final report

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Cogeneration Cost Benefit Analysis:

Description of Spreadsheet and Basis of Calculation

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Cogeneration Cost Benefit Analysis

Description of Spreadsheet and Basis of Calculation

Contents

1 Introduction

Cogeneration is the simultaneous production of both electrical power and utilisation of the waste heat from the generator engine. Cogeneration can also be referred to as Combined Heat and Power (CHP). Typical cogeneration installations in meat works are based on providing the electrical power by using a natural gas fuelled reciprocating engine generator and utilising both the engine cooling water (jacket water) and exhaust heat to provide hot water and/or steam for use on site. Overall efficiencies of greater than 80% can be achieved typically (and up to 88%).

The electrical power generated replaces the cost of grid purchased electricity. The quantity of fuel gas consumed is increased to generate the electricity, but there is a saving of some of this gas consumption in reduced boiler firing. Because of the high efficiency of the system there is a significant reduction in the emissions of CO_2 when compared to supply of electricity from the grid.

Cogeneration should especially be considered where it can avoid costs of other proposed capital works such as increasing the capacity of the grid supplied electricity, or the installation of new boilers. If there is also the possibility of using a locally available biogas fuel source, then this can improve the economics dramatically.

Cogeneration can also provide improved reliability of power supply, which is of particular interest for abattoirs located in a remote area with brown-outs or black-outs occurring frequently.

A spreadsheet based calculator for the cost benefit analysis of cogeneration in a typical meatworks has been developed for the MLA/AMPC. This report describes the inputs, outputs, assumptions and calculations used in this spreadsheet. The spreadsheet described here is the excel file “Meat Cogen CBA v1_1.xlsm” with issue date of 30 May 2012 produced by SDA Engineering. The purpose of this spreadsheet is to assist in making a preliminary assessment of the indicative viability of possible cogeneration. It is assumed that should this analysis indicate a satisfactory financial result to the operator of the plant, a detailed engineering study and further financial assessment would be undertaken.

2 Using the Spreadsheet

Users of the spreadsheet should be familiar with their meatworks operation, so that they can make their own judgement about the suitability of the inputs to the spreadsheet. The spreadsheet is not intended to replace a site specific study to assess the merits of cogeneration, but will provide guidance to the possible benefits of a typical installation only. The user is prompted to acknowledge a disclaimer at the program start up before proceeding with use of the spreadsheet. By no means can use of this spreadsheet be taken as investment advice or an investment recommendation. It is assumed that the user has a valid installation of Microsoft Excel installed on their computer, and is familiar with its use. Please ensure that macros are enabled within the excel environment when using the MLA/AMPC Cogen CBA spreadsheet.

The user input and outputs are located on the "Cogen" tab. Other worksheet tabs with calculations and tabulated data are not required to be edited and are hidden from the end users.

All spreadsheet cells are locked from selection and editing, except those cells highlighted in pink/light maroon, where user inputs are required. The blue cells are summary outputs. There are general help comments about the required inputs located to the right-hand side in column E.

	A	B	C	D	E	F
1						
2		**Meat Processing, Cogeneration Cost Benefit Analysis**			SDA Engineering Pty Ltd	
3		Version 1.1	30-May-12		www.sdaengineering.com.au	
4						
5		*Site Name*	Test Sample			
6		*Reference Date*	May 2012			
7						
8		**Input data from typical monthly bill**		**units**	**comments**	
9	1	***Electricity Costs***				
10		**Contract Charges**				
11		Peak energy consumption	0.075385	$/kWh (rate)	Price for electricity during peak times including distribution and	
12		Off peak energy consumption	0.036922	$/kWh (rate)	Price for electricity during off-peak times including distribution a	
13						
14		large scale generation certificates	0.003434	$/kWh (rate)	include distribution loss factor	
15		Small scale technology Certificates	0.006712	$/kWh (rate)	include distribution loss factor	
16		AEMO Market fees	0.0004617	$/kWh (rate)	include distribution loss factor	
17		AEMO Ancillary charges	0.000623	$/kWh (rate)	include distribution loss factor	
18		Others peak	0	$/kWh (rate)	set to zero if all peak charges are included above	
19		Others off peak	0	$/kWh (rate)	set to zero if all off-peak charges are included above	
20		metering charge	92.55	$ (rate)	for information only	
21		**Network**				
22		standing charge	12.44	$ (rate)	for information only	
23		peak consumption charge	0.020122	$/kwh (rate)	set to zero if all peak charges are included above	
24		Off peak consumption charge	0.011455	$/kwh (rate)	set to zero if all off-peak charges are included above	
25		Contract Demand charge	4.5699	$/KVA	for information only	
26						
27		**Total tariff peak**	**10.67377**	**c/kWh**		
28		**Total tariff off peak**	**5.96077**	**c/kWh**		
29						

Startup | Cogen

Ready

3 Inputs

3.1 Electrical Cost

The electrical costs are input in the first section as shown above. Categories for the electrical costs are labelled as per a typical electrical bill. The total cost is summed to provide a cost per kWh of electricity for peak and off peak times. Some data inputs are provided for information only (labelled to match data given on a typical bill) and are not used in the calculation. Note, the structure of electrical charges is different in different states and for different providers, thus some specific charges may need to be included under “others”.

3.2 Electrical Demand

The Electrical Demand inputs are the total peak and off-peak electricity used for a typical one month period. This can be taken from a typical electricity bill. The off peak consumption excluding weekends should be calculated by the user and is used for cogen off-peak operation. A typical meat works does not operate over the weekend, so the cogen would only be required for off peak power during weeknights. The hours of operation entered per section 3.5 below should also reflect the actual hours of operation used for the off-peak operation without weekends.

Proportion of average power is used to account for the variability of the load. If the power consumed on site is steady the proportion of average can be higher. A minimum import power is provided to ensure that the generator does not produce more power than required at any time (eg during a sudden stop of equipment).

	A	B	C	D	E	F
29						
30	2	*Electricity Demand*				
31		Peak energy consumption	688290	kWh	Total consumption for the month during peak hours	
32		Off peak energy consumption	558902	kWh	Total consumption for the month during off-peak hours (for info	
33		Off peak consumption exclude weekends	370984	kWh	Actual off peak electricity consumption when operating (boilers	
34		Maximum Demand	2404	kW	from bill	
35		Average load at peak demand	1955	kWe		
36		Average load at off peak, operating days only	2108	kWe		
37		Proportion of average power (peak hours)	0.90		proportion of average power that could be delivered by cogener	
38		Proportion of average power (off-peak hours)	0.90		proportion of average power that could be delivered by cogener	
39		Minimum import power	200	kWe	A minimum import power is set to ensure no export to grid. Dep	
40		With or Without Off-Peak operation	☐ Peak Only		select this box to operate the cogen at peak times only	
41						

3.3 Gas Cost

The gas costs are input here. Categories for the gas costs are labelled as per a typical gas bill. The costs are summed to provide a total marginal cost of gas. Some data inputs are provided for information only (labelled to match data given on a typical bill) and are not used in the calculation.

	A	B	C	D	E	F
41						
42	3	*Gas*				
43		Gas consumption	13,785	GJ	Total gas consumption for boilers in typical month during the ma	
44		Gas commodity charge	4.3946	$/GJ	added into total cost of gas	
45		Energy safe vic	0.0227	$/GJ	added into total cost of gas	
46		Commodity charge	0.0339	$/GJ	added into total cost of gas	
47		Transmission charge	1.1836	$/GJ	added into total cost of gas	
48		Other gas charge per GJ		$/GJ	added into total cost of gas	
49		Peak injection charge*	2.388	$/GJ	* not included in calculation of running $/GJ (for information onl	
50		Spot purchases*	186	$	* not included in calculation of running $/GJ (for information onl	
51		meter handling fee*	75	$	* not included in calculation of running $/GJ (for information onl	
52		Network usage*	4323	$	* not included in calculation of running $/GJ (for information onl	
53		O&M*	998	$	* not included in calculation of running $/GJ (for information onl	
54						
55		**Gas Cost per GJ**	**5.6348**	**$/GJ**		
56						
57	4	*Heat demand*				
58		Gas Consumption	26.11	Gj/hr	average per hour based on operating hours	
59		Boiler Efficiency	75%	%	Boiler efficiency (typically 75 to 85% depending on age and condi	
60		Heat Demand	5.44	MWth		

3.4 Heat demand

The total heat demand is calculated from the typical monthly gas consumption. This can be taken from a typical gas bill. Some analysis of the bill may be required to input the gas usage for periods of operation when the electrical demand is high. The boiler efficiency input is used to convert the gas input to the actual heat demand.

3.5 Working hours

The working hours are input here to define peak and off peak times for electricity. These inputs also provide the actual hours and days of operation of the works that correspond to the times of operation with high heat and electricity demand during the typical month. This would typically exclude weekends.

	A	B	C	D	E	F
61						
62		5 *Working hours for typical month*				
63		working days	22	Days	Number of days in billing month that heat demand and power a	
64		peak charge hours	16	Hours	Number of operating hours during peak electricity time	
65		off peak charge hours	8	Hours	Number of operating hours during off-peak electricity time	
66		Generator running hours (yearly)	6019.2	Hours	actual hours x 95% availability	
67						
68						
69		6 *State of Operations*	South Australia		select the Australian State, to allow electricity emissions of carl	
70		Carbon Dioxide cost	23	$/tonne	Do not use CO2 cost here if already included in the Electricity an	
71		State based factor for CO2 emissions from grid electrical power	0.72			
72						
73		7 *Generator*				
74		Manual selection of generator Auto Select Generator	1560	size kWe	Generator size is selected automatically or can be Manually sel	
75		*Autocalculate after setting all inputs*	$ 2,600,000		indicative capital cost of cogeneration installation, without con	
76		Avoided Cost	$ -		reduction of capital requirement, eg due to government grant, a	
77						
78		8 *Financial Inputs*				
79		Project Life	15	Years	Cogen project life for NPV calculation	
80		Discount Rate	8.0%	%	applied in Net Present Value calculation	

3.6 State

The State in Australia where the meat works is located is input here. This is used for calculation of the CO_2 emission savings for the local grid electricity.

3.7 Generator selection

The size of generator is selected here. This can be selected manually or sized automatically by pressing the "Auto Select Generator" button. A typical range of sizes for the generator is provided to select from. Based on the size selected the capital cost of installation for that cogeneration system is estimated. There is an additional input here for the avoided capital cost. The user can input a cost that could be saved if cogeneration was installed, such as electrical supply upgrade or boiler replacement. If a Government grant will provide some of the capital cost then the value of this can be included here too.

3.8 Financial Inputs

The financial inputs of *Project Life* and *Discount Rate* are required for calculation of the project net present value (NPV). No financing costs have been taken into account.

4 Outputs

4.1 Monthly Summary

The first items of the output section are the monthly totals for electricity generated, gas saved and gas used. These are used to calculate the net savings per month for electricity and heating gas.

	B		D	
82	9 *Output*			
83	Tota lkWh generated per month	782,496	kWh	TotalkWh electr ity generated by the Cogen per month
84	Totalboilergas saved per month	3,819	GJ	Gas saving due to use of waste heat from the cogen
85	Gas usage for Cogen per month	7,163	GJ	Gas used to generate electricity and heat above.
86	Est mated net saving for electricity per month	15,218		allowing for running costs of cogen (gas and maintenance)
87	Est mated heating gas saving per month	14,345		cost of gas saved in boiler
88				
89				
90				
91	10 *Cost BeM[it Analysis*			
92	Totalnetsavingannuallywithout002saving	440,823		
93	S mple Payback without C02 saving	5.90	Years	
94				
95	Carbon Dioxide saving annually	4,702	Tonnes	Totalnetsavingforchanges in electricity and gas consumption (
96	Carbon Dioxide saving annually	108,148		
97	Totalnet saving annually with C02 sav ng	548,972		
98	S mple Payback with C02 saving	4.74	Years	
99				
100	Net Present Value (without C02 saving)	1,173,219		
101	Net Present Value (with C02 saving)	2,098,914		
102				
103	11 *Produaion*			
104	Head count of Animals processed annually	165000	head/year	
105	Savings per head processed (without C02 saving)	2.67	S/head	
106	Sangs per head processed (with C02 saving)	3.33	S/head	
107				
108				
109				
110				

Stlrtup

4.2 Cost Benefit Analysis

The cost benefit is presented both with and without allowing for CO_2 savings. The total net saving annually is the sum of the monthly savings over 12 months. A simple payback is calculated based on the estimated capital cost divided by the annual savings.

4.3 CO_2

Annual CO_2 saving is calculated and presented in tonnes and dollars. The dollar value of CO_2 is a single fixed input and no allowance has been made for a time varying price of CO_2. The CO_2 is added to the previous net savings and a simple payback presented again

4.4 Net Present Value

Net present values are calculated and displayed for both cases: with and without CO_2 saving. These are based on the inputs of *project life* and the *discount rate* input under the financial inputs section.

5 Assumptions

It is assumed that the heat load profile matches the electrical demand, which is typical of meat works in Australia. This matching of heat and electrical demand is due to the operations electrical demand peak closely matching the steam or hot water demand peak. Alternatively, sufficient storage of hot water could be available to allow for any mismatch.

The cost benefit is calculated with a minimum import of electrical power from the grid (eg 200kWe). Having no allowance for export of power to the grid ensures easier transmission network compliance (grid safety). A detailed engineering study is required to determine the actual minimum import for a specific site.

Capital cost estimates used in the calculations are typical for cogeneration of the size selected, and do not allow for additional costs. A site specific review and engineering study would be required to determine if there are additional costs of installation of cogeneration.

6 Calculations

6.1 Electrical Cost

Total peak and off peak electricity charges (c/kWh) are determined by summing the component costs.

6.2 Electrical Demand

Electrical demand is used to calculate the generated electricity. Total demand divided by the hours of operation provides the average power requirement. The minimum import power is subtracted from the average power to determine the power to be generated for selecting the cogen size.

6.3 Gas Cost

Total gas cost is the sum of the part costs. This does not include supply charges that are incurred anyway, but only the charges for incremental use of gas.

6.4 Heat demand

The total heat demand per hour is calculated from the typical monthly gas consumption divided by the hours of operation when the electrical demand is high. This is corrected to actual thermal heat required using the boiler efficiency input.

6.5 Working hours

Total yearly working hours are calculated from the hours of operation by the number or days per month.

6.6 State

A look up table of CO_2 emission factors for each state in Australia is used. This data is sourced from the Australian government department for climate change.

Table 1: Indirect (scope 2) emission factors for consumption of purchased electricity from a grid.

State	Emission factor
South Australia	0.72
Western Australia	0.82
Victoria	1.23
ACT	0.90
NSW	0.90
Queensland	0.89
NT	0.68
Tasmania	0.32

6.7 Generator selection

The automatic generator selection is sized based on the average power used multiplied by the proportion of average power input. The generator selected is the next smaller generator from the look up table below.

Table 2: Generator set selection table

Engine	**Electrical output**	Jacket Water heat	Inter cooler low grade heat	Exhaust heat (cooled to 120C)	Total high grade heat	Fuel cons	Fuel cons LHV	Fuel cons HHV	Elec eff.	Therm eff.	Total eff.	Maint rate	Indicative cogen cost*
	kWe	kWth	kWth	kWth	kWth	kW	Gj/hr	Gj/hr	%	%	%	$/kWh	$
1	**600**	317	39	337	654	1430	5.15	5.66	42	45.7	87.7	0.02	1,300,000
2	**800**	409	56	446	855	1891	6.81	7.49	42.4	45.2	87.6	0.02	1,500,000
3	**1200**	606	106	591	1197	2750	9.90	10.89	43.7	43.5	87.2	0.02	2,100,000
4	**1560**	790	134	796	1586	3606	12.98	14.28	43.3	44	87.3	0.02	2,600,000
5	**2000**	978	178	1012	1990	4583	16.50	18.15	43.7	43.3	87	0.02	3,000,000

*2011 prices

After the generator is selected based on the electrical load, the engine waste heat output is calculated to replace boiler gas consumption. The spreadsheet uses only the high grade heat, from the engine jacket water and the exhaust. Intercooler heat is not included as it is at low temperature, but it may also be recovered if the site has a suitable use for it.

A nett capital cost is calculated by subtracting the avoided cost from the cogen cost. It is this net capital cost that is used to calculate the payback and NPV.

6.8 Outputs: Monthly Summaries

The first items of the output section are the monthly totals for electricity generated, gas saved and gas used. These are used to calculate the net savings per month for electricity and heating gas.

6.9 Cost Benefit Analysis

The cost benefit is presented both with and without allowing for CO_2 savings. The total net saving annually is the sum of the monthly savings over 12 months. A simple payback is calculated based on the estimated net capital cost divided by the annual savings.

6.10 CO_2

Annual CO_2 saving is calculated and presented in tonnes and dollars. This is added to the previous net savings and a simple payback presented again.

6.11 Net Present Value

Net Present Value (NPV) is calculated using the input project life and discount rate, assuming a fixed yearly saving as income at the end of each year of project life, and the up-front capital cost occurs at the beginning of year 1. Maintenance costs are estimated and included in the ongoing running costs, though there are major engine services required at specific intervals that mean the costs are not as smooth as assumed in the simple model.

NPVs are calculated and displayed for both cases: with and without CO_2 saving.