

Other biomass fuel types

Many other biomass types exist (including purpose-grown fuel crops), horticulture residues etc. – These may be valuable, but it is not possible to cover all such options in this paper. Consideration of any fuel that is purpose grown or specific to a location should include consideration of the future risks of non-availability.

A number of biomass-derived fuels can also be considered: these include torrified biomass (pellets or chips), pyrolysis oils or low calorific value gas. Although these fuels have attractive characteristics, neither the production technology nor the markets for these fuel-derivatives can be considered to be mature.

Some biomass fuels such as algae with high oil content, or cellulose-derived ethanol are under intensive research, but production technology is not mature.

In cases where waste products from a business (e.g. horticulture) have negative cost (i.e. disposal costs) and the production is linked to the business heat demand, then these fuels obviously need consideration and may not need a contractual relationship between supplier and user.

Biomass fuel key issues for combustion plants

- **Energy content of fuels** can be expressed as gross or net calorific value (GCV, NCV) but for biomass fuels it is normal practice to quote GCV. Statements of fuel calorific value must nominate GCV or NCV (and normally GCV), must nominate units (normally kJ/kg or MJ/kg) and must nominate the fuel moisture content and the basis of the moisture content (dry or wet basis) and must nominate the fuel type specification.
- **Fuel moisture content.** Moisture content is the most significant determinant of biomass calorific value. Moisture content can be quoted on either dry basis or wet basis, and it must be quite clear which is being used. The basis of these assessments are defined (and conversion calculators supplied) on the EECA website, http://www.eecabusiness.govt.nz/wood-energy-resources/wet-dry-basis-converter.
- **Standard fuel specifications** exist and should be used where possible, and in particular BANZ Technical Guide - Wood Fuel Classification Guidelines, Version 5 http://www.bioenergy.org.nz/resources.asp#technical_guides). These specifications include limits to dimensions. It is possible that fuel which does not conform to a standard BANZ specification will be available/offered, in which case the purchaser must determine what maximum dimensions and also minimum dimensions (or minimum percentages below stated dimensions) will be offered, and what range of moisture contents, GCV etc. can be offered.
- **Fuel contaminants.** Contaminants can potentially include Copper-Chrome-Arsenic (CCA), Boron-based or other preservatives, mud (silica-bearing mud originating from NZ’s volcanic plateau is a particular issue), grit, rocks, bolts that have fallen off transport vehicles, other bits of metal (bicycle frames have been known), wiring or gypsum association with demolition timber and almost every other type of miscellaneous rubbish.
- **Mechanical effects of contaminants**. Items like wire and rope are a particular problem as they tend to bring conveyors to a halt, and are difficult to remove. All fuel hoppers should have some sort of coarse screen if possible, to prevent major items getting into conveyors.
- **Combustion effects of contaminants.** Each non-combustible component (whether ash or contaminant) will have a characteristic slag softening temperature. If non-combustible material contacts a boiler surface while the non-combustible material is above its softening temp, it will stick and will present a removal problem. Combinations of non-combustible material can dramatically reduce the gross slag softening temperature (timber preservation chemicals, for example, have this effect on silica).
- **Materials handling requirements.** Different fuels necessitate different handling approaches. Pellets are relatively free flowing and can be discharged from conical bottom silos, whereas more fibrous biomass fuels may resist flow and require “live bottom” discharge systems – refer to section 6.6 for further discussion of fuel handling considerations.

Biomass fuel testing methods

The as-delivered moisture content of biomass fuel can be established accurately by using a laboratory oven to determine bone-dry weight and moisture loss, or with somewhat lesser accuracy using handheld instruments or using inline infrared measurements.

Calorific value can be measured using a calorimeter, in an appropriately certified laboratory.

Ash softening tests and fusion temperatures can be established in an appropriate laboratory

Ash content can be chemically analysed in an appropriate laboratory

“Combustion test rigs” exist in New Zealand and offshore, and it is possible to arrange for a realistic test of the combustion properties of a poorly characterised biomass fuel: this is an excellent approach if the fuel sample that is tested is a truly representative sample of the fuel to be used – and conversely this approach is a total waste of time and money if the tested fuel sample is not representative!

Biomass testing arrangements

Fuel properties should always be quoted with reference to the point of transfer of ownership, since Clients need assurance of the quality and quantity of biomass fuel, at the point of change of ownership.

For a tightly-specified fuel such as pellets, the Client may consider that the factory quality control measures (production, storage and packaging) are adequate, and may reasonably purchase such fuels on a weight-only basis (but making sure that there is no moisture ingress between factory and plant).

For less tightly specified fuels (e.g. hog fuel or chips), a quality control plan should be established prior to commitment to a fuel supply agreement, and should include a review of fuel suppliers’ operation including fuel sources, pre-treatment, size control, storage (prevention of ingress of moisture, contaminants etc.), blending and dispatch. The quality control plan should also address:

- Sampling method (ensuring samples are fully representative of fuel at the point of change of ownership.
- Sampling frequency (ensuring fuel consistency across loads and across seasons)
- Sample testing and reporting

Such a plan should give due consideration to the observed homogeneity and consistency of the proposed fuel, and the resources at the disposal of the project owner’s organisation

BANZ Technical Guide 5 - Standard Methods for Specifying and Verifying Wood Fuel Quality in New Zealand (http://www.bioenergy.org.nz/resources.asp#technical_guides), should be used wherever applicable.

5.3 Biomass fuel supply investigation

Plant fuel supply

Low cost fuel supply ($/GJ on a GCV basis) is a key enabler of bioenergy projects.

The Consultant/specifier should separately consider the range of possible fuel supplies available, and the likely range of fuel specifications that can be tolerated. Excessively tight specifications will almost certainly lead not only to high priced fuel, but also to a reduced number of alternative sources.

A due-diligence investigation of the fuel supplier is considered to be good practice, and should include consideration of possible alternative suppliers, financial stability of firm, and capability to perform all of the following fuel supplier roles, for the project duration. Reliability and security of supply for the lifetime of the heat plant is an issue of primary concern, and the capability of a fuel supplier to offer this reliability should be investigated thoroughly.

It is useful to note that BANZ’s wood fuel interest group, through the “UseWoodFuel” website, provide a “Wood Fuel Supplier Accreditation Scheme (WFSAS)”, which is designed to give purchasers confidence in the security of supply of biomass fuel.

Fuel supplier roles and capabilities

The fuel supplier's responsibilities will be specified in the fuel purchase agreement, but should include sourcing of "raw" fuel, fuel preparation, storage, insurance, quality control and delivery to the point of change-of-ownership, within the agreed quality specification. Delivered price should include all cost components up to the point of transfer of ownership.

5.4 Start-up fuels, co-firing fuels

Requirement

Biomass heat systems normally require a start-up fuel, which is generally either bottled gas or LPG (diesel or LFO can also be used).

Many biomass heat systems are able to use a secondary or co-fired fuel (which may be the start-up fuel) to either support low-load operation on biomass, to stabilise the boiler operation in cases where fuel parameters vary slightly, or to allow improved response-times for the boiler.

Arrangements must be made to supply and re-supply, and safely store start-up fuel. The consultant should make provision for these, pending confirmation by the boiler supplier of detailed requirements.

5.5 Summary - basic decisions re fuel supply

Fuel supply options and associated issues should be clarified in consultation between Consultant, Client and boiler supplier. Issues requiring clarification include:

- **Fuel quality (moisture content, measurement, variability - practical ranges, contaminants and effects) or standard specification**
- **Fuel purchase requirements: Supply conditions, responsibilities, contract term and renewals**
- **Fuel supplier – capabilities and experience**
- **Comparative good design practice requirements for (each type of) biomass handling systems**
- **Fuel combination options, fuel switching options and requirements for tolerance of changes to fuel characteristics**
- **Start-up fuel and supplementary fuels – purchase, storage, usage**

A clear decision on fuel type to be used, and on basic supply approach, should be reached at this stage, and should be incorporated into a Fuel Purchase Agreement (contract) and the boiler specification.

6. Plant design and selection

6.1 Introduction

Having confirmed heat demand and fuel supply preferences, a high level design of the complete plant can be carried out. This design should first be undertaken at a system level – i.e. analysing and refining detailed alternative project configurations (different component sizes, operating conditions, overall flow-sheets, operating philosophies), leading to a final design basis and Process Flow Diagram(s) for the project.

A system level design should be sufficient to enable a full feasibility assessment to be undertaken prior to further commitment to the project. This feasibility assessment should be based on refined inputs with significantly less uncertainty than the concept level economic evaluation. In particular heat demand and fuel pricing should be much more certain, and the finalised system design should enable accurate pricing for major equipment, construction materials and installation cost estimates. A positive full feasibility assessment should enable progression into project detailed design / specification, and subsequent execution.

After discussing system design and feasibility assessment, the remainder of this section serves to discuss detailed design considerations which remain relevant regardless of whether the Consultant is developing the detailed design themselves (apart from major equipment supplied by original equipment manufacturers – i.e. the boiler) or specifying plant functional and performance requirements for implementation by others.

6.2 Safety in design

All designs should include safety (both at construction and operation stages) as a non-negotiable requirement. In practice this is likely to require:

- Documented safe working practice document for the Consultant (including PPE, site escort arrangements and awareness of emergency procedures)
- A requirement for a detailed safe working document from the Contractor responsible for supply and installation of equipment, and particularly for commissioning and testing equipment
- Attention to the development of system designs that are intrinsically safe, and that have adequate safety measures (fire protection, alarms, automated shutdown conditions) incorporated into their design.
- Training program, signage and other provisions to ensure that Operation and Maintenance staff can operate the plant safely
- Documented safe practice document related to fuel deliveries (especially reversing and tipping trucks and other mobile machinery)

For larger plant consider more formal tools such as HAZOP or HAZID

6.3 System design

Depending on the project scope (Section 2) a system design is likely to be required.

A system level design refers to analysing and refining alternative project configurations (different component sizes, operating conditions, overall flow-sheets, and operating philosophies), leading to a final design basis and Process Flow Diagram(s) for the project.

A system design will optimise and define the rating and configuration/interconnection of major components, and will include an explanation of operational principles.

The system design will assume that the project heat demand has been characterised and agreed (and hence that options for smoothing the heat demand and for minimising net plant heat demand have been explored).

Confirmation of plant capacity and type

The heat demand profile, covering a representative period (which may be a year, month, week or day – but must be representative) should be tabulated (from the "agreed heat demand" document, and the operational status of each plant item noted for each separable section of the heat demand profile. This exercise will develop confidence that the plant can meet the load profile, and will also highlight the utilisation of plant items.

System design can be highly optimised, however generally the agreed heat demand profile will include a significant margin of uncertainty, as will plans for business change. It is essential that the selected plant and configuration can operate within these uncertainties – and this may preclude a highly optimised design.

System design is likely to be an iterative process
.

6.3.1 Reduction of heat load, options for system design

Heat recovery options

Options for heat recovery from heat plant (Client operations) should be considered: Wherever heat is discharged to the environment (hot air to atmosphere, hot water to drain) the options for heat recovery should be explored. A simple process-integration (Pinch) analysis will allow the practicality of options to be explored. As a guideline for pinch analysis work, a temperature differential (dT) of 10^{o}C for a liquid-to-liquid heat recovery system is generally practical, and a 20^{o}C dT for a gas-to-liquid system. Standard texts on heat exchanger design are available, and manufacturers in the process engineering field will be able to accurately predict the performance of specific units.

Recovery of heat from gas streams may result in gas streams dropping below the temperature at which condensation occurs (dew point). The layer of flue gas that is closest to a heat recovery surface may reach dew point even when the bulk gas temperature is significantly above dew point: Particularly in the case of finned-tube heat exchangers, the possibility of condensation close to the root of the fins should be considered, and a significant margin allowed between calculated dew point and calculated bulk gas temperature. If flue gas stream drops below dew point, the condensed vapour is likely to absorb other contaminants from the gas stream and the designer must consider the corrosion potential of the condensate. Flue gas streams arising from biomass combustion may (but should not) also contain combustible gases/tars, which will not necessarily deposit at the same temperature as water vapour.

Heat recovery from a flue gas stream is normally via a heat exchanger, in which the exchanger tube walls isolate the flue gas from the heated liquid. A direct contact approach to heat pickup is possible (i.e. using a wet scrubber) however the heat uptake in the liquid of wet scrubber plant is severely limited by the effect of evaporation from the water droplets, and the build-up of contaminants in the scrubber fluid requires careful design.

Heat demand levelling

Plant options for heat demand levelling include:

- Steam receivers – Only very limited capacity is possible, and this approach is seldom practical.

- Hot water tanks and particularly those designed for stratified temperatures can make a very significant contribution to load smoothing for hot water systems.
- Other passive heat storage options (eutectic materials, “Thermal Energy Storage”) should be at least considered, although these are likely to only have niche applications.
- Ice banks are not within the scope of this paper, but are in the category of load smoothing.
- The use of somewhat oversized boiler drums will smooth very temporary steam loads, but at a significant additional capital cost.

For very “peaky” loads, it will commonly be less expensive to use the above approaches than to meet the load profile with multiple boilers of graduated capacity.

Matching plant capacity selection to demand profile

Once heat recovery and load-levelling options have been explored, the number and rating of new heat plant can be confirmed and will need to address issues including:

- Lowest stable operating load for each boiler, and duration/frequency of this load
- Highest capacity for each boiler
- Difficulties of operating a boiler at no-load.
- Feasible rate of load change for boilers
- Practical capacity for any heat-load-smoothing plant

In addition to the possibility of simply selecting a boiler, these considerations may lead to a requirement for a boiler’s performance to be optimised.

If existing plant is to be incorporated into the completed project (e.g. use of existing boilers for peak loads), then this usage must be evaluated and documented.

6.3.2 Feasibility study - agreed project evaluation

Utilising the known heat demand, fuel pricing characteristics and the developed system design, further work should be undertaken to develop a final assessment of project viability.

Initial plant layout

Plant layout must consider:

- Fuel storage areas and loading/unloading arrangements
- Realistic plan areas of new boilers, taking account of minimum clearances for accessibility and maintenance, and minimum clearances to other plant.
- Constructability of plant (access for transporter and crane access diagrams)
- Realistic plan areas and locations for all other major plant items including fuel storage and conveying
- Flue gas clean-up plant, chimney, any heat recovery plant, and ash storage and disposal access.
- Boiler plant including pumps, deaerators, fuel supply conveyors
- Feedwater treatment and storage areas, including storage for feed-treatment chemicals, ion exchange etc. plant if required, and treated-water storage.
- Pipework corridors to Client plant
- Maintenance areas and staff amenities if required
- Access for emergency vehicles (fire, ambulance)

- Fuel delivery access – biomass, and also start-up fuel. Truck access and turning, tipping or conveyor discharge corridors

Performance review

With a process flow diagram, a realistic layout and a system design, the feasibility and performance of the complete system can be reviewed - it must be demonstrated that the plant capacities and configurations are both practical and appropriate.

Project Costing

Using Design Basis and System design data, budget quotations should be sought for probable/shortlisted suppliers for major plant and equipment (i.e. the boiler and materials handling plant), based on the agreed Project Team Structure and preliminary contracting strategy (further discussed in section 7).

Suppliers are usually willing to provide budget pricing in advance of tendering for a fixed price quotation, however the scope of such budgetary estimates should be considered carefully, and a suitable margin of uncertainty should be assumed, in advance of detailed specification.

Quantity estimates for balance of plant items (foundations, pipe racks, pipework) can be used in conjunction with local unit supply-and-install costs to complete the cost estimate. The project cost estimate should include allowances which reflect the way the project is likely to be delivered (e.g. EPC contractor margin as noted in section 7, development costs incurred by the Client). The estimate should be independently reviewed (by a Consultant and Client staff member independent of the project) to ensure no ‘material’ gaps.

Economic evaluation

AS/NZS 4536:1999 “Life cycle costing - An application guide” sets out the principles for life cycle costing: Life cycle costing can be generally described as a means to determine the most cost-effective option among project options, taking account of the full lifecycle of the project, including user costs.

Clients will likely have their own standard approach to capital project evaluation, which may be one of the methods outlined in AS/NZS 4536, or some variation thereof. It may already have applied for concept level assessment of the project. The feasibility phase economic evaluation is likely to expand upon the evaluation method / financial model developed at concept phase, consistent with the Client’s practices. Where the Client has no standardised approach, one of the methods outlined in AS/NZS 4536 may be adopted.

It is common for heat plant to have a nominal "design life", and it is recommended that an industry standard figure of 25 years is quoted. The client should however note that "design lifetime" has limited actual effect; most mechanical and electrical plant that is well-maintained will last a very long time, however critical control components may become obsolete after 15 years (spares become un-obtainable). Very few issues are likely to be closely tied to the nominal "design lifetime".

The process of system design, layout, costing and economic evaluation is inherently integrated, and is likely to be somewhat iterative in nature.

Environmental Impact Report.

For larger projects, and/or those for which regulatory assents are required, a separate “Environmental Impact Assessment" should be prepared, and should deal with issues such as traffic increase, impact on neighbourhood traffic safety/noise, emissions to air/water, solid residues disposal, required licenses and any other significant effects on environment generally or on neighbouring properties specifically.

6.3.3 Agreed documents: Feasibility study

The feasibility study report is designed to establish, with a high level of certainty, that all aspects of the project have been carefully considered, and that a feasible design for the whole project has been defined!

As such, the most important attribute of a feasibility study is its completeness and the realism of the design adopted, and the availability of sufficient detail to allow confirmation of performance and to allow tendering with confidence that suitable plant will be offered.

6.4 Project design

If detailed design is to be carried out by the Consultant, then the system design carried out in the course of the feasibility study should be expanded and translated into drawings of a quality suitable for construction.

If the detailed design is to be carried out by a Contractor, then a purchasing specification must be developed by the Consultant, based upon the basis of design document and the feasibility study.

Regardless of which of the above approaches is adopted, the items discussed below within this section remain valid.

6.4.1 Layout, access

Plant layout and layout context drawings are required: if detailed design is by Contractor, then available plant areas must be identified.

The layout should address not only all plant, but also pipe and services corridors, and fuel delivery access.

Temporary laydown areas for delivered plant items and temporary construction areas should be specified.

6.4.2 Civil and structural

Structural design criteria

All structures must be designed to appropriate national design codes and regional seismic loadings.

Specific issues

Specific guidance is available for some specific cases (e.g. IPENZ Practice note re seismic design for pressure vessels) for pressure vessels.

AS 4041-2006 Pressure piping should be considered, and ASME B31,1 is commonly used for pipework design, and allows confirmation of acceptable stresses arising from wind, seismic and thermal loads. Other approaches are possible, but the B31.1 code is very well established. Where statutory requirements exist, these must of course be followed.

6.4.3 Electrical

Supply points

Clients generally make power supply available to a single point for the project (a contractual terminal point). Details of circuit breakers and metering required at the terminal point should be specified. Responsibility for earthing should be nominated in the purchase specification, and agreed in the purchase contract. Supply voltage should be confirmed.

Local reticulation

Commonly, the Contractor will supply a distribution board to supply power to motor controllers (fans, pumps, conveyor motors) and arrange local wiring. The Consultant should also consider requiring the Contractor to supply an uninterruptible power supply to allow the control system to carry out a graceful shutdown in case of power supply failure.

6.4.4 Heat and mass balance diagrams

At least two complete heat and mass balance (HMB) diagrams should be prepared by the Consultant.

One HMB should correspond to the situation where the new boiler is operating at maximum continuous rating (MCR) and one should be completed for the situation where the new boiler is operating at the lowest stable firing load.

The system boundaries for the HMB should be clearly identified.

A reference atmospheric condition must be nominated - commonly 20ºC, 1.01325 b(a).

Heat and mass balances should be calculated and presented for the case where the boiler is operating at a stable load and has reached equilibrium conditions.

Both heat and mass balances should include a process flow diagram, and should include all mass and energy flows, in sufficient detail to demonstrate that all mass and energy flows balance, and do generate the heat outputs required.

These heat and mass balances should be signed as accepted by all parties: These documents are important means of ensuring that all parties are agreed on the expected basic performance and operational parameters.

The HMB’s should reference the fuel GCV and the fuel flows, assuming the same fuel properties as are used in the fuel supply agreement, and the same point of transfer of ownership.

6.5 Boilers

A great deal has been written about biomass combustion and boiler design. Both biomass combustion and boiler design are specialist topics in their own right. This paper does not set out to cover these issues in detail, merely to draw attention to the features that must be taken account of during the design of an efficient and reliable biomass heat project.

6.5.1 Biomass combustion

Biomass burns in quite a different way to many coals, and in three different (overlapping) stages:

- Firstly, moisture is driven off (for a high-moisture fuel, this step is very important and may require specific boiler design features.
- As the particles are dried, combustible volatiles are progressively driven off, and need to be well-mixed with correct proportions of over-fire air for good combustion: failure to design this aspect correctly will lead to the deposit of tars, and other volatiles on gas-side boiler surfaces
- Finally, carbon is burned out, primarily relying on under-fire air, and residual ash is discharged.

Biomass combustors require specialised design, which is normally the responsibility of the boiler suppliers. Biomass combustors can be generally characterised as:

- Pile burners. Biomass is either dropped onto a pile, or fed vertically upwards into a pile
- Inclined (static, vibrating or reciprocating grates) grates. Biomass is fed onto the top of an inclined grate and moves down the grate as it burns. If refractory surfaces are arranged above these grates, they are capable of handling high moisture-content fuel.
- Horizontal grates (moving chain grates, “vibrating” or “dumping” grates. Biomass is distributed by a feeder so that a relatively thin, even layer is maintained across the grate. This type of combustor is suitable for larger capacity units.
- Fluid beds. Biomass is fed into a shallow bed of inert material that is fluidised by a controlled upwards airflow. This type has somewhat higher parasitic energy use than other types, but is more tolerant of fuel specification changes.

This list is not exclusive: some manufacturers have well-developed proprietary designs. The Specifier will need to consider track record, ongoing service/spares support – as well as the capability to use the agreed fuel, when selecting a combustor type.

6.5.2 Boiler types, characteristics and selection

Boiler construction type.

Several types of boiler commonly fall within the scope of this paper, including:

- Shell and tube (fire tube) steam boilers. This construction is commonly used for smaller capacities and lower steam pressure. The boiler is constructed with an outer cylindrical pressure vessel (horizontal axis), with end plates. Horizontal tubes containing combustion the area and to carry flue gases pass between end plates. End covers direct flue gases along the “fire tubes”, and the water level is maintained somewhat below the top of the vessel to allow separation of saturated steam.
- Sectional HW heaters. Modular heating sections (for hot water), which enclose the combustion chamber, and ash removal systems.
- Water tube steam boilers, in which high pressure water and steam are carried in multiple tubes terminating in cylindrical pressure vessels “drums”. Many manufacturers offer similar designs, a typical design can be seen at http://www.babcock.com/products/Pages/Water-Tube-Package-Boilers.aspx. Fluid bed combustors may have water tubes within the bed.

Some boiler designs have the combustion chamber incorporated within an enclosure formed by heat transfer surfaces; less commonly, a separate refractory-lined combustion chamber is used, and flue gases are passed into the heat transfer portion of the boiler.

For an excellent introduction to boilers, see “Industrial Boilers and Heat Recovery Steam Generators: Design, Applications, and Calculations” by V. Ganapathy. CRC Press, 16/10/2002 - Technology & Engineering.

Steam or hot water

The selection of steam or hot water as the heating medium, and the selection of operating temperature and pressures, should be made on the basis of the heat plant requirement.

Factors to be established prior to boiler selection

- The boiler’s capability to burn the selected type of fuel: Note that boilers are generally designed to only burn fuel that is within a certain specification band (which may not be a wide band).
- Steam or hot water heating fluid (generally dictated by typical use, or by supplier of heat-use equipment)

- The detailed and signed-off heat demand profile
- The fuel type and specification
- The high level system design

Technical factors in boiler selection

- Any highly project-specific requirements (e.g. food-grade steam, site prohibitions on storage of particular chemicals, particularly stringent dust specifications)
- Boiler turndown, response times (and hence the boiler specification that is driven by the project system design requirements)
- Ability of the boiler design to cope with the type of fuel selected. Note: boilers are commonly designed for a relatively narrow fuel specification, and it cannot be assumed that a boiler (nor a fuel supply system) will be able to continue to operate properly if fuel type/specification change during the boiler's life. Security of supply of fuel within a given specification is important.
- Local availability of skilled operators for particular boiler types
- Local availability of service and repair facilities (including supply of consumables)
- Flue gas clean-up requirement to achieve required air emission standards
- Compatibility of control systems with other Client systems.

Economic factors in boiler selection (input to life cycle costing calculation) include the lifetime costs of:

- Primary fuel
- Start-up and support fuel
- Boiler thermal efficiency
- Boiler power consumption (fans, motors etc.)
- Consumables (water treatment)
- Operation and maintenance costs, including boiler surveys

Capacity ratings

Boiler capacity rating is commonly specified in terms of thermal output (e.g. “5 MW”), however more detailed definitions of output should be used in the design process.

The Consultant should note that, particularly in smaller sizes, boilers may only be available in nominated capacities – whereas in larger sizes designs are adjusted for specific output requirements.

Boiler peripherals: flue gas clean-up

Clean biomass is a low-ash fuel, commonly achieving ash figures close to 0.5% of fuel mass. Nevertheless, flue gas immediately post-combustion can contain entrained contaminants of several types, including oils/tars/unburned components, ash "flakes" (often in the form of thin white flakes), and entrained fine particulates.

In addition to responsible operation practices, flue gas clean-up must meet all local air quality requirements. Flue gas clean-up options include cyclone separators, plus either wet-scrubbers, baghouse or electrostatic precipitation. Cyclone separators are fitted to many boilers but their efficiency is less than the other options. For many cases, the high temperature baghouse with automated cleaning will meet air quality requirements.

Co-firing

Many coal-fired boilers can be adapted to burn small to moderate proportions of biomass fuel in conjunction with reduced coal fuel. The proportion of biomass that can be co-fired will be different for each make of boiler and limits could arise due to mechanical or combustion performance constraints – bespoke advice should be sought on co-firing limitations, particularly for intended higher biomass fractions. It is essential that biomass and coal are only mixed at the point where they are introduced to the combustion area, and that the fuel metering into the combustion zone is modified for the new flows and material types.

Boiler conversion to complete biomass firing

In some cases, boilers designed for coal firing have been able to be converted to biomass firing. Consultants should note that:

a) Only some boilers will be able to be converted, and only to some fuels
b) Case by case advise will generally be required
c) Contractual guarantees of performance or reliability are unlikely to be available

The most common conversion is from coal firing to wood pellet firing, and for this case the Consultant is referred to BANZ Technical Guide 2 - Guidelines for the Conversion of Solid Fuel Boilers from Coal to Wood Pellet Firing, Version 1 May 2010 (http://www.bioenergy.org.nz/resources.asp#technical_guides)

Conversions of larger plant are likely to be less straightforward than conversions of smaller plant.

6.5.3 Boiler performance

General

Although boiler technology is a complex field, for the purposes of a Client contract a boiler can be considered as a combustor linked to a simple heat exchanger with a gas/fuel side and a steam/water side: Air and fuel go in, ash and flue gases are exhausted: various energy inputs are provided, and heat is output.

For a hot water boiler the water flows are balanced - supply plus any blowdown flows being equal to return flows plus any makeup.

For steam boilers, it is common for some condensate (condensed steam) to be lost in the Client's plant, and hence makeup feedwater is required in addition to condensate return. A good level of mass balance must however be calculated. The gas/fuel balances should be balanced.

In larger plants, a great deal of effort is put into "guarantee testing". This can involve stringent codes such as ASME Power Test Code (ASME PTC 4.1-1964, reaffirmed 1973, also known as ANSI PTC 4.1-1974, reaffirmed 1985.), specially calibrated instruments, very tightly defined operational requirements, a careful calculation of the effect of errors, and uncertainties, and carefully defined criteria for acceptance. This level of effort may not be warranted for plants that are within the scope of this paper, however it is strongly recommended that the Client arranges for a test to be carried out at the full design heat load, and ensures that this is demonstrated and witnessed immediately before the completion of the project, and linked to payment terms.

Heat and mass balance

As noted in section 6.4.4, heat and mass balance (HMB) diagrams should be prepared for the project. While a heat and mass balance (HMB) may require some effort calculate, such balances are conceptually quite simple:

Heat inputs (against a nominated reference condition) are generally:

- The combustion air (this may be a negative input)
- The main (biomass) fuel energy input (GCV and flowrate)
- Any secondary fuel energy input (GCV and flowrate)
- The total electrical power input (This may be small, but should not be neglected: fans pumps, etc.)
- The feedwater energy (enthalpy)

Heat outputs are generally

- The flue gas (flow, temperature and composition (are important - the flue gas will contain significant water vapour)
- The miscellaneous heat losses from the boiler - radiative and convective – typically about 1.5%
- The useful energy output (steam or supplied hot water)
- Any blowdown (steam boilers)

Mass inputs to the gas-side of the boiler are fuel and air: Mass outputs are flue gas and any ash.

Mass input to the working fluid side are feedwater, return water and makeup water. Outputs are steam, blowdown and/or supplied hot water.

Optimisation of boiler performance

The vast majority of the heat losses from a boiler are in the form of the flue gas losses, and these losses are primarily determined by two factors: the total gas flow and the temperature of the gas leaving the boiler. Since the losses are determined by gas flow and temperature, the primary approaches to improving boiler efficiency are reducing the airflow and reducing the exit temperature. EECA literature on boiler performance optimisation should be consulted. Completeness of combustion (ensuring that tars and carbon are all combusted) is important but is generally a secondary factor in determining boiler efficiency.

Fuel moisture content has a major effect on the operation and performance of a biomass-fired boiler: as a first approximation, most biomass has a similar bone-dry-basis GCV. The GCV of wet fuel can (as a first approximation) be estimated by subtracting from the bone-dry calorific value, the energy required to evaporate the water plus the temperature rise in the water vapour. As well as affecting the heat available from the fuel, the moisture content also affects the process of combustion: the water in the fuel must be substantially evaporated before the temperature of the biomass raises enough to allow the combustion to commence - a high moisture content requires a longer fuel residence time in the pre-combustion zone.

Boilers designed to burn low-moisture-content biomass may be able to be tuned for airflow of about 15% above stoichiometric (figure will vary between manufacturers), while boilers intended for biomass with high moisture content may require larger values: Such "tuning" is generally achieved by measuring the CO_2 percentage in the flue gases and adjusting the boiler management control system.

Operation at rated load

Boilers are designed for optimum operation with a specific fuel and at a specific load (which is commonly, though not always) their Maximum Continuous Rating. Achieving identical efficiencies across wide operating ranges is often a severe design challenge.

Operation at maximum turndown

Boilers will generally be specified to have a maximum turndown, or minimum controllable load.

Many boilers are not capable of operating in a stable mode below about 40% of MCR. This value is indicative and will vary with boiler make.

Below the minimum load, a specific boiler may:

- Fail to achieve design temperatures/pressures for working fluid
- Require secondary fuel to stabilise combustion
- Incur significant penalties in efficiency
- Risk condensation-related problems in the cold-end gas path.

No-load operation

For some boilers it may be possible to “box up” – i.e. maintain the boiler at design temperature/pressure but with no output, for short periods.

Response to load changes

Boilers have very significant thermal inertia; they require significant time to start from cold, they do not “follow” rapidly changing loads easily, and they require a significant period to shut down. These issues need to be considered carefully in the context of system design.

A common issue with industrial steam boilers arises when a sudden and large increase of steam demand occurs (major steam-consuming plant brought online quickly). In such cases the pressure in the boiler can drop, allowing saturated liquid to flash, and cause a rapid rise in drum water level. At worst this can actually allow water to enter the steam discharge lines. This is known as "priming", and is highly undesirable.

Boiler storage – off-season

A seasonal industry may have no heat demand for some periods of the year. It is possible that alternative uses for off-season heat can be found (allowing utilisation factors for boiler equipment to be improved), but such issues are beyond the scope of this note. For smaller boilers, explicit recommendations for storage should be obtained at the time of purchase, these commonly involve completely filling the boiler (steam/water side) with water to which Oxygen scavenger has been added, and including moisture scavenging material with or without low-level space heating for the closed-off gas-side.

Boiler inspection and maintenance

Boilers must (by regulation, as well as good practice) be inspected regularly. The nature and frequency of statutory inspections must be clarified at the time of purchase, and communicated clearly to the Client (who bears responsibility for ensuring that inspections take place. Inspections should include review of:

- Evidence of corrosion or adhesive deposits (slag) in the region of the grate. Non-combustible rubbish that has not been removed by ash system (nails, wire, etc.)
- Evidence of erosion of fuel feed components
- Breakages of components or missing parts
- Evidence of tar deposits on gas-side surfaces and particularly in the cold end of the boiler
- Water-side deposits indicating inadequate water treatment (if increased flue gas temperature has been observed, water side deposits are a likely cause). Sludge in lower regions of water spaces.

- Evidence of water-side corrosion. Three forms are common: cavities, cracks and/or generalised corrosion. These are likely to have separately identifiable causes; a water treatment specialist should be able to diagnose the problem.
- Evidence of water/steam leaks
- Evidence of water ingress to insulation, and “Corrosion Under Insulation”
- Breakages of steam drum furniture in steam boilers.
- Leaks from high pressure hot water systems
- Eroded valve seats
- Leaking steam traps, valve stem seals etc.

6.6 Fuel handling

Hog and chip fuels and other biomass fuels with irregular shapes are characterised by very high repose angles and a tendency to "bridge". Two common examples of fuel handling difficulties are noted for illustration purposes:

- A cylindrical silo (vertical, about 5m diameter) was commonly found to fail to deliver chips to the base conveyor - the chips formed a hemispherical arch starting close to the point where the cylindrical silo had transitioned to the conical base - the "arch" was quite stable, and required significant "percussive maintenance" to break.
- A drag-chain conveyor running along the floor of a bin failed to deliver chips - the chip fuel had developed a semi-cylindrical "rat hole" over the drag-chain: the common remedy (pushing a pry-bar through the fuel and into the draglink conveyor) presented a major safety risk and was unacceptable.

Material handling approaches that can reliably feed hog, chip, bark and similar fuels require careful design, and generally involve combinations of:

- "Moving floor" "walking floor", "live bottom" or similar types of mechanisms under fuel piles
- Conically rotating screw at conical silo base
- Large diameter screw conveyors with pitch that increases along the direction of travel
- Open, multiple-screw conveyors (silo bases)
- Efforts to reduce depth of pile and reduce tendency to "pack down".

Pneumatic conveying is effective and reliable, but operating costs (fans) are comparatively high, and airstream clean-up is required to avoid discharging particulate material.

Many conveyor types, including belt, drag-chain, screw, en-masse, and pneumatic conveyors are capable of moving biomass effectively; the most difficult aspect is reliably getting fuel onto such conveyors.

Pellets. Because of their regular dimensions and granular nature, pellets are comparatively very easy to move. Screw conveyors (augers) are commonly used, and pellets will self-discharge from conical-bottom silos. Pellets will mechanically degrade with each handling however, and hence it is recommended that they not be moved more than twice, following delivery. Provision must be made for cleaning up dust arising from pellet handling, as this can become a fire hazard. Pellets will degrade dramatically if wetted.

Water ingress to fuel storage and fuel handling facilities must be prevented.

6.6.1 Fuel reception/treatment

If fuel is generated on the same site as the proposed biomass heat project, then conveying, storage/reclaim and final conveying systems are required.

For fuel that is sourced off-site (the more common case) delivery will normally be by truck (dedicated chip transporter, or modified container, or open-top tray). The discharge mechanism may be either tipping trailer/body/container, self-discharging auger.

Components of the fuel reception and primary treatment system are likely to include:

- Access road (with adequate consideration of turning circles, traffic flow and road design capacity
- Access control (gate/card) system if required
- Pellets are commonly conveyed by auger to the top of a hopper, and auger discharge from hopper base is generally considered satisfactory.
- Chips and hog fuel are more commonly discharged onto a pad (at or below ground level). In either case it is essential that rain/runoff water is prevented from getting into the fuel.
- Reclaiming chip or hog fuel from the pad is (perhaps surprisingly) one of the more difficult design issues in a biomass heat project, and this design aspect should not be underestimated. Hog and chip fuel are prone to bridging and a reliable feed mechanism may require such options as a shaft-driven multiple drag-chain conveyor covering most of the pad surface. Having reclaimed fuel from the pad, a simple drag chain, screw or en-masse type conveyor may be adequate to lift biomass to the position from which it can be fed into the boiler combustion zone.
- If fuel is tipped from a truck, a very coarse primary screen should be considered, however careful design is required in order to prevent such a screen from bridging

Designers should provide a means of evacuating a hopper if a load is found to be contaminated or otherwise unsatisfactory. This is likely to involve the normal fuel reclaim method, and a means for diverting fuel from the boiler to a holding location or emergency offloading site.

6.6.2 Fuel handling

Fuel handling systems must take account of factors including:

- The severe tendency for hog and chip fuels to “bridge” and to bind together
- The necessity to exclude water (rain, runoff)
- Importance of avoiding mechanical damage to pellets from handling – and the associated danger of accumulating highly flammable dust arising from such damage). Pellets should not be handled more than twice between truck discharge and combustion, if at all possible.
- The need to vary speed to align fuel supply with boiler demand. This may require very low-speed operation. There may be a need to record flow speed at regular intervals
- The ability to monitor hopper/storage pad level and to re-order fuel when required.
- Fire detection systems and associated fire alarms and fire suppression systems
- Alarms to indicate failure of fuel feeding systems

6.6.3 Safety issues associated with fuel

An indirect consequence of poor materials handling plant design could be the requirement for manual operator intervention (e.g. to promote stockpile or silo flow) which could involve hazardous practices. Aside from such scenarios, biomass heat projects include several hazards specific to the fuel & fuel handling. Identification and mitigation/elimination of hazards must receive careful attention. Significant hazards include:

- Slow moving fuel feed equipment (e.g. drag chains) are commonly driven by high-torque gearboxes - slow speeds can generate a (false) perception of low danger.
- Fire hazard generally. As well as common ignition sources, specific issues can include (rarely) spontaneous combustion in long term hog storage, or the possibility of primary or secondary explosions/deflagrations associated with dust arising from pellet disintegration.
- Hot surfaces and discharge of hot liquid from steam vents and traps.
- Electrical hazards.
- Secondary (usually gaseous) fuel hazards – possible development of explosive atmospheres

6.7 Balance of plant

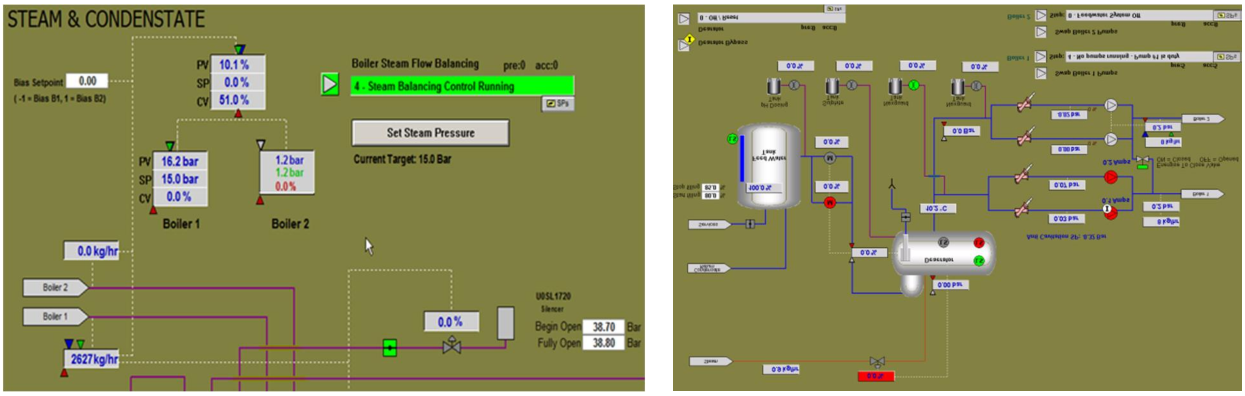
"Balance of plant" generally refers to all plant other than major items (e.g. boilers).

The Client should consider whether to specify makes and types of small plant such as electric motors, in order to reduce the scope of spares held across the Client site.

6.7.1 Control

The Boiler Management System is generally supplied by the boiler manufacturer. The specifier should ensure that the control system inputs and outputs are of compatible type to the Client's plant, and should ensure that basic heat plant information is both displayed locally to the boiler and can be accessed remotely as required by the client. The information should include stack temperature, stoker operation, key temperatures, pressures and flows and essential alarms. Logging of key information is generally considered to be good practice, however for very small project, local indications and logging of aggregated quantities may be considered sufficient.

Table 2: Common boiler control panel elements



6.7.2 Water

Feed water for either hot water or steam boilers must be treated in order to avoid either deposition of solids in the boiler, or corrosion of the boiler surfaces.

Water treatment should be recommended by the boiler supplier, however in rare cases (e.g. where working fluid could contact sensitive products) the Client may impose restrictions on the types of water treatment that is acceptable.

A standard specification for boiler water quality should be quoted: BS 2486:1997 "Recommendations for treatment of water for steam boilers and water heaters" is commonly quoted.

Raw water treatment will commonly include filtration, hardness reduction, ion exchange the addition of corrosion inhibitor chemicals, and storage of treated water. The plant design must make provision for storage of chemicals, any mixing or other maintenance operations, and for disposal of regeneration waste if required.

6.7.3 Emissions and discharges

Ash from the combustion zone must be discharged to a collection point: responsibility for the design of this process normally lies with the boiler supplier.

Liquid waste (common sources including steam boiler blowdown, water treatment plant waste) must be stored safely.

Bunding and related safety provisions (e.g. eyewash) must be provided for stored chemicals (e.g. water treatment plant chemicals)

Flue gas clean-up requirements must be determined by consented air emission requirements and predicted boiler particulate emission characteristics. Options include:

- High temperature baghouse filters. Filter bags (“socks”) are supported on frames, and flue gas particles are collected on the outside of the bag. Automatic cleaning mechanisms are available. Baghouse filters are capable of withstanding normal flue gas temperatures, however the specifier must confirm acceptable temperature ranges, and consider alarms to indicate exceedances. Baghouse filters are capable of very high levels of particulate removal, and since this performance is well-characterised, they are attractive for the Specifier who needs to meet a specific particulate emission criterion. Collected particulates are dry and simple to discharge. Principles and performance are presented in trades literature and online sources.
- Wet scrubbers. Water is sprayed into a chamber where flue gas moves upwards: particles and water-soluble contaminants are captured on/in the water droplets and water is removed at the base. Trades literature and online sources set out design principles for this type of equipment. Wet scrubbers are effective, however significant design effort is required if a specific level of performance is to be achieved, and treatment processes are needed to deal with the contaminated water that is generated. Since the water is in direct contact with hot flue gases, it is possible to recovery heat from a wet-scrubber, however the available recovery is small (limited by evaporation from sprayed water) and the potential for fouling of heat exchange surfaces (due to contaminants in the water) must be considered.
- Electrostatic precipitators (ESP’s) impart a high voltage onto particles, and collect these against oppositely-charged plates. They can be designed for relatively high flue gas temperatures and can be offered in large capacities.
- Simple cyclone (or multi-cyclone) separators on the back end of boiler are commonly provided but may not be able to meet the required air emission standards.

A good overview of this topic is presented in “Particulate Matter Emissions-Control Options for Wood Boiler Systems”. Produce by the Biomass Energy resource Center (BErC), Madison, Wisconsin. (http://www.biomasscenter.org/images/stories/PM_Emissions_electronic.pdf).

The specifier must make provision for the collection, storage and removal from site, of all waste collected as above.

6.7.4 Fluid handling

The fluid handling scope could include:

- Fans (particularly any not directly associated with the boiler)
- Ductwork and insulation
- Pipework, fittings and insulation and cladding
- Pumps, including circulation pumps
- Hot water storage tanks (including design for temperature stratification)

Significant design considerations include

- Tank design (including design for utilisation of temperature strata) and support requirements (including seismic design)
- Minimum and maximum fluid velocities in ducts and pipework
- Access corridors for inspection and maintenance of pipes/ducts
- Heat losses and insulation (including weatherproofing of insulation) for pipework.
- Expansion provisions for pipework, including design (e.g. to ASME B31.1) of guides, restraints and supports, and the calculation of maximum stresses.
- Support steelwork if required
- Ducts, trenches and conduits if required.

6.7.5 Other plant

Other plant requiring either design or specification is likely to include

- Buildings (for boiler, and related plant, for maintenance and O&M staff)
- Chimney/stack – interacts with air quality modelling which may be required for compliance with existing or modified environmental permits
- Conveyors
- Air compressors if required
- Fire detection and suppression systems
- Lighting
- HVAC equipment

6.8 Summary - checklist of completed docs

At the completion of this phase, the configuration of the project, the capacities and operating modes of all main plant and balance of plant items should be clear and documented. These should include:

- **Confirmed heat demand**
- **Confirmed fuel needs and plans**
- **A feasibility study including a robust and agreed system design, plus PFD and description of operation, and also feasible plans for project layout, civil/structural requirements, electrical and service supply information**
- **An Environmental Impact Assessment, if required**
- **Project design information covering capacities/types of boiler, fuel handling, and balance of plant**

7. Project execution - getting the job done!

7.1 Introduction: coverage of this section

In the previous section (Sections 3 – 6) the design of the project has been considered. At the conclusion of those sections the design aspects have been clarified. At the conclusion of previous sections, either a detailed design, or a specification for detailed design by others, has been developed.

This section considers (briefly) the process of actually contracting the project and bringing it to completion.

This paper has touched on many fields that are the subject of very detailed publications in their own right, and contracting is another such. This Section is not intended to substitute for the significant literature on the topic (including local documents such as BANZ Technical Guide 4 - Tender Guidelines Dec 2011 (http://www.bioenergy.org.nz/resources.asp#technical_guides), but is intended to set out the breadth of options and basic criteria for selection of approach. It is also intended to set out some of the issues commonly encountered during the contracting of biomass heating projects.

7.2 Contracting options

Even for small installations, a range of approaches to contracting should be considered. Contracting approaches can be generally categorised in terms of:

- Which party is responsible for finance capital, and how that party gets the return on their capital,
- Which party is responsible for detailed design, construction, commissioning and testing
- Which party is responsible for resolving technical problems, and
- Which party is responsible for ongoing operation and maintenance?

As with all contracting arrangements, good faith, good communication, and transparency are the keys to success, however parties' priorities must be carefully considered: The loss of steam for a day may have only marginal economic impact on a party whose only responsibility is to sell steam - the loss of steam for a day may have vastly greater consequences for a greenhouse owner whose heating fails during a snowstorm at a critical time for plant fruit setting! These issues need to be carefully considered when forming energy supply and purchase contracts.

Parties involved in the contracting can include: The boiler supplier, the installer, the suppliers of "balance of plant", the fuel supplier, the heat-client, design consultant, specialist consultants (environmental, fuel quality testing etc.).

Common approaches to contracting include:

- EPC (Engineer, Procure, Construct) approach. Acting on the recommendation of the Consultant, the Client lets a single contract for design, supply, installation, commissioning and handover of the complete plant. The Contractor accepts the engineering risk, and all the client needs to do is pay the invoices. The Client contracts separately for the fuel supply, and commonly obtains permits (which may require contracting an environmental consultant). Following handover (which should include spares, and a training package), the Client is responsible for operation and maintenance. Some care is needed to cover earthworks and geotechnical aspects, and road access issues. This approach is common and well proven, however the Client does pay for the Contractor's design efforts and for the main Contractor's management of all subcontracts. The client also loses some control over the design work and may need to review issues (for example, if the main contractor is a Boiler supplier, and the design of subcontracted fuel design causes concern)
- EPCM (Engineering, Procurement and Construction Management) approach. Consultant, under Client’s direction, carries out system design work, specifies and lets separate contracts for all supplied items and installation work. The same work needs to be done as in an EPC approach; if the Client/Consultant has skilled resources available and is willing to address technical risks, the contracted costs can be reduced however technical risk reverts to the Client/Consultant. As for EPC, the Client contracts separately for the fuel supply.
- Heat supply contracts. In this type, a commercial entity will finance, design, supply, install commission and operate the plant, and contract for fuel supply. The contract with the Client will simply be for supply of heat. Such an approach is very simple for the Client, but the other party will need to be sure that they can make a return on their investment (after covering capital, fuel, operation and maintenance costs) and the Client will need to ensure that their priorities (security of supply) align contractually with the heat supply contract.
- Other approaches. A range of other contracting models (e.g. BOT (build–operate–transfer), BOOT (build–own–operate–transfer), BOO (build–own–operate), BLT (build–lease–transfer), DBO (design-build-operate), DBOO (design-build-own-operate), DBFO (design–build–finance–operate), DBOT (design–build–operate–transfer), DCMF (design–construct–manage–finance) are possible. Some of these designations are only subtly different from others, and some specifics are only applicable to particular projects. Generally these approaches are considered for larger projects and are beyond the scope of this paper however it is valuable to consider whether local situations allow innovative approaches to project financing and control.

7.3 Responsibilities

In the case of EPC or EPCM type construction contracts, the Consultant is responsible for the preparation of tendering specifications, the evaluation of bids and the recommendation to purchase. The actual parties to the contract are however, always the Client and the Contractor, and so the Client must carefully review the recommendation to purchase and confirm suitability before signing.

The Consultant should carefully consider whether to carry out the tender process in two stages, with an initial “request for expression of interest”, leading to the prequalification of a short list of tenderers, followed by the tender process. For projects of the size covered in this paper, a prequalification process is likely to be justified only rarely.

The tendering specifications documents should include:

- The invitation to Tender (including close dates, decision dates etc., and any specific bidding instructions, processes for clarification of bidder enquiries, and possibly an indication of the approach to tender evaluation.
- contract general terms
- Any site-specific technical information e.g. requirement to use certain brands of electric motor, pipework colour coding etc.
- The technical specification.
- Schedules of supplied information and drawings
- Schedules of information to be supplied by the Tenderer

The tendering specification(s) should make clear which party has responsibilities for:

- Detailed design
- Component purchase
- Site access dates
- Temporary facilities (for staff, storage, power, water etc.)
- Installation work (including sourcing of skilled tradespersons and safe working)
- commissioning – temporary disruption to Client while new plant is commissioned and changed over
- Client staff training and handover

Conditions of contract could be the International Federation of Consulting Engineers (FIDIC) Conditions of Contract for Electrical and Mechanical Works including Erection on Site: The Yellow Book (1987) or Conditions of Contract for Design-Build and Turnkey: The Orange Book (1995). NZS 3910:2013 conditions of contract for building and civil engineering construction could be used as an alternative.

7.4 Fuel purchase contract

In the case of timber- or some crop-processing plants, biomass may be available as a waste product of the Client's operations. In these cases there may not need to be a contractual interface between the fuel supplier and the Client, however it is strongly recommended that all other aspects covered in this note (long term fuel supply security and long term assurances of specifications, definition of present and future heat demand, and design of equipment) are addressed.

For fuel supply, a tendering approach may also be used but a point of particular importance is the alignment between the guaranteed fuel specification, and the acceptable fuel specification provided by the boiler supplier: It is strongly recommended that negotiations are conducted with tendered boiler supplier and tendered fuel supplier until the specifications from each are completely aligned.

A fuel purchase contract should consider:

- Fuel specification
- Contract start date and end date

- Point of transfer of ownership
- Rights for renewal, and earliest/latest dates for renegotiation,
- Provisions for price or other changes to be calculated
- Process for verification of fuel quality (including GCV as delivered, moisture content and contaminants)
- Process for verification of fuel weights delivered
- Actions upon rejection of a load of fuel
- Scheduling of fuel deliveries: notice required for delivery
- Provisions for alternative supplies, provisions for emergency stockpiles
- Contract termination criteria and processes

Fuel delivery quantities should be checked by weighbridge values, as close as possible to the point of transfer of ownership. Fuel moisture content is authoritatively established on the basis of "oven dried weight", and test methods are determined moisture content exist. The Client can decide whether to arrange for random samples to be tested, or can request that the fuel vendor supply certified results. In either case it is essential that the samples be truly randomised (not from bottom or top of truckload, and separately for wet and dry seasons. As with all contractual matters, prevention is better than cure, it is worthwhile spending time and effort prior to contract signing, in determining how the fuel supplier will ensure consistent moisture content and quality, and setting up a well-considered Quality Control and Assurance system.

Scheduling of deliveries must be agreed: Either the Client needs to monitor fuel stocks and request delivery, or (less commonly) the fuel supplier needs to be assigned the responsibility for maintaining an agreed stock in the Client’s store.

7.5 Heat sale/purchase

Measurement of delivered heat (Hot water)

Hot water systems are invariably circulating supply-and-return systems (leakage is readily detected by level change in the header tank, and is not expected). For such systems, the heat delivered to the Client is simply calculated from instantaneous mass flow-rate and the temperature difference between supply and return legs, at the agreed point-of-supply (terminal point).

A range of flowmeters are possible – the Consultant should confirm the selected meter has accuracy appropriate for metering duty. Water supply temperature is normally controlled by the boiler control system, but separate measurement is recommended if the heat supplied is a contractual term.

Since heat transfer coefficients from water/steam to metal pipe, and through metal pipe walls, are high, an adequate temporary measure of water temperature can be obtained by firmly attaching a thermocouple to the external surface of the pipe (band clamp), and providing a generous layer of insulation over the pipe and thermocouple for 200mm each side of the thermocouple. For more permanent measures, thermocouple wells are required.

The method of measuring heat delivery, and the level of accuracy required, should be agreed as a part of the system design.

Heat delivery should preferably be logged frequently to provide guidance on maintenance intervals and to underpin contractual arrangements.

Measurement of delivered heat (steam)

For steam systems, it is common to measure steam flow, and to specify a minimum percentage of condensate to be returned to the boiler (allowing the water treatment facility to be sized correctly), and sometimes a minimum condensate return temperature. Delivered steam flow can be measured by venturi meter, "annubar", orifice plate, or Coriolis force meter. For the scale and type of applications that are within the scope of this note, a venturi meter is likely to be satisfactory however accurate results are highly dependent on observing the manufacturers' installation instructions particularly as these relate to straight pipe lengths up-stream and down-stream of the meter. Unless care is taken, measurements are likely to have an uncertainty band of 5%, and accuracy will be further decreased at low steam flows. The heat delivered in steam is dependent on steam quality (i.e. the percentage of steam and water in the delivered fluid): Steam quality should be specified (typically 98% dry), however this value is difficult to measure and the most practical assurance of steam quality is inspection and maintenance of the steam drum separators.

In many industrial plants that consume steam, some condensate is lost (either as a result of direct heating applications, steam trap discharged, or other issues). Condensate loss is undesirable (it is expensive to treat makeup water, and condensate is generally hot, so energy is lost to drains) and should be minimised, and maximum losses should be specified.

7.6 Project installation contract

The Consultant is normally responsible for the evaluation of tenders, and for clarifying outstanding matters arising from bids, and delivering a recommendation to purchase, to the Client.

When tenders have been evaluated and any matters requiring clarification have been resolved, the Consultant should recommend to the Client that the Client appoints an Owners Engineer to supervise the installation of the plant and the administration of the contract.

The Consultant should also recommend an approach to administering the contract, including:

- Monitoring progress
- Resolving technical issues
- Monitoring and reporting Contractor practices

7.7 Contract management

Every single activity within a biomass (or any other) project will take time and resources, and every activity is likely to depend upon the prior completion of other activities (and have activities that depend upon it in turn): Estimating the duration, dependencies and sequencing of activities, establishing the critical path activities and the long-lead-time activities will result in a project that runs smoothly and efficiently and is completed on-schedule.

The project schedule should be generated by the Contractor, and should take account of all significant activities: Most engineers spend significant effort in project planning (whether using dedicated project management such as Microsoft Project™, similar freeware such as Project Libre, or the trusty pencil-and-paper. Regardless of approach, Client and contractor should take particular note of critical dates for delivery of items - whether this is the delivery of site access and permission documents to the contractor, or delivery of major project hardware by Contractor to the Client.

A project schedule, showing each activity with start and end dates, dependencies, and responsibility is considered an essential document for a successful project. The format is not critical, but completeness, realism, and clear understanding of responsibilities and consequences of lost time are essential. The document should be produced by agreement, and accepted by all parties as the guideline for project activity scheduling.

During project execution, the project plan should be reviewed regularly to check progress, forthcoming deadlines, and issues that have arisen

Project schedules are commonly prepared at a high level earlier in the project, and increased detail may be required within major activities as the project progresses: For example, a high level schedule may show a single "commissioning" activity, whereas at a later date a detailed schedule of all commissioning activities may be required.

The Owners Engineer is responsible for administering contractual milestones (including payment milestones) and certificates (practical completion, handover)

7.8 Operation and Maintenance

Lifecycle analysis should be the basis of designing/selecting boiler plant, however the validity of the analysis (and hence the long term viability of the project) depends upon managing the actual economic performance of the boiler during its working lifetime.

Managing the actual economic performance requires management of the boiler operational state (tuning, maintenance), and managing the transfer of ownership costs of fuel and heat (covered under fuel supply contracting).

For some categories of boiler, local guidelines are available for operators, and specifically Technical Guide 3 BANZ Technical Guide - Guidance Document for Wood Pellet Boiler Operators Aug 2010 (http://www.bioenergy.org.nz/resources.asp#technical_guides)

For other categories, the purchasing specification should include a requirement to provide operation and maintenance manuals, and guidelines for tuning.

The Client and the Specifier should discuss and agree on the approach to be adopted for maintenance and inspection requirements: these can be contracted on a case-by-case basis, but a Long Term Service Agreement should be considered.

7.9 Summary - Contracting

A variety of contracts may be needed to successfully execute a project. Key contracts may include fuel supply, major equipment supply and/or installation, project engineering and management, and operation and maintenance.

When a Consultant/Specifier assists in the development of such contractual documents, they should:

- **Take note of the significant existing literature from relevant organisations such as BANZ and FIDIC which may assist in contract development**
- **Take care to be thorough, explicit, and avoid ambiguity – extra time spent developing coherent and consistent contract documents can avoid confusion, conflict and delays in project implementation**

The Consultant is generally responsible for evaluating tenders and recommending purchase to the Client.

Parties responsible for administering contracts must be defined by the Client.

8. Bibliography

The topic of this paper is broad, and a great deal has been written: This bibliography is not intended as an exhaustive list but simply as a resource to accompany the paper.

Biomass projects and case studies

EECA - "Usewoodfuel" - sector players list (http://www.usewoodfuel.org.nz/resources.html#sectorplayers)

EECA Guide: Wood Energy - Using wood as a renewable energy source (http://www.usewoodfuel.org.nz/documents/guides/EECA-wood-energy-renewable-energy-source-feb-2011.pdf)

NZ Home heating Association: Guide to good wood. (http://www.nzhha.co.nz/articles-1/a-guide-to-good-wood)

Wood-Chip Heating Systems A Guide For Institutional and Commercial Biomass Installations By Timothy M. Maker (http://www.usewoodfuel.org.nz/documents/guides/Wood-Chip-Heating-Guide.pdf)

A Guide to Utilizing Combined Heat and Power in the Wood Resources Industry.
The Department of Architectural Engineering at the Pennsylvania State.
University and the Pennsylvania Technical Assistance Program (PennTAP)
(http://www.usewoodfuel.org.nz/documents/guides/Guide-Utilizing-Combined-Heat-Power-WRIndustry.pdf)

Wood Pellets In New Zealand (http://www.woodpellets.org.nz/training.asp) small scale biomass heating (http://www.usewoodfuel.org.nz/documents/factsheets/Factsheet_SmallScaleHeating.pdf)

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EECA guide Transport guidelines for wood residue for Bio-fuels (http://www.usewoodfuel.org.nz/documents/guides/EECA-transport-of-wood-residue-guide-may-2009.pdf)

Woody Biomass Resource Library (http://ucanr.edu/sites/WoodyBiomass/Woody_Biomass_Utilization_2/)

Types of wood fuel - image/description http://www.usewoodfuel.org.nz/wood_fuel_supply.html

The Wood Fuel Supplier Accreditation Scheme (WFSAS) provides independent assessment of a wood fuel supplier's ability to consistently deliver contracted quantity and quality of wood fuel The aim of the Scheme is to provide assurance to customers that when they buy wood fuel from an accredited supplier, the fuel is of the contracted quality and has been subjected to quality assurance to ensure its consistency. The Scheme is administered by the Bioenergy Association (BANZ). Successful applicants to the Scheme are accredited per the fuel type they supply. (http://www.usewoodfuel.org.nz/accreditation.html). Registered wood energy adviser (http://www.usewoodfuel.org.nz/accreditation.html)

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Performance, operation and maintenance, system design, Emissions control, Pipework design, Heat systems design, Heat recovery Energy audit

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https://www.niwa.co.nz/sites/niwa.co.nz/files/import/attachments/Wilton-et-al-2008.pdf
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Energy Efficiency Best Practice Guide Steam, Hot Water and Process Heating Systems "Sustainability Victoria". (http://www.sustainability.vic.gov.au/~/media/resources/documents/services%20and%20advice/business/srsb%20em/resources%20and%20tools/srsb%20em%20best%20practice%20guide%20heating%202009.pdf)

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AS/NZS 1200:2000 – Pressure equipment sets out basic requirements and good practice for the design, materials, manufacture, examination, testing, installation, conformity assessment, commissioning, operation, inspection, maintenance, repair, alteration and disposal of pressure equipment (boilers, pressure vessels and pressure piping) but excluding gas cylinders. Includes detailed requirements for various pressure equipment by direct reference to a range of Australian, New Zealand and other standards.

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