Best practice guideline for life cycle analysis of heat plant projects

Bioenergy Association Technical Guide 14

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About this Guide:

1. The compilation of this Technical Guide has been facilitated by the Bioenergy Association[1].
2. 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.
3. This guide is provided in good faith as an addition to the ongoing body of knowledge relating to wood energy and the wood 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.
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Caveat

Bioenergy Association recommends that any party undertaking a project to upgrade or replace a bioenergy facility should undertake a full evaluation of all possible options prior to fixing on a specific new project solution. As a decision maker, it's important to understand the pro's and cons of each option and have them set out by an appropriate expert in a way that ensures they are easily comparable. Too often a client rushes into a solution without properly evaluating all the options.

1 INTRODUCTION

This Technical Guide is intended to provide guidance to advisers and decision makers considering the installation of heat plant, providing background information and a methodology and tools 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. Analysts may choose to use their own in-house analysis tools but it is suggested that for consistency of comparison between different projects that the input parameters set out in this Guide are used.

The lifecycle analysis is based on identification of 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

Some 52% of heat plants in New Zealand are owned by government agencies. The financial evaluation of proposals for publicly owned heat plant differs in some respects from those for private sector owned facilities. The guideline discusses these differences and provides guidance for each case based on New Zealand Treasury guidelines for analysis related to publicly owned facilities and guidance from other sources for privately owned facilities.

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

The heat produced from the intended facility may be used in a wide range of applications including steam, hot water or space heat. The full scope of the facility needs to be taken into account when considering the capital and operating costs. 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 essence everything for both option A and option B must be included. In this guide there are some examples included in order to help discussion of the methodology but it is a guide to using life-cycle methodology and not a comparison of options.

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.

2 HEAT DEMAND

Before any analysis can start it is critically important that the heat requirements are clearly identified and quantified. What type of heat (temperature and pressure) is required, where is it required and when it is required. A heat demand analysis will provide boundaries for evaluation of options. It will also eliminate some options, or dictate say ancillary equipment eg heat storage.

A heat demand analysis is a key initial part of a life-cycle analysis as it also has to identify possible future changes in the demand profile over the economic life of the facility. The heat demand profile over time may also guide the choice of analysis period.

The heat demand profile will be strongly linked to the future use of the heat and the business risk applying to each option.

Preparing a heat demand profile at the outset not only ensures that everyone is in agreement of what is required but focuses the discussion on feasible options, some of which can be immediately discarded. For example some technologies can not produce high temperature or high pressure steam and so can be ignored. On the other hand if there is a mix of high temperature and low temperature heat requirements in a factory it may be that a low temperature solution can provide the low temperature heat demand, and a smaller high temperature boiler installed only for the high temperature/pressure heat demand, instead of installing an oversized boiler to cover both applications.

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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

The heat demand analysis must always be the first part of the life-cycle analysis undertaken. It sets the framework for: the amount of fuel required; the technology options; identification of uncertainties; and for the financial and risk analysis.

The only thing certain about the heat demand profile over time is that it will not be as currently assumed so this needs to be included for when setting the baseline heat demand profile to be used by the rest of the life-cycle analysis.

3 HEAT PRODUCTION TECHNOLOGIES

This Guide is prepared for the analysis of technology options for the production of low, medium and high temperature and pressure process heat or heat production for commercial scale space heating, but does not cover residential heating. The Guide sets out a methodology for evaluation between options. Reference to the technologies is to assist understanding of the characteristics and parameters that need to be included in the analysis.

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. Alternative technologies not considered in detail by this Guide 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. When undertaking an analysis of those options care should be taken to understand how the costs, performance and risks differ from the options to which they are being compared.

While the focus is on traditional technologies, the analysis principles and methodology may be applied to other heating technologies with inputs to the spreadsheet may require some minor alterations in order to be directly comparable.

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

There are new electrically-based technologies potentially able to displace coal in applications such as milk powder production, but these are also outside the scope of this guide.

4 FUEL, COSTS AND RELATED CONSIDERATIONS

Costs associated with a project will be very specific to the location and the application for which the heat plant is required. Capital costs will be similar across geographies but some costs such as those associated with fuel supply may be very specific to the location. 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). Many of the variable costs may also differ significantly in the comparison of options.

However there is a risk of focusing too much on fuel cost when the characteristics of different fuels maybe important considerations which should be considered at the outset. It is important when considering the different fuels to understand their constraints. A whole of facility focus is required e.g. for hog fuel it is important to know its availability and the implications of moving, storing and using hog fuel as a heating option compared to say pellet or chip biomass fuel. The physical constraints of an option could often be a larger consideration than fuel price i.e. not needing bulky fuel deliveries would favour diesel or electricity vs solid fuels. The turndown efficiency can be important too, solid fuels being relatively poor vs diesel, gas or electricity. Many of the fuel characteristics will affect the assumptions on capital or operating cost.

It is recommended that an understanding of local fuel costs is undertaken before the consideration of technology types as over the life of the facility it is most likely that the fuel cost and availability will change. Some more significantly than others.

4.1 Fuels and their key characteristics

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

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 $0.17- 0.28/kWh, $20-36/GJ	For electricity at 17c/kWh heat cost is in range $10 - 14/GJ, at 28c/kWh 17-23GJ	$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

	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 \$0.17- 0.28/kWh, \$20-36/GJ	For electricity at 17c/kWh heat cost is in range \$10 - 14/GJ, at 28c/kWh 17-23GJ	\$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	55 KT CO_2/PJ	Deemed to be nil	Deemed to be nil	140 KT CO_2/PJ
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
- Indicative costs are as at July 2018

4.2 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 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 $0.17- 0.28/kWh, $20-36/GJ	For electricity at 17c/kWh heat cost is in range $10 - 14/GJ, at 28c/kWh 17-23GJ	$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.

4.3 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 fuelled 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.

Early discussion with fuel suppliers can assist optimisation of equipment to suit the fuel, resulting in significant project cost savings.

4.3.1 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 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 ETS will 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 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.

Other emissions: LFO and diesel are significant emitters of undesirable gases SO_2 and NO_x

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

4.3.2 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: Local connection to the network, which 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.

4.3.3 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. LPG 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. If more than 100 kg on site then hazardous site regs start to apply- costly and hassle. For the analysis clarify who will fund the connection.

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.

4.3.4 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.

4.3.4.1 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

4.3.4.2 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: 62% for very wet fuel, up to 73% for a well-seasoned (air dried) fuel

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

4.3.4.3 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.

4.3.4.4 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.

4.3.4.5 Biomass crops

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

4.3.5 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 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 making consenting an issue

4.3.6 Electricity

Electricity can be used directly or via heat pumps for space heating and low temperature water heating, but not realistic for high temperature/pressure steam process heat. Hot water for medium temperature hot water for say meat processing can be supplied by electrode boilers.

The capital cost associated with electricity-based heat supply is low, but electricity itself is expensive in heat-terms.

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 can add to the cost of electricity supply

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

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

Price: Contracts are available from a range of suppliers, and prices are regionally specific region

4.4 Equipment selection analysis 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) 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 options the effect of equipment sizing and capacity vs the load factor should be evaluated. High load factors favour solid fuel devices, but if there is likely to be a low load factor then the capital cost component will often exceed the fuel cost. Similarly there can often be a trade-off between fuel quality and equipment capability with consequential cost implications. 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 quality.

There is also a trade-off of the amount of operator time required according to the fuel type. Eg a homogenous fuel such as wood pellets and 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 / 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 can often be reduced if:

- Buffer tanks - 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 - Seeing if the peak load can be spread over longer time, i.e. 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 with a 100kW diesel or LPG boiler if there are 'cold-snaps' or as backup. This likely to be cost-effective where the fossil fuel plant is an off-the-shelf appliance such as an instantaneous gas water heater.

4.5 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.

4.6 Operating and maintenance

All 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.

4.7 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.

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

4.8 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.

5 PROJECT ASSESSMENT STEPS

This process 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 is structured under (indicatively) the following eight steps:

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

Step 1: Assessment of required heat and analysis criteria

This key step requires careful consideration of all project parameters and expected outcomes, and the assessment and quantification of the heat requirements that the proposed heat solution is intended to satisfy; as the basis for determining the options for fuel supply and for heat system selection and business case development.

Consideration must include whether the project involves the replacement of an existing heating system, and if so any differences in scale and heat output, or is it a new system? If an existing system is being replaced the dismantling of it is a cost that must be taken into account and changes in scale may mean additional land 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)

This will provide the information required by prospective heat plant suppliers so they can advise on technology and capital costs for the facility. Do not assume that a replacement should be like for like as this may result in the replacement plant being oversized as technologies have advanced.

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 https://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.

6 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 https://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 origional 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 in Section 6 below:

Sheet 0: Introduction to model.

Sheet 1: Capital costs. This sheet comprises a check list of capital cost components of 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.
All costs will not be required in all heat supply options

Sheet 2: Operation 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, so that for inclusion in the financial model.

It is noted that the preferred basis for the calculation of fuel use is the specific fuel consumption of the boiler, this quoted by 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: 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 DCF modelling sheets.

Sheet 5: outputs: This summary/report sheet is fed by the 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 six DCF models, covering different fuel options, each input with data from the Sheet 5. 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.

7 FINANCIAL ANALYSIS OF ENERGY SUPPLY OPTIONS

Modelling Inputs

The following guidance applies to the attached LCOE model, which comprises twelve sheets covering 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, for input into the DCF models **(Sheets 6 - 12)**. Costs can be entered into the relevant cells of the model. Most of the cost categories identified will be incurred in the case of a heat plant solution involving a biomass or coal boiler, but in the case of other fuels requiring a less complicated facility some will not be required and can be left empty.

The heat plant cost 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. Consultants and services include cost areas that are likely to require expenditure, and therefore inclusion in the budget.

For heat pumps a life of 15 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 (**Cell C46**) as a percentage of total estimated costs, are intended to cover the 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 to the DCF models (**Sheets 5 – 11**) 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 electricity-based systems, either used 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:

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

- The total heat required by the facility annually (**Cell E7**) assessed by the analyst, or by external consultants
- The heat production efficiency (**Line 8**):
    - For biomass and coal: applicable to the heat plant using the nominated fuel (secure the figure from the heat plant supplier) and for the nominated operating pattern for all fuels
    - For direct use electricity a figure of 100% can be assumed
    - For heat pumps the supplier 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 **L8**). Care should be taken as COP provided by equipment suppliers is often theoretical. The actual COP in actual performance will depend on location and seasonal variations and must be confirmed with the supplier, or an independent advisor, for the heating period required. There may also be periods in the middle of winter when the COP approaches 1.
- The cost of the energy in the fuel in $/GJ (**Line 10**). Sheet 4, inputs, offers the opportunity to enter potential fuel cost escalation, by fuel scenario, from either escalation in the fuel cost itself, or in the impact of an increasing cost of carbon. Any figure entered should be considered the difference between normal inflation and the potential fuel cost inflation
- The present day cost of carbon dioxide, in $/tonne (**Cell F16**).

The total annual fuel cost, including CO_2 costs, for each scenario **(Line 19)** is transferred via the inputs sheet to the scenario DCF models.

Sheet 4: Economic parameters and scenario inputs

This sheet is used to input business or organization specific business parameters for the modelling process and records the total capital, operating and maintenance and fuel costs which are copied across to the DCF models (**Sheets 6 to 12**) that cover the specific scenarios.

The inputs to Sheet 4 are as follows:

- Assumed fuel inflation rate (**Line 10**). Fuels will escalate in cost at different rates, not least with the potential imposition of higher CO_2 charges over time. The model assumes that the fuel cost increases annually at the same rate as all other costs unless a rate is entered into **Line 10** for any fuel. The inserted figure is the estimated fuel cost inflation figure for that fuel <u>in excess</u> of the figure for general inflation

- Residual value (**Line 11**). This is a nominal figure intended to represent the value of the energy plant at the end of the modelling term, based on the fact that such facilities have a much longer life if well maintained. 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 may make some of the existing equipment redundant and therefore of zero value.

Note that the model for heat pumps 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, after only a short period installed.

- Additional benefits or costs (**Line 12**). 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

- WACC (Weighted average cost of capital) (**Cell C15**):
    - For the public sector project the "discount rate" (equates to WACC) is prescribed by Treasury in real terms. Currently this 6%
    - For private sector investments this is the calculated cost of the business' funding (a weighted average of cost of debt and equity). 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[8] between 7.2 1 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 inserted in **Cell C16**. 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 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 15-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 six fuels, or scenarios:

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

- The annual costs of heat (in year 1), excluding any consideration of capital costs
- The NPV of the heat costs, including capital, over the modelled period
- The levelised costs of heat supply from the scenarios considered in $/GJ, in both table and graphical form
- The sensitivity of the options to changes in input parameters (refer Section 8)

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.

Sheets 6 – 12: DCF models

These sheets show the key details 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 6**).

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.

8 Risk and Sensitivity Analysis

The financial assessment of the heat plant project is 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 around year 5 of the analysis. Sensitivity analysis is a tool for addressing these unknown costs.

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%

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

9 Other considerations and Non-monetary benefits/costs

9.1 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. For example if a new large biomass boiler is likely to provide a stimulus to the consolidation of the solid biomass fuel supply market, 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. These 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.

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 policyareas 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.

9.2 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[9] on the inclusion of benefits:

> *The Treasury Cost Benefit and Better Business Case guidance[10] has a preference (for State Sector expenditure) to analyse benefits 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.”*

https://treasury.govt.nz/sites/default/files/2016-03/managingbenefits-guidance.pdf [13] Page 25 Ibid
https://treasury.govt.nz/sites/default/files/2016-03/managingbenefits-guidance.pdf [13] Page 25 Ibid

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.

9.3 For private sector heating applications there may also be non-monetary[11] and intangible benefits[12] 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.

9.4 Non-monetary benefits

Significant decisions should be accompanied by some kind of CBA[13]*:.*[14]

- *A rough CBA is better than no CBA.*
- *A CBA is primarily about organising available information in a logical and methodical way.*
- *A CBA measures the impact of a decision on the public at large. It should attempt to be value free.*

Different methods should be used to measure the extent to which a proposal fits with decision-makers' objectives and policies.

a) All decisions require some kind of formal or informal CBA. The main purpose of this guide is to encourage all decisions to be accompanied by at least a rough CBA, on the grounds that it is likely to be better than decision-making based on prejudice or instinct. But it should also encourage doing a more comprehensive CBA where the importance of the decision warrants it. This might entail employing specialists where an agency doesn't have the necessary skills or resources in-house.

2. CBA is often rejected on the grounds that some benefits are hard to measure. While that is often true, a CBA is about organising in a logical and methodical way whatever information is available. And some information is always available. As this Guide aims to achieve, the purpose of CBA is not to calculate "the" benefits and "the" costs, but to reduce the degree of uncertainty that would otherwise exist around benefit estimates. There are a number of techniques for doing that. Without these, decision-makers would be left to rely on their own intuitions only, or worse, on the intuitions and prejudices of their advisors.

3. To emphasise this point, it is worth reflecting on the difficulty of intuitively estimating the total value of benefits that are spread across a large number of people, let alone comparing that value with a cost that may be in the tens of millions or even in the billions of dollars. These are sums that most of us have little experience with in our personal lives and find very hard to comprehend at an intuitive level. Systematic methods are therefore required for comparing the benefits and costs with each other.

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

[13] Page 25 Ibid
[13] Page 25 Ibid
[13] Page 25 Ibid
[14] Page 6 Guide to Social Cost Benefit Analysis, July 2015. https://treasury.govt.nz/sites/default/files/2015-07/cba-guide-jul15.pdf

programme. They can include improvements in areas such as risk exposure, social, cultural, heritage, and the quality of services provided to New Zealanders.

The same principles and level of rigour applied to monetary benefits should be applied to non-monetary benefits.

Often non-monetary benefits can be monetised using CBA techniques such as those in the Treasury CBA guidance[15]. While this is an excellent technique for being able to compare projects across varying outcomes to aid decision makers, this monetised outcome should not be used for non-monetary benefit realisation purposes as there is usually no associated cash flow impact.

The key to identifying the appropriate non-monetary metric is to ask; "What is the change the project will initiate

The Government Project Portfolio (GPP)[16] guidance provides explanatory notes on nonmonetary benefits to help estimate the level of non-monetary benefit levels 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.

9.5 Benefit identification

Treasury sets out a process of benefit identification that arise from the project linking to achievement of Government policies and programmes[17]:

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[18]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 model (Line 12, Sheet 4, Inputs).

9.6 Value the costs and benefits

- Benefits should be measured in terms of 'willingness to pay', and costs should reflect opportunity costs.
- Values should be adjusted for risk.
- Values should be 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.
- Multiplier effects should be ignored, unless there is high unemployment.

Valuation of costs and benefits is usually difficult. But this is not a reason not to make an attempt. Even a

[15] http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis
[16] http://www.treasury.govt.nz/statesector/investmentmanagement/think/governmentprojectportfolio
[19] 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
[19] 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

rough, back-of-the envelope attempt will 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 surprisingly useful information. In other words, a 'rough' CBA is better than no CBA.

People's willingness to pay for a service (or 'willingness to accept' payment as compensation for suffering a disadvantage, eg exposure to pollution) reflects their ordering of preferences; that is to say, 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). Using willingness to pay (or accept payment) measured in dollars, therefore ensures that all costs and benefits of all project alternatives are compared using a common yardstick.

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 should be discussed separately. It is generally not practical to attempt to quantify them and include them in the numerical evaluation.Social costs

These are primarily applicable to the Public Sector (for guidelines refer to the CABX[19] 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 or not they can be quantified, being specific about which individuals or groups will be affected, how and when
- Primary and secondary impacts such as opportunities to train individuals to get employment that may increase their income, quantifying these impacts if possible. If possible also impacts should be monetised by converting them into a dollar value, eg, '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 impact 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, evidence informing your analysis of these impacts and 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 (eg, 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.

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.

9.6.1 Avoided cost of current heat supply

If the proposed heat plant replaces an existing heat plant the reduction in the cost of owning and operating

[19] 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

the existing heat plant may be considered a project benefit and quantified into the financial calculations. These cost benefits may arise from 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; reduced requirement of on-site operator input because of remote monitoring capability and alarm rectification etc.

If there is a cost associated with transport and disposal of (say) wood residues by a timber processor as waste that will be saved this may be attributed to the project as a benefit.

9.6.2 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 now in order to set up site operations for the future if, say, the old equipment constrains capacity to take on future new activities. Replacement may also result in the new facilities supplying heat at a more appropriate pressure or temperature for new activities or provide incremental volume. Such future business benefits may be difficult to monetise but should be noted to decision makers if they are material.

When considering future demand for heat it is important to undertake a sensitivity analysis of the risks of not acquiring the initial excess surplus capacity. Too often plant is oversized on the assumption that it will be needed in the future. If future capacity is likely to be required analysis of the expansion options should be undertaken as there may be other ways of obtaining the possible expanded capacity. For example, if modular equipment is an option it may be strategic to install one module now and another when it is actually required. This may increase overall capital cost but under a life cycle cost and sensitivity analysis it may be the appropriate decision.

9.6.3 Green credentials

Marketing of product manufactured using renewable energy rather than that from fossil fuel may have significant brand value. This may or may not be tangible depending on the business' view on consumer's preferences regarding the source of products and their green credentials. This can also be important when presenting a corporate image such as "green and friendly" because of the use of renewable energy, rather than being perceived as "dirty" because of use of fossil fuels.

The use of "green fuels" eliminating emissions to air including CO_2, or even 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.

9.6.4 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.

9.6.5 Air pollution

A material issue from the combustion of fuels, including coal, wood, diesel and light fuel oil, is the emission of gaseous and particulate emissions to air. A new facility may have resource consent conditions which require emissions reductions compared to the existing facility but assessing the benefits of the resulting clean air of this is difficult, even if the reduction is significant.

For larger heat plant where emissions calculations are required for a resource consent application a useful reference is the cost of air pollution which can cause fatalities amongst people (normally those in poor health). Health effects are mainly caused by very small particles of less than 10 microns in diameter, referred to as PM10. Epidemiological studies suggest a 0.101% increase in daily death rates (across the population as a whole) for a 1 microgram per m^3 increase in PM10.

Based on UK costs (assuming similar death rates and adjusting for New Zealand costs of life), the annual mortality costs in New Zealand have been estimated by the New Zealand Transport Agency at $30 per person exposed per year per microgram/m^3 increase in PM10. This figure can be increased by 30% (based on US and French contingent valuation studies) to take account of poorer health amongst those who do not die, to give a total annual cost of $40 per person per year per microgram/m^3. By contrast, health costs of ground level ozone are believed to be an order of magnitude less[20].

This effect is highly geographically specific. If a plant is located somewhere where the population is low or where the 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 facility will exceed new resource consent conditions. In this case the business benefit may be the avoided need to close the manufacturing facility with the value of this the subject of a range of business considerations including the analysis of the heating options and associated risks.

9.6.6 Employment and regional economics

Increased employment and regional economic growth are all of government objectives and so if a project contributes to these in a material manner these should be taken into account when analysing the benefits of different heating options for public owned heat plant facilities. This is less likely to be material in the private sector.

Replacement of existing heat plant with new is likely to reduce the need for operator and maintenance time. However, a new wood-fuelled plant fuelled with biomass may mean that the processing of wood into fuel and delivery to the end use site increases employment opportunities overall. If the wood fuel is for a new large facility there is a greater driver for new employment.

Most significant is the value even a small new demand for wood fuel can have on creating new business if it supplements other small new wood fuel demands. In a locality where there is not currently a significant number of wood fuel suppliers the lure of a number of small wood fuel supply contacts may be enough to encourage new suppliers to enter the market, or others to expand their capacity.

For evaluation the actual effects on regional communities should be considered.

[20] See NZTA (2013); Maibach, M., Banfi, S., Doll, C., Rothengatter, Prof. W., Schenkel, P. Sieber, N., Zuber, J., (2000).

9.6.7 Land use changes

Most heat plant investments will not affect land use. However an increased demand for wood fuel may encourage over time land use changes to increase fuel supply impacting on farm and forestry productivity. If the new demand for wood fuel is big enough to stimulate a farmer to make better use of parts of their farm which is currently under utilised. This encouragement of a new land use activity may be beneficial from a public good perspective.

9.6.8 Footprint of facility

Heat systems, with the exception of the electricity options, require a material area of land for buildings, plant, fuel storage and handling, emission control equipment and ancillary plant. Additionally, a flue is required for the discharge of gases produced which may impose height and aesthetic issues.

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

9.6.9 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, depending on the impacts of the risks, effect the selection decision. 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

9.7 Fuel specific 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
- 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
- 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 some 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
- A project risk for electric heating options is the continuity of electricity supply during very bad weather when storms can adversely affect the electricity distribution network. In many cases it is during bad weather that the heating is most required, particularly for applications such as rest homes. If supply of heat is required at all times then either provision for backup heating equipment needs to be included in project costs

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
- 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
- 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
- High emissions of carbon dioxide and other combustion products (NO_x, SO_2 and particulates)
    - Need for sophisticated particulate emission control equipment
- Potential cost from future higher carbon charges, given the very high levels of CO_2 emissions
- Potential issues with supply as use dwindles and economics deteriorate

- The marketing and public perception benefits of using the fuel
- Potential consenting issues given emissions
- 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

10 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**

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