Best practice guideline for life cycle analysis of heat supply projects

Bioenergy Association Technical Guide 14

Version 2

November 2018

About this Guide:

1. This guide, along with the associated Excel model, is intended to provide a standardised methodology for the assessment of options for commercial and industrial scale heat supply.
2. The compilation of this Technical Guide has been facilitated by the Bioenergy Association[1].
3. It is an outcome of industry discussion and collaboration. It captures the collective technical knowledge of a range of leading bioenergy industry personnel. In addition, it benefits from the collective experience of the Members of the Bioenergy Association Wood Energy Interest Group.
4. This guide is provided in good faith as an addition to the ongoing body of knowledge relating to the energy sector in New Zealand and Australia. However, none of those involved with its preparation accept any liability either for the information contained herein, or its application.
5. As with all Bioenergy Association technical guidance documents, this guide is a 'living document' and will be revised from time to time and reissued, as new information comes to our attention. If you have suggested additions to this guide please contact admin@bioenergy.org.nz
6. The Bioenergy Association takes all care with regard to the information contained in this guide but users are advised to obtain professional advice on specific matters as there may be aspects which are particular to their application where alternative solutions should be adopted.
7. These Technical Guides are only a guide and users should ensure that they have engaged appropriate expert to consider their specific application.
8. Preparation and maintenance of Bioenergy Association Technical Guides are overseen by association Interest Groups to ensure that current best practice is always included however the Bioenergy Association cannot take responsibility for any decisions that are made as a result of following this Guide.
9.

[1] Bioenergy Association of New Zealand Inc

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Caveat

This guide is intended primarily as an evaluation tool to provide a consistent methodology for the comparison of heat supply options. The Bioenergy Association recommends that any party undertaking a project to install, upgrade or replace a heat supply facility completes a full evaluation of all possible options prior to fixing on a specific new project solution. The guide provides an appropriate methodology, and guidance, but cannot cover the specifics of heat supply to specific facilities different locations.

1 INTRODUCTION

This Technical Guide is intended to provide guidance to advisers and decision makers considering the options for the supply of heat to commercial and industrial users, providing a consistent methodology for:

- The evaluation of the costs and benefits of the available options for heat supply over the life of a facility, and for the selection of the best option
- Assessment of the comparative lifetime costs of heat from plant fuelled by electricity, gas, oil, coal and biomass over the project lifetime, and
- The basis for the preparation of the financial business case for the heat project and obtaining project approvals

The standardised framework for evaluation provided in this guide will ensure that comprehensive assessments are undertaken while providing the basis for consistency of decision making. The Technical Guide includes an Excel based analysis tool for users, as the basis for financial and risk analysis, and presentation of the results.

The lifecycle analysis calculates the levelised cost of energy (LCOE) through discounted cash flow analysis of financial aspects of the heat project, along with the identification of the non-monetary and intangible benefits of externalities.

The methodology includes recommendations on how to deal with assumptions, and how to undertake a financial risk and sensitivity analysis and present the findings to decision makers.

The concept of LCOE is used to compare the cost of energy generated by different means. An understanding of the relative costs of the options is critical to making an informed decision to proceed with development of a community or commercial-scale energy project[2]. It:

- Compares the cost of heat produced using different fuels and technologies (e.g., wood, oil, natural gas or electricity)
- Is calculated by dividing the present value (NPV) of lifetime costs of generating the heat by the NPV of the energy production, discounted by the same rate as the energy
- Calculates pre-tax NPV of the total cost of building and operating the energy plants over the assumed lifetime

Many heat plants in New Zealand are owned by government agencies, and while the financial evaluation of these is generally the same as that for private sector owned facilities the decision criteria around required returns or the importance of externalities may differ. The guideline discusses these differences and provides guidance based on New Zealand Treasury guidelines for analysis related to publicly owned facilities, and guidance from other sources for privately owned facilities.

The heat may be required for a wide range of applications including process heat, hot water or space heating. The full scope of the energy facility and heat supply systems need to be taken into account when

[2] https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf

considering the capital and operating costs across the lifetime of the facility. The costs must include direct items such as the boiler, but also the ancillary equipment necessary produce the desired heat in the required place. In this guide and the spreadsheet is information included in order to help discussion of the methodology.

The guide has been prepared with reference to New Zealand Treasury guidelines for life cycle analysis of investment decisions[3], interpreted for heat projects. Similar guidelines are used in the United States of America[4,5] and the United Kingdom[6].

Consultation with officials of Treasury, Health, Education and EECA has been used to review and advise on content and methodology. Additionally, consultation with members of the Bioenergy Association Wood Energy Interest Group ensures that the Guide benefits from collective industry experience.

The Bioenergy Association first provided such guidance through the short course (WE7 – Writing a Business Case). This and the Technical Guide and associated financial model have been published on the Association administered website www.usewoodfuel.org.nz and these are freely available.

Any enquiries regarding this guideline should be referred to:

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This process detailed in this Guide involves assessment and clarification of project objectives, analysis of potential heat supply options, and then in detail of the financial parameters of the selected solution, followed by the preparation of the business case for the project. It is structured under (indicatively) the following eight steps which are discussed in detail in Section 5:

Step 1. Identify and quantify the site heat requirements, assessment criteria, analysis assumptions, financial parameters and economic life for analysis

Step 2. Assess fuel options: availability, cost and reliability of supply over the economic life of the facility

Step 3. Assess comparative costs of heat from fuel options based on capital, risk, operational and fuel costs and any quantifiable project benefits

Step 4. Assess non-monetary and less tangible benefits and quantify where possible in business terms

Step 5. Select preferred option on basis of Steps 4 and 5 and refine costs and benefits to complete the financial assessment

Step 6. Consider risks, potential upsides and sensitivities

Step 7. Confirm project timescale and key milestones and monitoring mechanisms

Step 8. Prepare the business case, submit and gain project approvals

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[3] https://treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates
[4] https://www.nrel.gov/analysis/tech-lcoe.html
[5] https://financere.nrel.gov/finance/content/crest-cost-energy-models
[6] https://assets.publishing.service.gov.uk/media/57a0897b40f0b652dd00023e/61646_Levelised-Cost-of-Electricity.pdf

2 HEAT PRODUCTION TECHNOLOGIES

This Guide is intended to provide the basis for the analysis of options for the production of low, medium and high temperature and pressure process heat, or heat production for commercial scale space heating. It is not intended for use at residential scale. The following sections contain references to the commonly available technologies to assist understanding of the characteristics and parameters that need to be considered.

The applications referred to in this Guide, with the exception of those using electricity as the primary energy supply, will generally require boilers to produce hot water or steam for the transfer of the heat to the processes or spaces utilising it. The analysis principles and methodology may be applied to other heating technologies though inputs to the spreadsheet may require some minor alterations in order to be directly comparable. Such technologies could include the gasification of fuels and the subsequent combustion of the gases to provide required heat, and direct firing to provide heat in the form of exhaust gases or the new electrically-based technologies potentially able to displace coal in applications such as milk powder production

The conversion of electricity to heat for space or comfort heating below 80^{o}C can either be direct or via heat pumps. The production of heat from electricity is, for economic reasons, generally limited to around 80^{O}C. The other fuels and technologies considered can also provide space heating via radiators or ducted hot air, at some additional capital cost for heat distribution and transfer systems.

3 FUEL, COSTS AND RELATED CONSIDERATIONS

Capital costs will be similar across geographies but some costs such as those associated with fuel supply may be specific to the location and the application for which the heat produced is required. In undertaking the analysis of a project, it is important that the analyst get the best advice on all costs, and understands the cost drivers so that project risks can be assessed by sensitivity analysis (refer chapter 8).

The characteristics and constraints of different fuels and their associated technologies should be considered at the outset of the project. For all fuels it is important to understand their availability and the lifetime costs and implications of delivering, storing and using them at the site in question. In some cases physical constraints of an option may be a larger consideration than fuel price: for example an inability to handle bulky fuel deliveries of wood or coal, or the larger footprint of the heat facility may eliminate options using these fuels. Turndown capability and ramp rates can be important too, solid fuels being less responsive in comparison to diesel, gas or electricity.

3.1 Fuels and their key characteristics

The fuels most commonly available in New Zealand for commercial heat production are shown in Figure 1, along with a summary of key parameters related to their use, intended only as a guide and to provide a framework for option analysis.

The comments and costs in the figure and used in this Guide are INDICATIVE only and will vary significantly on a regional basis and with time, and it is very important that the analyst researches and understand the drivers of these trends to establish an accurate project-specific basis for fuel comparisons and lifecycle project assessment.

Figure 1: Available fuels, and key parameters

	Energy wood chip Biomass hog fuel	Wood Pellets	Diesel, fuel oil	Natural Gas and LPG	Electricity	Electricity (heat pump)	Coal
Capital cost	High reflecting compexity of plant and larger storage requirement	High reflecting compexity of plant	Moderate	Moderate	Low	Relatively low	High reflecting compexity of plant
Fuel calorific value	Circa 8.8 to 15 GJ/tonne	Circa 18 GJ/tonne	42 GJ/tonne	54 GJ/tonne	N/A	N/A	14-30GJ/tonne
Indicative fuel cost	$7 - 11/GJ (forest residue) or $9-15/GJ (wood processing residue)	$12 - 20/GJ	$30/GJ	Commercial scale: natural gas $17/GJ, LPG $26/GJ	Say $0.11- 0.18/kWh, $13-21/GJ	For electricity at 11c/kWh heat cost is in range $3 -4/GJ, at 28c/kWh 7-9/GJ	$8.5-12/GJ, depending on location, quality
Fuel availability and drivers of future cost	Extraction, chipping or hogging, transport and drying costs. Available from local agricultural and forestry sources	Available nationally. Costs tend to be driven by market, economies of scale	Location, international oil prices, carbon charges	Nat gas only in NI, LPG nationally	Available nationally, but pricing varies	Available nationally, but pricing varies	Location, carbon charges and declining mining options
Best practice (combustion) efficiency	In range 62 to 73%, dep. on moisture	73%	80-85%	85%	Nominally 100%	COP say 3.5, up to 5 for commercial scale facilities, limited COP in cold weather	Up to 80%, depending on moisture content
Operational considerations	Slow response to load changes. Automated, reliable operation available	Slow response to load changes. Automated, reliable operation available	Flexible, fast response to load changes, automated operation	Flexible, fast response to load changes, automated operation	Flexible, fast response to load changes, automated operation	Limited to up to around 80°C output temperature	Slow response to load changes. Automated, reliable operation available
Operational and maintenance costs	Indicatively 5% of capital cost, pa	Indicatively 5% of capital cost, pa	3% of capital cost, pa	3% of capital cost, pa	Essentially nil	Negligible	Indicatively 5% of capital cost, pa
CO2 emissions	Deemed to be nil	Demmed to be nil	80 kT CO_2/PJ	60 kT CO_2/PJ	Deemed to be nil	Deemed to be nil	Nominally 90 kT CO_2/PJ (varies)
Emission and consenting issues	Particulates requiring flue gas cleaning equipment, opacity, smoke, odour	No real issues with well designed equipment	Carbon emissions plus some potential SO_2, NOx emissions	Negligible	None on site	None on site	Particulates requiring flue emissions filtration equipment, opacity, smoke, odour, CO_2

Notes to Figure 1:

- COP: coefficient of performance (energy out per unit of input)
- 1 kWh equates to 0.0036 gigajoules
- Fuel costs are ‘delivered”
- Indicative costs are as at July 2018

3.2 Carbon emissions: effect on fuel costs

The future effective cost of coal, oil, diesel and gas as fuel will be driven in large part by the cost of carbon. The cost of carbon is likely to materially increase over time under New Zealand’s emission trading scheme (ETS). This results in a relative escalation in diesel, coal and gas costs very different from the other project costs. This escalation differential must be addressed in any project evaluation (refer Section 7).

Carbon prices in April 2018 were above $20/tonne. The impact of nominal carbon charges on fuel costs is shown in Figure 2 below.

Figure 2: Impact of Carbon costs on fuel prices

	Wood chip	Wood Pellets	Diesel, fuel oil	Natural Gas and LPG	Electricity	Electricity (heat pump)	Coal
CO_2 emissions	Deemed to be nil	Deemed to be nil	80 kT CO_2/PJ	60 kT CO_2/PJ	Deemed to be nil	Deemed to be nil	90 kT CO_2/PJ
Indicative fuel cost	$7 - 11/GJ (forest residue) or $9-15/GJ (wood processing residue)	$12 - 20/GJ	$30/GJ	Commercial scale: natural gas $17/GJ, LPG $26/GJ	Say $0.11- 0.18/kWh, $13-21/GJ	For electricity at 11c/kWh heat cost is in range $3 -4/GJ, at 28c/kWh 7-9/GJ	$8.5-12/GJ, depending on location, quality
Effective fuel cost, CO_2 emissions at $20/tonne	As above	As above	Adds $1.60/GJ, for a total fuel cost of $31.60/GJ	Adds $1.20/GJ for a natural gas cost of $18.20, LPG $27.20/GJ	As above	As above	Adds $1.80/GJ, for a total fuel cost of $10.30 to $13.80/GJ
Effective fuel cost, CO_2 emissions at $40/tonne	As above	As above	Adds $3.20/GJ for a total fuel cost of $33.20/GJ	Adds $2.40/GJ for a natural gas cost of $19.40/GJ, LPG $28.40/GJ	As above	As above	Adds $3.60/GJ for a total fuel cost of $15.60 to $15.6/GJ

From Figure 2 it can be seen that a carbon price impacts most significantly on the price of energy from coal and to a lesser extent the price of energy from oil and gas, but does not impact on the price of energy from electricity or biomass. For the modelling and business case preparation the future price of carbon is a material consideration will need to be assessed by the analyst and included in the modelling and the discussion on project risk in the business case.

3.3 Fuel specific considerations

Fuel prices and in some cases supply are regionally specific so it is recommended that at the outset of any heat project discussions be held with fuel suppliers before consideration of possible heating equipment. This is particularly important with biomass fueled plant as fuel suppliers can provide advice of the possible fuel types and grades available in the locality. Once the types and grades of fuel available over the life of the plant have been established the fuel specification(s) can be finalised. Only then should discussions with equipment suppliers be undertaken. It is easier to find equipment to handle specified types and grades of fuel than to sometimes find fuel for particular designs of equipment.

A clear understanding of fuel availability and the specification of this fuel is required to ensure optimisation of equipment to suit the fuel.

3.3.1 Light fuel oil (LFO) and diesel

LFO and diesel are readily available from the major oil companies. An on-site storage tank installed in a bunded area is required, with the cost of these and the pipework and fittings often able to be included in the fuel price against a long-term supply contract. The scope of supply of capital equipment included in the fuel cost needs to be established by discussion with fuel suppliers so that any missing items are costed into the financial model.

No issues with supply are seen in the foreseeable future but the carbon emission costs are expected to cause the price of these fuels to increase over time at a greater rate than other project costs so this must be allowed for in the analysis (refer Section 6).

Supply considerations: None

Contracting: Long term supply contracts should be available, subject to adjustments for cost escalation based (primarily) on oil prices

Capital requirements: Boiler system, tanks, bunds and ancillary fuel supply equipment. Diesel storage on site – this is a hazardous fuel and installations must comply with relevant regulations – it may not even be possible to store on site in some situations

Carbon emissions: The emission factor is 80 kT CO_2/PJ. At (for example) $25/tonne of CO_2 this equates to an additional $2/GJ on the fuel cost

Consenting: LFO is a significant emitter of undesirable gases SO_2 and NO_x which may cause consenting issues. For both fuels consenting issues should be discussed with local authorities early in the project

Future cost escalation: It is not seen as possible to predict with any accuracy future oil fuel costs, excepting to observe that they are at the time of writing increasing on world markets, and the associated carbon costs are expected to rise significantly

A related product is heavy fuel oil, but this has some unattractive characteristics and is not universally available.

3.3.2 Natural gas

This fuel is available via an extensive network in many locations around the North Island, and despite some recent concerns seems likely to remain available for many years for commercial use. However, the risk of non-supply should be considered in the risk analysis. Natural gas is not available away from the gas distribution network or in the South Island, and this is unlikely to change. In those areas LPG is available.

Supply considerations: Natural gas is available in many North Island locations adjacent to the distribution pipeline, but not available in the South Island. Risk of non-supply should be included in the risk analysis

Contract terms: May require a contract period of (say) 5-years if the connection is provided by the gas supplier, and a minimum take or pay volume may apply. However, a long-term supply contract may be difficult to secure on favourable terms

Capital requirements: In addition to the boiler and ancillary plant local connection to the network is required. This may be funded by the supplier against a long-term contract. For the analysis clarify who will fund the connection

Carbon emissions: Emission factor is 55 KT CO_2/PJ. At $25/tonne of CO_2 this equates to $1.37/GJ

Consenting: Consenting issues are expected to be minor

Future cost escalation: Not clear, but prices are expected to rise with those for other hydrocarbon fuels while the associated carbon costs are expected to rise significantly

3.3.3 Liquefied petroleum gas (LPG)

This fuel is readily available, from a number of suppliers. A storage vessel and ancillary equipment including a vaporiser is required and the supply and maintenance this equipment may be amortised into the cost of the gas under a long-term contract.

Supply considerations: None, in most locations.

Capital requirements: Tanks and ancillary equipment. This is a hazardous fuel and installations must comply with relevant regulations while storage on site may not be possible in some situations.

Carbon emissions: Emission factor is 60 kT CO_2/PJ. At $25/tonne of CO_2 this equates to $1.37/GJ

Contracting and cost escalation: We would expect that a fixed price contract can be agreed for a period of few years, including amortisation of the cost of fuel storage equipment, followed by price reviews (parameters to be agreed) for the tenure of the contract. A minimum take or pay volume is likely to apply. In the longer term the price of LPG will generally follow those in international markets

Consenting: Consenting issues are expected to be minor

Future cost escalation: Not clear, but prices are expected to rise with those in world markets the associated carbon costs are expected to rise significantly

3.3.4 Wood

Wood fuel can be sourced throughout New Zealand in a range of forms from low grade arborist chip to export chip and premium grade wood pellets. Draft fuel specifications and guidance on the purchase of wood fuel is available on the Bioenergy Association website, www.usewoodfuel.org.nz

3.3.4.1 Wood pellets

Wood pellets are a premium fuel, manufactured from sawdust and other wood fibre sources, which is dry and consistent in quality. There are a number of producers in New Zealand. Although pellets are more expensive fuel than wood chip it is still cheaper than fuel oil or LPG.

Supply issues: None. Available throughout New Zealand in bag and bulk supply

Price: Prices vary with quality and throughout New Zealand. Pellets are more expensive fuel (indicatively $12 - $20/GJ) than wood chip but still cheaper than fuel oil or LPG

Capital requirements: Requires, in addition to the boiler, covered fuel storage and fuel delivery systems, but these are less complex than those required for wood chip

Contracting and cost escalation: The wood pellet market is well established throughout New Zealand. Cost price escalation is expected to be low as the price of the raw material from which pellets are made, wood processing residues, is readily available

Consenting: Consenting issues are expected to be minor

3.3.4.2 Energy wood chip and biomass hog fuel

The upper limit of the cost of energy wood chip is set by the price for clean export wood chip, a significant export product, or by the price of chip sold to local MDF or similar processing plants. Energy wood chip is generally sourced from wood processing residues which may not reach export or MDF grade quality.

Biomass hog fuel is a product produced from forest, sawmill and timber processing residues, processed through a chipper or grinder to produce coarse chips and “clumps” suitable for use as a fuel. The hog fuel can also include bark, sawdust, planer shavings, wood chunks, fines and often dirt, requiring care in boiler selection. The fuel can be relatively cheap (free if site generated) depending on extraction, processing and transport costs; the latter critical given the fuel’s low energy density.

This high moisture content means that boiler efficiencies are lower than for other fuels and the costs associated with fuel delivery, storage and handling are higher for a given energy production. That said it is a fuel that can be reliably utilised given a well specified boiler and consistent delivery of fuel that meets a well-defined specification which the boiler is designed to utilise.

CV: In the range 8 GJ/tonne (wet chip) to say 13.5 GJ/tonne for fully seasoned (air dried) fuel

Boiler efficiency: the combustion efficiency varies significantly with moisture content, in the range 62% for very wet fuel, up to 73% for a well-seasoned (air dried) fuel. It is recommended that this be obtained from the boiler supplier in terms of fuel consumption per GJ of energy produced

Price: this is very strongly influenced by location being a function of availability, quality transport distance and competition. Indicatively $7 - 11/GJ (forest residues) or $8.5-15/GJ (wood processing residues)

Contracting: Wood fuel can be contracted short or long term in most locations

Carbon emissions: Deemed to be zero

Consenting: Consenting issues are expected to be minor, given appropriate particulate control equipment

Future cost escalation: Not clear, but expected to be a function of availability and demand

3.3.4.3 Sawdust

Sawdust is available as a fuel in some locations at a price that may be seen as low (it presents a disposal problem for mills). However, it is difficult to burn, having a moisture content, ex-sawmill, in the range 50 – 55%. Drying is possible and equipment for this purpose is available, or sawdust can be blended with a drier fuel before combustion.

3.3.4.4 Other biomass residues

Agricultural and horticultural biomass (wood or herbaceous) may be available in some regions, but the combustion characteristics must be evaluated as they may be different from wood chip and hog fuel.

3.3.4.5 Biomass crops

Biomass crops such as miscanthus are beginning to be grown for potential fuel use, offering medium term potential.

3.3.5 Coal

Coal is available in New Zealand in a range from high quality coking coal to low quality and low energy density lignite in Southland.

New Zealand's coal industry is in some difficulty following the Pike River disaster, the collapse of Solid Energy, and given the political objective of a carbon free New Zealand by 2050. While the current Government's policies in terms of coal mining and carbon pricing are not yet clear, overall energy policy objectives will require the discouragement of coal use over time. There is a strong push to displace coal with biomass and other forms of largely renewable energy in smaller commercial institutions and coal is not seen as an appropriate fuel for new energy facilities.

CV: 19 MJ/kg but varies with coal types

Boiler efficiency: Nominally 77%, but varies with coal types and is lower with high moisture content

Price: Coal prices are driven in New Zealand primarily by the costs of extraction which are high, except in the case of the lignite deposits in Southland, and. Prices need to be considered on a location by location basis, but are generally in the range $8.5-12/GJ, depending on location and quality, though Southland lignite is cheaper

CO2 emissions: Nominally 90 kT CO_2/PJ. At $25/tonne of CO_2 this equates to $2.25/GJ or at $50/tonne $4.5/GJ

Other emissions: Coal is a significant emitter of particulate matter, though this can be largely removed with bag filters or precipitators, and also gaseous emissions such as SO_2 and NO_x which cannot easily be controlled making consenting a significant issue

Future cost escalation: Not clear, but prices are expected to rise significantly with carbon pricing

3.3.6 Electricity

Electricity can be used directly or via heat pumps for space heating and low temperature water heating, but is not generally considered a realistic option for high temperature/pressure steam process heat; though new technologies are emerging electrode boilers are planned. Space heating may be via air to air systems, or air to water systems, with the hot water delivered via piping and radiators.

The capital cost associated with electricity-based heat supply is low, but electricity itself is expensive in heat-terms unless utilised via heat pump technology.

Electricity supply: Available nationwide. The need to upgrade the electricity distribution network to the site will be a cost on the site owner and may be considerable particularly if line and transformer capacity needs to be expanded. Additional congestion period demand charges may add to the cost of electricity supply if the network is constrained; something that requires assessment as part of the project

Conversion efficiency: Essentially 100% for direct use, but in the case of heat pumps using the energy out is between 3 and 5 times the energy in (lower if higher temperatures are required (consult suppliers)

CO_2 emissions: 80% plus of New Zealand's electricity is generated from renewable resources: without emissions, except for geothermal generation which emits modest amount of CO_2. The balance is generated from gas and coal, with this to be phased out by 2050. Emissions are generally taken as zero and consenting is not an issue

Price: Contracts are available from a range of suppliers with prices are regionally specific

3.4 Equipment selection considerations

Only after the heat demand profile and fuel options are identified and able to be specified over the economic life of the facility should heat plant equipment suppliers be approached to establish capital costs.

For all heat plant the primary heat production equipment (i.e. boilers and ancillary equipment) is likely to be the single biggest capital expenditure item. The level of confidence in the capital cost will depend on the level of project investigations and costs used in project assessments should be based on advice from equipment suppliers. The detail and accuracy of quotations sought, to provide a basis for the financial assessment, depends in part on the analyst's knowledge of project costs and on the stage of the project: from first comparative assessments requiring broad brush costs to the case for project commitment which requires a high degree of cost accuracy.

With heat plant, and in particular that fuelled on biomass, care should be taken to ensure that the type of combustion plant proposed is suitable for the fuel specified, and that this fuel is likely to be available throughout the economic life of the project. If this is not possible the analyst should work with boiler suppliers to specify suitable plant capable of burning the range of fuels available.

Ideally heat plant costs will be determined on the basis of "turnkey" proposals, these including all equipment supply, installation, commissioning and staff training, and based on a clearly defined fuel specification. It is important to request and assess exclusions in any quoted scope of supply so that provision can be made for any costs not included.

For electric heating of water using heat pump technology it is important that the performance of the equipment is specified for the ambient temperatures of the project site during the heating season, as performance drops off in cold conditions when demand is highest. Geothermal heat pumps are less weather dependent as there are only small fluctuations in source temperatures.

In comparing a centralised heating system using fuels such as gas or biomass with distributed heating systems such as electric heat pumps installed in each room and corridor of a building, it is important that the heat distribution systems and radiators or ducting are included for like-for-like cost analysis.

For a large electric system there may be costs for upgrading of electric wiring and transformers etc which should be included within the capital cost.

When considering equipment sizing the issue of capacity vs. load factor should be evaluated. High load factors tend to favour lower fuel cost solid fuel devices, but in the case of lower load factors the capital cost component may outweigh the lower fuel cost. Similarly, there can be a trade-off between fuel quality and equipment capability (cost). For example, a cheaper boiler may only be able to use a very narrow range of fuel types but a more complex/expensive boiler may be able to combust a wide range of fuel qualities.

There is also a trade-off of in the amount of operator time required, in relation to fuel type. For example, a homogenous fuel such as wood pellets or diesel may require minimal operator attention whereas a non-homogenous hog fuel may require more operator attention.

There is generally a trade-off between capital cost, peak output and load factor. This reinforces the importance of having a good understanding of the load profile before equipment selection. It is extremely important that new equipment is not just sized according to the current peak output, or the size of equipment being replaced. If the replacement equipment is oversized this could mean it has a higher capex than needed and operates with poor efficiency much of the time (if operating at high turn down).

During equipment selection the size of a boiler may be reduced by:

- Buffer tanks to store heat for peak periods; if space heating is the main load, it is fairly common for wood fuelled systems to include a buffer tank to reduce the required boiler size.
- Heat demand spreading; rather than a half-hour warm up on Monday morning, this could be spread over a few hours
- Retaining (or adding) a small fossil fuel system to meet extreme peaks i.e. say a 100kW pellet boiler or heat pump for base load with a 100kW diesel or LPG boiler to assist with 'cold-snaps' or as backup.

3.5 Ancillary equipment

Many heat plant projects require significant expenditure in addition to that for the heat plants themselves. For coal and biomass fuelled heating facilities the fuel storage and handling equipment is a significant additional area of spend, and technical complexity.

Care must be taken to ensure that limits on capital expenditure do not result in cheaper ancillary equipment being installed or some equipment being left out with the result that a heating facility does not operate at optimal performance or that additional costs are incurred at a later stage.

3.6 Operating and maintenance

All non-electric heat plants require some level of operating supervision, monitoring, and attendance for activities such as fuel receipting and handling, de-ashing and checks on operational performance. Some of this may be done remotely, either by the on-site staff, or under a support contract under which alarms may be monitored and plant operation controlled remotely according to safety protocols.

Biomass boilers and those fuelled by coal are more complex that those fuelled with gas or liquid fuel, require more operational inputs, and have higher maintenance costs. Coal boilers produce significant volumes of ash (volumes depending on the coal type and ash content) incurring considerable cost in handling and disposal, while biomass boilers produce much smaller volumes of ash that is easier to dispose of.

It is recommended that unless there is significant heat plant expertise on site a support and maintenance contract be entered into with the boiler supplier or an alternative specialist contractor; to support the operation in terms of performance monitoring, trouble shooting and regular servicing. Most boiler suppliers offer this service.

Most modern heating facilities do not require highly trained operating staff and in many situations the site maintenance person will be the heat plant operator. Advice on operating and support requirements is important for comparing options and costs. For example, a biomass or coal fuelled boiler will require regular observation of the plant to ensure optimal and safe operation and periodic de-ashing and fuel management.

This can be compared to electricity solutions, including heat pumps, where there will be essentially no operational input required apart from electrician input for servicing.

3.7 Consents

All projects will require building consents from the local territorial authority, and boiler plants require resource consents for land use and discharges to air and to water from the regional consenting authority. For boiler systems a flue is required for the discharge of gases produced which may be an issue for height and aesthetic reasons.

Early discussion with the consent authorities is always encouraged so that the requirements and timescales for consents, and associated costs, are fully understood.

3.8 Siting issues

All heat plants, regardless of whether they are to be constructed on an existing site, in existing buildings or on a greenfields piece of land will be subject to cost uncertainties relating to foundation conditions, and issues that may be discovered during site preparation such as hidden services or weak or unstable soils. It is recommended that expert site-specific advice be received.

The level of cost provision for this uncertainty will depend on the level of investigation that has been undertaken and should be reflected in the level of contingency sums allowed.

4 PROJECT ASSESSMENT STEPS

The evaluation and assessment process generally follows eight steps:

Step 1: Assessment of required heat and establishment of analysis criteria

Before the analysis is undertaken it is important that the heat requirements are clearly identified and quantified, establishing the type of heat (temperature and pressure) required, where it is required and the load profile. This sets the framework for assessing the amount of fuel required, the technology appropriate and equipment specification, the evaluation of options, identification of uncertainties and the financial risk analysis. It will also eliminate some fuel and technology options.

This will provide the information required by prospective heat plant suppliers so they can advise on technology and capital costs for the facility.

This heat demand analysis must identify possible future changes in the demand profile over the economic life of the facility, which will be strongly linked to the future use of the heat, and the business risks applying to each option. It may also guide the choice of analysis period.

Some technologies cannot produce high temperature and high pressure steam which is required for some applications while if there is a mix of high and low temperature heat requirements it may be that a low temperature solution can provide the low temperature heat demand, with a smaller high temperature boiler installed only for the high temperature/pressure heat demand instead of installing an oversized boiler to cover both applications. Fluctuating demand may drive consideration of options such as heat storage to cover peak demand periods.

Consideration must cover the option of refurbishing or supplementing existing heating systems to meet differences in scale and heat output, as well as new systems. Replacement requires the dismantling and disposal of the old system at a cost that must be taken into account and changes in scale may mean additional land requirements and costs, or a smaller footprint given new or different technology. Care must also be taken to ensure that all potential and reasonable options are explored.

Required data on heat requirements includes:

- Overall heat demand
- Peak and average heat requirements and rate of change of heat load

- Load fluctuations on an hourly, daily, weekly and seasonal basis
- The temperature required in the case of process heat (generally transferred in the form of steam or hot water)
- An understanding of operational support available on the site, given the requirements for operation and maintenance of each technology (refer Section 9 below)

The financial analysis parameters should also be established at the project outset so that aspects such as project life can be known prior to seeking advice on the availability of fuel.

Step 2: Assessment of fuel supply options

The fuels generally available in New Zealand are discussed at high level in Section 4 above, with more specific discussion in Section 9 below. Factors to be considered in the fuel selection process include:

- Costs and availability of fuel within a reasonable/economic delivery distance (noting the high transports cost of fuels such as wood)
- The reliability of supply considering sources, potential volumes and potential/actual competition from alternative users or uses
- The contractual terms under which supply may be secured:
- Pricing and future price path
- Reliability and security of supply over the life of the project
- Capability and track record of suppliers in terms of reliable supply and their ability to consistently deliver to agreed fuel specification over an extended period
- The availability of a regional fuel market with a range of suppliers; considered essential to ensure long-term competitively prices for fuel supply.

Assessing the availability and cost of fuel for the latter periods of the analysis period is difficult for all fuels. This uncertainty can best be addressed by risk and sensitivity analysis (refer section 8).

Step 3: Option assessment

The spreadsheet-based levelised cost of energy (LCOE) model has been written to assist with the analysis of different fuel and technology options. The model is available for download from the Bioenergy Association website www.usewoodfuel.org.nz/wood-tools-calculators. This is the basis for the financial assessment of the project options, and subsequently the chosen solution, with the modelling process detailed in Sections 6 and 7 below. The model is formatted to allow consideration of seven project options based around different fuels.

This financial assessment process may be repeated as financial and other information is hardened up in the course of the project.

The cost of construction of a boiler house or fuel store versus the reuse of an existing boiler room and or fuel store needs to be considered and included in the comparisons.

Step 4: Assessment of non-monetary and "less tangible" benefits/issues

The key non-monetary and "less tangible" considerations are outlined in Section 9 below and should at least be assessed in qualitative terms as they may prove to be material in the decision-making process. If they can be quantified there is provision in the model for their inclusion.

Step 5: Selection of preferred option and financial assessment of preferred option for heat supply

More detailed (if required) financial analysis of the preferred option identified in Step 3, combined with consideration of the non-financial information (Step 4) is intended to provide the basis for selection of the preferred solution and for securing project approvals and commencing the heat facility development. It requires robust financial figures and analysis to establish the recommendations for inclusion in the business case for the project, usually meaning a re-run of the numbers with firmer and more accurate cost inputs.

It is recommended that uncertainty be reduced by seeking quotations for key plant items, and for other items estimates from experts, unless the analyst is satisfied with the accuracy of institutional knowledge.

Step 6: Consideration of risks, upsides and sensitivities

The financial model generates figures showing the impact on the project's financial outcomes of changes in some financial inputs to the modelling. These can be used in assessing some project risks, upsides and sensitivities (refer Section 8).

Step 7: Confirmation of project timescales

This step is required for the business case, but is outside the scope of this guide.

Step 8: Preparation of the business case for decision makers

A framework for the preparation of the business case for the heat supply project can be found in Section 10 below.

Often only a few options are considered from the many available but it is useful to discuss why certain fuel options are considered in the report and others are dismissed.

A graph showing the life cycle cost over time for the various options provides an easy to read comparison between fuel options so can be very informative.

5 THE FINANCIAL ANALYSIS MODEL

The lifecycle financial assessment, and the business case it contributes to, must quantify all benefits and costs and translate them into the impacts on the organisation or business, especially its financials. There are many ways of considering the attractiveness of an investment or project in financial terms, depending on project scale and complexity, and the requirements of the organisation or business. Some are:

- **i.** Simple cost reduction: the reduction in annual (business or just energy supply) costs post-project, ignoring capital expenditure

ii. Simple payback: calculated by dividing the project cost by the net annual project benefits to give a simple payback in years

iii. Post tax payback period: calculated using the financial model, being the period to the date at which initial investment is repaid from after-tax cash-flows

iv. ROI (return on investment): expressed as a percentage it is a measure of project profitability, calculated post tax

v. Present value (PV) of cash flows, being the difference between the present value of cash inflows and the present value of cash outflows, after tax

vi. Levelised costs of energy supply (LCOE): the net present value of the cost of heat over the lifetime of the heat generation project. It is primarily intended as a basis for the comparison of energy costs under different generation scenarios and can be taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime. Mathematically the LCOE calculated:

$$\text{LCOE} = \frac{\text{PV of total life cycle energy costs}}{\text{PV of total lifetime energy production}}$$

For this Guide the financial analysis model uses future free cash flow projections, and the energy production, and discounts them, using the nominated discount rate, to arrive at the LCOE on a pre-tax basis. It also assesses the pre-tax NPV of project costs and calculates the financial sensitivity to changes in a number of key parameters.

LCOE is considered the most relevant indicator for heat plant decision making as for such facilities there is generally no offsetting revenue to be included: leaving the decision between different technology and fuels scenarios that produce the required amount of energy.

LCOE model overview

The model attached to this guide is available for downloading and use from the Bioenergy Association website www.bioenergy.org.nz/documents/resource/Technical-Guides/TG14-DCF-Analysis-Heat-Plant-Manual.xlsx. The link below shows you the financial model which provides the methodology and tools for calculating the LCOE (levelised cost of energy) from a range of fuel and technology options. It is a companion to this Technical Guide 14: Best practice guideline for life cycle analysis of heat plant projects.

The model is based on a conventional discounted cash flow financial model written in Excel, simplified for this analysis of heat plant options. The original model was developed for specific use on energy projects and refined via a wide range of actual heat plant studies carried out to advise businesses on their long-term energy supply options.

The model attached is a “real” model which means that all inputs are in “today’s” dollars (today being the year chosen for setting the costs). The WACC (weighted average cost of capital) used must be that for a real modelling (refer Section 7 below) rather than that for nominal modelling which is higher by the rate of inflation. Te WACC varies by industry and business.

The instructions for using the model are detailed in Section 7 below. **Note:** This financial model has some cells hidden and others, not required for data input, will be locked in the final version, but are left open during the consultation stage.

The model is structured as follows, with detailed instructions for its use in Section 6 below:

Sheet 0: Introduction to model.

Sheet 1: Capital costs. This sheet comprises a check list of capital cost components for the installation of a heat plant and associated systems and services, against which estimated or quoted costs can be entered, with the sum being the capital cost transferred to the DCF calculation of heat costs. It is noted that all cost items will not be required for each heat supply option.

Sheet 2: Operating and maintenance costs. This provides a check list of cost categories against which estimated or quoted costs can be entered, with their sum being the operation and maintenance cost transferred to the DCF calculation of heat costs.

Sheet 3: Fuel cost calculation sheet. This sheet calculates the fuel cost, by fuel type, for inclusion in the financial model, and the associated carbon cost.

It is noted that the preferred basis for the calculation of fuel use is the specific fuel consumption for the boiler being considered, this figure being obtained from the heat plant supplier. Alternatively, the calculation of boiler efficiency may be made (external to the model) on the basis of boiler efficiency and fuel calorific value, but this approach is not recommended as all boilers operate differently and will have different combustion characteristics.

Sheet 4: Modelling inputs: This is a master input sheet into which the project and business specific economic parameters are entered. Rows 7, 8 & 9 are populated automatically from the earlier worksheets while the figures on this sheet are automatically copied across the scenario modelling sheets.

Sheet 5: Modelling outputs: This summary/report sheet is fed by the DCF models in sheets 6 to 12 to provide numerical and graphical figures covering heat supply costs (refer Section 7 for details).

Sheet 6 - 12: Scenario analysis. These sheets contain seven DCF models, covering different fuel or technology options, each input with data from Sheet 4. They calculate the annual heat cost of each option and the financial sensitivity to parameter changes. They are available for review, and to show financial information such as annual cash flows, but not for any inputs. Note that costs are all "real".

6 FINANCIAL ANALYSIS OF ENERGY SUPPLY OPTIONS

The following guidance applies to the attached DCF model, which comprises thirteen sheets which together cover a step by step process for assessing the lifecycle cost of the options for heat supply.

Sheet 1: Capital costs

The table in Sheet 1 lists the capital cost areas that should be considered and quantified, where applicable to the project options, for input into the DCF models **(Sheets 6 - 12)**. Costs can be entered into the cells relevant to the scenario under consideration. In the case of a heat plant option involving a biomass or coal boiler, costs will be incurred in most of the cost categories listed, but in the case of other fuels requiring a less complicated facility some will not and the cells can be left empty.

The heat plant costs should be based on advice or quotations from suppliers, with the addition of costs required to cover any exclusions from their supply. Ancillary and site works comprise a range of requirements that would not normally be included in a quoted scope of supply for the heat plant itself, but which are required to complete the physical construction of the project. Under “Consultants and services” are cost areas that are likely to require expenditure, and therefore inclusion in the budget.

For smaller scale heat pumps a life of 14 years is suggested by the industry, at which time replacement units will be required. This replacement is automatically included in the heat pump scenario model.

Contingencies, applied as a percentage of total estimated costs (**Cell C42**), are intended to cover unexpected expenditure or cost overruns likely to be incurred in the course of the project implementation. Project contingencies vary with the accuracy of the estimating process and the degree of cost risk that falls to the developer as opposed to contractors. A contingency of 25% is recommended for early stage project assessments, reducing to perhaps 15% at the time of project commitment, if the estimates at that time are considered to be accurate.

Sheet 2: Operational and maintenance costs

This sheet comprises a check list of cost categories against which estimated or quoted costs can be entered, with the sum being the capital cost to be used in the DCF calculation of heat costs. The total annual operations and maintenance cost will transfer via the Inputs Sheet to the DCF models (**Sheets 6 – 12**) for each scenario. It is likely that staff wages will be a major component of these costs so it is important to obtain recommendations from equipment suppliers for staffing and maintenance requirements.

It is noted that systems using electricity, either directly or through a heat pump, require little operational support or maintenance except for regular servicing in the case of heat pumps per manufacturer’s recommendations.

Sheet 3: Fuel Costs

Fuel will be the major cost component over the life of the heat plant project, especially in the cases of the lower capital cost/higher fuel cost heat supply options: oil, gas and electricity.

The estimation of actual fuel use, and therefore fuel cost, is complex for biomass and coal systems. The required fuel is a function of the heat required in the process, the conversion efficiency of the heat plant (a function of the technology and the fuel combustion characteristics, in particular moisture content) and the calorific value of the fuel.

It is strongly recommended that quotations are sought for the supply of heat plant. The request for quotation should clearly describe the heat requirements, the characteristics of the heat load and provide, for the more complex fuels (coal and wood in its available variants), a clear fuel specification (refer

Technical Guide 1: Solid biofuel classification guidelines[7]). The request should also require specific fuel consumption of the designated fuel, ideally with some form of guarantee. If the type or grade of the fuel to be used is likely to vary over time due to changes in availability this should be stated along with the range of fuel specifications expected. Boilers capable of burning a range of fuels are available, but at a cost.

The preferred basis for the calculation of fuel use is the gross (not net) specific fuel consumption of the boiler, quoted by the boiler supplier for the specified fuel and operating profile – requiring this to be obtained from that supplier. Alternatively, the fuel use may be calculated on the basis of boiler efficiency and fuel calorific value but this approach is not recommended.

The inputs to Sheet 3 are as follows:

- The total heat required annually by the facility (**Cell E7**); assessed by the analyst, or by external consultants
- The heat production efficiency (**Line 8**):
    - Note: this is “gross” not “net” efficiency
    - Heat plant efficiency is specific to the heat plant using the nominated fuel, and also the load profile for the nominated operating pattern; particularly for biomass and coal systems. It is strongly recommended that the figure should be secured, with performance guarantees from the boiler supplier
        - Indicative figures for both CV and combustion efficiency are however shown in the table at the foot of Sheet 3
    - For direct use electricity a figure of 100% can be assumed
    - For heat pumps the supplier, or an independent advisor, will advise the COP (coefficient of performance) applicable to the unit(s) proposed (normally in the range 3.5 to 5) being the ratio of heat in (in the form of electricity) to heat out. This figure is inserted in Cell **M8**). Care should be taken as COP provided by equipment suppliers is often theoretical with the actual COP depending on location and seasonal temperature variations across the usage period. This should be confirmed with the supplier for the heating profile required
- The cost of the energy in the fuel in $/GJ is inserted in **Line 10**. It is noted that Sheet 4, inputs, offers the opportunity to enter a figure (above normal inflation) to cover potential fuel cost escalation, by fuel scenario, over the modelling period
- The cost of carbon dioxide, in $/tonne is input into cells **G17, 18 and 19** for the period commencing with the year nominated in cells **F17, 18 and 19**.

The total annual fuel cost is shown in Line 1, based on the figures inserted while periodic CO_2 costs are shown in lines 17 to 19 for each scenario. These are transferred via the inputs sheet to the scenario DCF models where they are shown on separate lines. Also shown (lines 22 to 24) is the total fuel cost including the cost of carbon at the nominated rates.

[7] https://www.bioenergy.org.nz/resource/tg01-solid-biofuel-classification-guidelines

Sheet 4: Inputs

This sheet is used to input business or organization specific business parameters for the modelling process and other inputs, and also records the total capital, operating and maintenance and fuel costs. All these inputs are copied across to **Sheets 6 to 12** that model the specific scenarios.

The inputs to Sheet 4 are as follows:

- Lines 7 to 12 are populated from previous sheets
- Fuel inflation rate (**Line 13**). Fuels will escalate in cost at different rates. The model assumes that the fuel costs will increase annually at the same rate as all other costs[8] unless a specific rate is entered into **Line 13** for a particular fuel; in which case the fuel cost escalation. The inserted figure is the estimated fuel cost inflation figure for that fuel in excess of the figure for general inflation.
- Residual value (**Line 14**). This is a nominated figure intended as a proxy for the value of the cash flows from the energy plant after the modelling term, based on the fact that such facilities generally have a much longer life, if well maintained and if demand for their heat remains.

  For a well-maintained heat plant with an ongoing application at the site a residual value in the range 25 to 40% of the initial cost is seen as appropriate. The residual value may be of this order of magnitude when it includes costs such as site purchase, services supply and ancillary buildings etc., but would be less than this if it is expected that new technologies, or cost impositions such as carbon charges, may make some of the existing equipment redundant and therefore of zero value.

  For heat pumps the model assumes a new system will have to be installed after 14-years, reflecting the life of such plant. This means that the residual value of this plant will be higher than for other scenarios, as this will apply after only a short-installed period.

- Additional benefits or costs (**Lines 15 and 16**). If some additional benefits (positive) or costs (negative) have been identified for a scenario, perhaps by quantifying some of the less tangible benefits in Section 9 below their annual value can be included in the analysis by entering this in the relevant column. Such benefits might include:
  - Savings on wood residue disposal
  - Heat sales to third parties
  - In the case of a decision on heat plant replacement the avoided costs of running the heat plant/system that is being replaced
  - Other quantifiable financial benefits associated with the project

  Line 15 applies an annual cost or benefit, while Line 16 applies only to Year 1

- WACC (Weighted average cost of capital) (**Cell C19**). This is the discount rate that applies to the lifecycle analysis. It is normally the rate that a company is expected to pay on average to all its security holders to finance its assets (a weighted average of cost of debt and equity):

[8] Modelling is on a real basis, with all inputs entered in dollars applicable to the date at which the modelling is carried out, so no general inflation figure is used

  - For the public sector project the "discount rate" is prescribed by Treasury in real terms. Currently this figure is 6%
  - For private sector investments this is the calculated cost of the business' funding. The cost varies by business and industry as a function of factors such as industry, size, proportion of debt and company risk profile
    - Typically, for industrial products companies this is likely to be in the range[9] between 7.2 % and 9.1% with an average figure of 7.7%

- Project life: The term over which the project is to be financially assessed will be determined by company/organisation practice and is inserted in **Cell C20**. It is noted that:
  - The shorter the modelling period the higher the heat cost will be as the capital costs will be amortised over a shorter period, and that a shorter period tends to "favour" project options with a lower capital cost (i.e. gas rather than wood fuel)
  - Heat plants have long lives, certainly in excess of 20-years, if well maintained, but that over time business requirements may change leading to changed demand for heat
  - It is suggested that:
    - A term of 20-years be used as a default
    - In cases of heightened project uncertainty a term of 15-years is used
    - In the case of heat pumps the industry advises that the life of a system is around 14-years and the model automatically costs a new heat pump system into the analysis in year 14.

Costs and other inputs from this sheet are automatically copied across to the Scenario analysis sheets.

Sheet 5: Modelling Outputs

The following are reported on this sheet, for up to seven fuel or equipment scenarios:

- The annual costs of heat in year 1, excluding any consideration of capital costs
- The pre-tax NPV of the project costs, and benefits if applicable, including capital, over the modelled period
- The levelised costs of heat supply from the scenarios considered, in $/GJ and $/kWh, in both table and graphical form
- The sensitivity, considered in $/GWh, of the options to changes in input parameters

Clearly, the scenario with the lowest levelised energy cost, and lowest NPV, is the least cost option for energy supply, and may be considered the favoured heat supply option unless some of the non-monetary and less tangible considerations (refer Section 9 below) prove compelling.

[9] https://www.pwc.co.nz/pdfs/pdf-pwc-appreciating-value-nz-edition-6-march-2015-deal-activity-ipo-listed-share-price-performance.pdf

Sheets 6 – 12: DCF models

These sheets show the key output figures of the modelling of the six scenarios, based on data entered into the input sheets. No inputs are required or possible on these sheets which are shown for reference only. Modelled outputs are shown in the output sheet (**Sheet 5**).

The cash flows are however shown for the duration of the modelling period, and may be valuable for reference or as a basis for further financial analysis if required, noting that they are in real dollars.

7 Risk and Sensitivity Analysis

The financial assessment of a heat plant project is necessarily based on a number of assumptions, and a range of variables that may prove in reality to be incorrect, or which may change over the course of the project. It is important in understanding the likely financial performance of the project and, in preparing the business case for the new heat plant, that the sensitivity of financial outcomes to potential changes in input assumptions or costs are assessed and compared with the base case. This is particularly important with regard to fuel supply which will be uncertain after the initial period of the analysis.

The following sensitivities are assessed for each the heat plant options modelled:

- Capital cost: plus 20%, minus 10% against modelled base-case costs
- Fuel: costs: + 20%, -10%
- O & M costs: + 20%, -10%
- Heat demand: +/-20%

It is important when advising decision makers on the analysis results that the range of possible outcomes is discussed to provide a guide as to the robustness of the project economics.

8 Other considerations and Non-monetary benefits/costs

8.1 Government policies

Government agencies have an "all of government" responsibility to consider the potential effects of the full breadth of government policies when making any decision. Government procurement guidelines apply[10]. For example, if the new heat plant may provide stimulus to the local fuel supply market and thus assisting create new jobs and regional economic development then this may be a non-monetary benefits which the agency should include in its evaluation of options. Such benefits will often be intangible and will only apply in specific situations.

Such considerations are generally not relevant to private sector heat projects. However, these could be an intangible benefit of private sector decision makers if they wish to act as a "good corporate citizen" or give back to the community in which they operate.

[10] www.procurement.govt.nz/procurement/principles-and-rules/government-rules-of-sourcing

For heat projects there are a very wide range of applicable government policies and programmes where the potential effects should be considered but key ones include:

- Reduced air pollution
- Use of renewable energy
- Use of clean technologies
- Increased employment
- Improved regional economic performance
- Better productivity from land and resources
- Better value from forestry and wood processing
- Increased skills training

Clearly, a small heat project may have limited public good impact arising in these policy areas but the cumulative effect of a number of small projects may be material. As a result, specific projects should not be analysed in isolation from other potential projects by central or local government entities.

8.2 Community and other benefits

There is a range of public good considerations associated with heat plant projects that may be material in the decision on what fuel and equipment to use for a specific heating application. In some cases, these may be considered to have material value that can be monetised into the financial assessment, though that clearly depends on the view of the organisation. Others may have monetary value that is not able to be quantified in which case inclusion of an estimate may be considered better than nothing. Where an estimate cannot be provided then unquantified information on the positive or negative value should be provided in the business case write up.

For government entity owned facilities there are specific Treasury Guidelines[11] on the inclusion of benefits:

> *The Treasury Cost Benefit and Better Business Case guidance[12] has a preference (for State Sector expenditure) for benefit analysis from a national economy perspective rather than a narrower project, programme, agency or all-of-government perspective. It is helpful to keep this in mind when identifying benefits as it will assist later in the process.*
>
> *The government has a focus on boosting skills and employment, encouraging innovation, and achieving safer workplaces. The Government Rules of Sourcing principles state that agencies should:*
> - *"Get best value for money – account for all costs and benefits over the lifetime of the goods or services, and*
> - *Make balanced decisions – consider the social, environmental and economic effects of the deal."*

Therefore, the procurement process should consider the wider benefits that could be generated from heat plant investments and build these wider benefits into the business case, benefits realisation plan and procurement strategy.

11. https://treasury.govt.nz/sites/default/files/2016-03/managingbenefits-guidance.pdf

For private sector heating applications there may also be non-monetary[13] and intangible benefits[14] which should be included in the analysis. Some of the matters which apply to public sector decision making may not apply to a private investor but others may, depending on the business strategy and objectives of the investor.

8.3 Non-monetary benefits

Significant decisions in the Government sector should be accompanied by some kind of CBA[15 and 16]. A CBA measures the impact of a decision on the public at large. It should attempt to be value free, and is primarily about organising available information in a logical and methodical way. Different methods should be used to measure the extent to which a proposal fits with decision-makers' objectives and policies.

The main purpose of the guide is to encourage all decisions to be accompanied by at least a rough CBA, on the grounds that it is better than decision-making based on prejudice or instinct. The preparation of a more comprehensive CBA is encouraged where the importance of the decision warrants it. This may entail employing specialists where an agency doesn't have the necessary skills or resources in-house.

A CBA is about organising in a logical and methodical way whatever information is available and it is recognised that information is always available. Its aim is not to calculate the benefits and costs, but to reduce the degree of uncertainty that would otherwise exist around benefit estimates.

In public sector heating projects non-monetary (or non-financial) benefits can be as important, if not more so, than monetary benefits; depending on the desired outcomes from the project or programme. They can include improvements in areas such as risk exposure, social, cultural, heritage, and the quality of services provided to New Zealanders.

Non-monetary benefits may be monetised using techniques such as those in the Treasury CBA guidance[17]. The Government Project Portfolio (GPP)[18] guidance provides explanatory notes on nonmonetary benefits to help estimate the non-monetary benefits from a proposed project, primarily from a national economy perspective. The table in the GPP guide shows indicators that can be used to assist agencies in identifying the level of non-monetary benefits early on in the project life cycle, using the Economic Welfare Impact for the assessment.

8.4 Benefit identification

Treasury sets out a process of project benefit identification, linking them to achievement of Government policies and programmes[19]: Project risks should also be included in the benefits identification:

> *"The focus is on identifying the risks that may impact on the successful achievement of the benefits. Benefit risks should be included in the Benefits Realisation Plan and managed in the project/programme risk register. Benefit risks will change throughout the project's life[20].* Some examples of benefits that should be included in a heat plant project analysis are outlined below".

There is provision for the inclusion of benefits that can be quantified in monetary terms in the financial

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[15] Page 25 Ibid
[16] Page 6 Guide to Social Cost Benefit Analysis, July 2015. https://treasury.govt.nz/sites/default/files/2015-07/cba-guide-jul15.pdf
[17] http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis
[18] http://www.treasury.govt.nz/statesector/investmentmanagement/think/governmentprojectportfolio

model: Lines 15 and 16, Sheet 4 (Inputs).

8.5 Valuing the costs and benefits

Valuation of costs and benefits can be difficult but should be attempted with even a rough, back-of-the envelope attempt able to convey some useful information to decision-makers. In fact, just identifying the main costs and benefits, and summarising them in a table on one page, often reveals useful information.

- Benefits should be measured in terms of 'willingness to pay' for them, and opportunity costs should be recognised.
- Values should be adjusted for risk and expressed in terms of ranges.
- The evaluation period should be 'whole of life'.
- Benefits and costs should be measured in real terms, i.e. net of inflation.

People's willingness to pay for a service (or 'willingness to accept' payment as compensation for suffering a disadvantage, e.g. exposure to pollution) reflects their ordering of preferences; if they are prepared to pay more for one service than for another, then it seems reasonable to infer that the first service impacts more positively on people's welfare (or at least on their perception of their own welfare).

While it is recognised that willingness to pay depends on ability to pay, any ethical or equity issues that arise should be noted in the CBA report and on the summary CBA table, but discussed separately. It is generally not practical to attempt to quantify them and include them in the numerical evaluation.

8.5.1 Social costs

These are primarily applicable to the Public Sector (for guidelines refer to the CABX[21] [MS1]tool that advises on estimating the dollar value impacts of policy changes, drawing from a common database of impact values - these intended for social investment) and require consideration of:

- All impacts (including financial, social and environmental) that can be identified, whether they can be quantified, being specific about which individuals or groups will be affected, how and when
- Secondary impacts such as opportunities to train individuals for employment that may increase their income, quantifying these impacts if and monetising them by converting them into a dollar value, i.e. 'money saved from reduced social costs. Ranges may also be used, with wider ranges indicating more uncertainty. Benefits are to include Government benefits (costs) and wider societal benefits (costs).
- The additional positive and negative impacts of the proposal compared to what would happen if the proposal doesn't go ahead (the counterfactual).
- The CABX tool requires discussion of the assumptions, the evidence informing your analysis, assessment of the strength of this evidence, and how well the results can be applied to the proposal. It requires specific discussion about how effective the policy is assumed to be across different groups (i.e. is there a positive impact for all students on a training programme, or only the ones who complete the course) and which assumptions have the greatest impact on the results of the analysis.

[21] https://treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool

Care must be taken to ensure that identified social benefits from new small-scale heat plant would actually occur in practice and that there would not be, for example, just a transfer of already employed people from one sector to another.

8.5.2 Avoided cost of current heat supply

If the proposed heat plant is necessary to replace an existing heat plant, the reduction in the cost of owning and operating the existing facility may be considered a project benefit and quantified into the financial calculations. The benefits may arise from such areas as the avoided need for engagement of contractors, annual boiler surveys, removal and disposal of ash, cost of disposal of waste biomass, reduced operator time input and reduced requirement for on-site operator input because of remote monitoring capability and alarms.

8.5.3 Future proofing the business

Replacement of old equipment, even if it may still have some life in it, may be an appropriate decision to make in order to set up site operations for the future. This may apply, for example, if the old equipment constrains capacity to take on future new activities. Such future business benefits may be difficult to monetise but should be noted to decision makers if they are material.

When considering future heat demand it is important to undertake consider the risks of not acquiring what may be initially surplus capacity, as subsequent installation of a second heat plant may be an expensive option.

8.5.4 Green credentials

Marketing products manufactured using renewable energy rather than that from fossil fuel may offer significant brand value. This may be considered tangible depending on the business' view on consumer's preferences regarding the source of products and their green credentials.

The use of "green fuels" eliminating emissions to air including CO_2, or a move from a higher emitting fuel such as coal to gas, may be considered to have marketing and public perception benefits with a quantifiable value, or at least intangible benefits that should be assessed and recorded.

8.5.5 Greenhouse gas emissions

A decision to change fuel for heat plant from fossil fuel to renewable fuel can have a significant benefit to a business. There is little current guidance available on how the cost of carbon will affect the cost of fuel into the future, but it seems clear that carbon costs will increase though the level of importance will also depend on whether the business is included within the Emissions Trading Scheme.

Provision has been made in the attached LCOE model for inclusion of an assessed cost of carbon on the cost of fuel but the impact of different future fuel costs should be tested by sensitivity analysis and included in assessment of the risks associated with the project in the business case.

8.5.6 Air pollution

A material issue from fuel combustion (including coal, wood, diesel and light fuel oil, and to a lesser extent gas) is gaseous and particulate emissions to air. In the case of replacement heat plant new resource consent conditions may require lower emissions than those from the existing facility.

For larger heat plants, emissions assessment will be required for a resource consent application. The effect of such emissions is highly specific to the location: if a plant is located where the population is low or where wind blows the particulates away from residential areas, then the potential effect is much reduced.

A new heat plant may be required because the existing heat plant will exceed new resource consent conditions. In this case a business benefit of an alternative compliant heat facility may be the avoided need to close the manufacturing facility itself.

8.5.7 Employment and regional economics

For significant public sector projects the effects on regional communities should be considered. Increased employment and regional economic growth are "all of government" objectives, and if a public sector project contributes to these in a material manner this benefit should be taken into account when analysing the benefits of heating options. This is less likely to be material in the private sector.

Replacement of existing heat plant with modern technology is likely to reduce the need for operator and maintenance support. However, a new plant fuelled with biomass will require the processing of wood into fuel and its delivery increasing employment opportunities overall and may encourage new suppliers to enter the market, or others to expand their capacity.

8.5.8 Footprint of facility

Heat systems, with the exception of the electricity options, require a material area of land for buildings, plant, fuel storage, delivery and handling, emission control equipment and ancillary plant.

This may require consideration of the opportunity cost of the land required and materially impact on the choice of system.

8.5.9 Generic project risks

A range of project risks apply, in some cases fuel dependent, and should be considered in the project analysis as they may affect the selection decision, depending on their impact risks. Such risks include:

- Capital and operating cost risks
- Technical and operational risks, increased with more complex plant
- Alignment with business objectives, and changing business parameters and requirements over time, particularly given a heat plant life of 20-years plus
- Counterparty risks: equipment supply, fuel supply, service and support

8.6 Fuel specific project benefits and issues

Wood fuel

Benefits:

- Elimination of carbon dioxide emissions and emissions of other products of combustion (SO_2, NO_x) in comparison to combustion of coal/oil/gas
- Breaking from dependence on coal/oil/gas fuels and potential supply and price issues, with biomass seen as available long-term on a more stable price path
- No potential exposure to future higher carbon costs
- The marketing and public perception benefits of a using clean, renewable fuel
- Gaining experience of biomass-fuelled energy supply for wider application

Key drivers of project risks and costs and the potential risk mitigations:

- High capital cost, lower fuel cost option
- Large footprint, including fuel storage and access for fuel delivery vehicles, and a boiler house is also required
- For solid fuel (coal and wood fuels (perhaps not pellet)) – larger area requirements for the plant and fuel storage, deliveries required, turn down performance can be quite poor, larger installations have more onerous emission consenting reqs,
- Plant less responsive to load changes, slower than gas or diesel to start, and lower efficiency when turned down
- More onerous requirements for emission consents
- The availability, on a sustainable basis, and satisfactory price path of fuel over the project lifetime:
  - Long-term contracts on including agreed price paths and the risks associated with counterparty contractors
  - The potential availability of fuel from further afield provided as a backup
  - Growth of fuels crops
  - The development of a local or regional market to support supply
- Fuel quality:
  - Ensure a comprehensive fuel specification is agreed and that fuel is delivered to it
  - Variance from specification can mean operational issues, loss of efficiency
  - The relative complexity of this type of plant, requiring higher staffing inputs and expertise, mitigated by:
    - Contract maintenance and operational support to an expert provider
    - Ensure a formal training programme by the supplier is included in contracts
    - Remote dial-in by support provider recommended
- Wood pellets - As for wood chip, but higher quality and more consistent fuel increases benefits and reduces risks.

Diesel and fuel oil

Benefits

- No issues with fuel supply or quality
- Lower capital cost and lower operating costs, offset by relatively high fuel prices Operationally easy, with operation automated and plant is flexible with rapid responses to load changes

Key drivers of project risks and costs and the potential risk mitigations:

- Future fuel costs uncertain, and likely to be increased by costs of carbon emissions
- Emissions of SO_2 and NO_x

Natural gas and LPG

- Lower capital cost and lower operating costs, offset by higher fuel prices
- LPG offers no issues with fuel supply or quality while natural gas has the same benefit where available
- Operation is automated and plant is flexible with rapid responses to load changes

Key drivers of project risks and costs and the potential risk mitigations:

- Some "commentators" are suggesting that natural gas supplies in New Zealand may last only for a limited period, perhaps of the order of 15-years
- Future fuel costs uncertain, and likely to be increased by high costs of carbon emissions
- No other serious emissions, or consenting issues seen

Electricity direct use

- Low capital cost means that despite the high energy (electricity) cost it may be an attractive option for space heating that is required only for limited periods annually
- Installation and maintenance easy and cheap
- Operation very flexible and responsive, support requirements are essentially zero
- It is noted that electricity cannot realistically be stored and is subject to continuity of electricity supply risks.

Electricity via heat pumps

- Lower capital cost than all options except direct use of electricity, easily installed, operated and maintained.
- This and the low effective fuel cost means that this is an attractive option for space or water heating
- In the case of air to air heat pumps has added advantage of offering cooling in hotter periods, though this means that electricity consumption may be higher than that estimated for heat supply only
- Note that the COP drops as required output temperatures rise – refer suppliers)
- No issues with consenting or emissions

Key drivers of project risks and costs and the potential risk mitigations:

- The industry advises that the life of a system is around 15-years, meaning a replacement system will be required at that time
- Maximum temperatures of around 70^{o}C mean it is not effective for producing high temperature process heat

Coal

Benefits

- None, apart from the fuel cost in some locations and the established nature of the combustion technology

Issues

- High capital cost, low fuel cost option
- Large footprint, including fuel storage and access for fuel delivery vehicles, and a boiler house is also required
- High emissions of carbon dioxide and other combustion products (NO_x, SO_2 and particulates)
    - Need for sophisticated particulate emission control equipment
    - Potential consenting issues given emissions

- Potential cost from future higher carbon charges, given the very high levels of CO_2 emissions
- Plant less responsive to load changes, slower than gas or diesel to start, and lower efficiency when turned down
- Potential issues with supply as use dwindles and economics deteriorate
- The marketing and public perception benefits of using the fuel
- The availability of fuel over the project lifetime on a satisfactory price path:
- The relative complexity of this type of plant, requiring higher staffing inputs and expertise, mitigated by:
    - Contract maintenance and operational support to an expert provider
    - Ensure a formal training programme by the supplier is included in contracts
    - Remote dial-in by support provider recommended

9 THE BUSINESS CASE

Each organisation will have its own format and requirements for a project business case, differing in formality, detail and length depending on business requirements and the complexity and cost of each project. The level of detail will also depend on the stage of project investigation. However, at all stages of project development the business case should include all the information covering the life cycle of the project to provide the decision maker with all information, financial and non-financial, necessary to make a sound decision. It must include the financial and non-monetary benefits and costs, explain risks and provide guidance as to the reasons why the investment should be approved.

The following outlines typical business case requirements:

i. **Executive summary:**
    - Short (two-pages max)
    - Summarises case for project and commitment required of the business
    - Designed to give decision maker complete overview of project proposal (it may be all that they read)

ii. **Introduction:**
    - Project background
    - What business problem or opportunity the project addresses
    - Alternative options/solutions considered
    - What the project intends to achieve: outcomes, timescale …

iii. **Description of drivers for the project:**
    - Future heat demand, profile and costs
    - Current heat supply and distribution systems (if applicable)
    - Limitations of/issues with current systems and expected heat-related spend under business as usual

iv. **Alternative options for meeting project objectives:**
    - Fuels available and considered
    - Technologies considered, covering this in sufficient technical detail to satisfy the decision maker
    - Comparative analysis of options:
        - financial outcomes from modelling based on first run of modelling, per Section 6
    - Outline of non-monetary benefits of each

- Risks of each option, with sensitivity analysis summary
- Proposed solution and basis/rationale for selecting it (cost, technology, other considerations such as environmental ….)

v. **Fuel supply for recommended option:**

- Possible sources and contractual arrangements (term, security, delivery, supplier capability) over the expected life of the facility
- Fuel specification and how this will be ensured: moisture, sizing, type …
- Fuel supply risks, and the means of mitigation

vi. **Environmental and social considerations, consenting**

- Site limitations
- Soil and foundation risks
- Possible consenting issues or conditions

vii. **Project costs:**

- Capital costs of:
    - Existing site demolition, modification, or remediation costs
    - Heat generation plant, its installation and commissioning,
    - Civil and structural estimates
    - Electrical and other services connection costs
    - Estimates for the balance of plant items, other equipment
    - Estimates for the balance of plant items, other equipment
- Operational:
    - Costs of operation, maintenance and support
    - Staffing requirements
- Assumptions made and basis
- Level of confidence in costs
- Financial analysis of chosen solution: figures and assumptions made in the financial assessment, i.e.:
    - Inflation assumed
    - Fuel cost escalation above inflation, and basis for this figure
    - The (real) discount rate assumed
    - Contingency figure applied to cost items
    - Company tax rate (28%)
    - Project life assumed
    - Residual value modelled
    - Operational or other savings/benefits associated with dispensing with existing heat supply systems (as applicable)
    - Assumptions around availability, operating hours, annual maintenance

viii. **Key financial parameters of project (from modelling per Section 7)**

- Capital costs
- Operating and maintenance costs
- Modelling outcomes:
    - levelised heat cost
    - Sensitivities

ix. **Non-monetary benefits:**

- Discussion of key issues, benefits

x. **Risks considered, quantified:**
   - Long-term fuel availability and cost
   - Fuel quality
   - Technical risks
   - Capital cost escalation
   - Operating and maintenance costs
   - Staffing levels and capability
   - Counterparty risk: contractors, fuel and service suppliers.

xi. **Project plan/timescale and key milestones**

xii. **Performance measures to apply post commissioning**

xiii. **Recommendation**

10 DISCOUNTED CASH FLOW ANALYSIS – FINANCIAL MODEL

The Excel based financial model for undertaking discounted cash flow analysis is available for free download from www.bioenergy.org.nz/resource/tg14-evaluation-of-heat-plant-opportunities

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