Sizing the Cogenerator

Bernard F. Kolanowski, M.E.
Regional Sales Director
Capstone Turbine Corporation

By using the data gathered from the utility bills and the analyzing of that data, a cogenerator can be selected that meets the optimum needs of the facility. One of those optimum needs is not to overproduce either electricity or thermal energy. The other need is to see that the economics are suitable to the customer. Whatever altruistic benefits derive from cogeneration, i.e. environmental and fuel conservation, customers will not be attracted to spending their money unless it shows a fair return on their investment.

The computer is a valuable tool in making this selection. Variables in energy production and hourly operation are easily handled by a computer with the results readily viewable. The following analysis is from a project where the client's actual electrical and gas usage as well as the cogenerator's specifications have been entered to present a complete picture.

Table 1 shows that this customer has consumed 199,264 therms during the year, which cost $122,152; Table 2 shows 4,390,560 kilowatts used at a cost of $307,339 for the energy; and Table 3 shows a demand usage of 10,284 kW, which cost $102,840.

Table 4 depicts how this gathered information is put into the computer and is analyzed.

The computer calculates the cost per therm of the gas; the cost per kilowatt of the electrical energy and the cost per kW of the demand, Lines A-1, A-2 and A-3. The thermal-load factor (amount of gas the cogenerator will attempt to displace) and the efficiency of the heaters used to heat the water are put into the computer, Lines A-4 and A-5.

Line A-6 relates to the hours in which the facility is open on an annual basis. For instance, a hotel is a "24-hours-a-day, 7-days-a-week"

Table 1.

MONTH	GAS IN THERMS	DOLLARS
JANUARY	23,456	$14,379
FEBRUARY	22,867	14,017
MARCH	24,398	14,956
APRIL	18,985	11,638
MAY	15,763	9,663
JUNE	12,457	7,636
JULY	8,956	5,490
AUGUST	4,765	2,921
SEPTEMBER	6,789	4,162
OCTOBER	14,374	8,811
NOVEMBER	22,980	14,087
DECEMBER	23,474	14,392
TOTAL	199,264	$122,152

Table 2. Electric Energy Usage

MONTH	ELECTRIC USAGE KILOWATTS	DOLLARS
JANUARY	294,500	$20,615
FEBRUARY	260,890	18,262
MARCH	306,000	21,420
APRIL	330,980	23,169
MAY	356,700	24,969
JUNE	389,760	27,283
JULY	458,380	32,086
AUGUST	484,680	33,928
SEPTEMBER	513,470	35,943
OCTOBER	368,590	25,801
NOVEMBER	332,450	23,272
DECEMBER	294,160	20,591
TOTALS	4,390,560	$307,339

Table 3. Electric Demand Usage

MONTH	DEMAND USAGE KILOWATTS	DOLLARS
JANUARY	480	$2,400
FEBRUARY	430	2,150
MARCH	490	2,450
APRIL	520	2,600
MAY	760	9,120
JUNE	950	15,200
JULY	1,120	17,920
AUGUST	1,340	21,440
SEPTEMBER	1,244	14,810
OCTOBER	1,080	5,400
NOVEMBER	980	4,900
DECEMBER	890	4,450
TOTALS	10,284	$102,840

business. Even at night, the load factors are quite high in both electrical and thermal load. However, it is usual to select a factor of 90% of the actual hours in a year. So, of the 8760 actual hours in one year it is prudent to use only 7800 hours of cogenerator run time. This allows for scheduled and unscheduled maintenance of the cogeneration system.

The computer has the operating data for the manufacturer's cogeneration sizes in its memory and suggests the size of the system for both the electrical load as well as the thermal load. In the case of our example it is suggesting multiple 120 kW units to meet the electrical load, Lines A-7 and A-8.

Lines A-9 through A-14 represent the rating of the cogenerator(s) in kilowatt production; gas used to run the cogenerators (thermal input); useful thermal energy produced (thermal output); and then the overall efficiency of the system if all the energy is used on site is calculated. In this case it is 88%, Line A-12.

Line A-13 is the computer's calculation of the number of hours needed to satisfy the thermal needs of the facility. This case says over 11,000 hours are needed, which means that the selection of two (2) 120-

Table 4.

Line				
A-1	Is this Cost/Therm OK?		$0.613	
A-2	Is this Cost/kWh OK?		$0.070	
A-3	is this Cost/Demand OK?		$10.00	
	Is Site Time of Use Metered?	yes		
	Will Run Time be in all periods?	yes		
	Demand Standby Charge/kW		0.000	
	Utility Sell Back Rate		0.000	
A-4	Thermal Load Factor		80.00	
A-5	Present Efficiency		80.00	
	Closed Thermal Load Percentage		0	%
	Closed Electric Load Percentage		0	%
	A/C kWh Displaced per year		0	
	A/C Demand Displaced per year		0	
	Useful Thermal Increase per year		0	
A-6	Maximum hours open per year		7800	
	Average therms/open hour		16.35	
	Average kWh/open hour		562.89	
	Average peak demand/month		857.00	
A-7	Thermal Load suggests a	120		
A-8	Electric Load suggests a	120's		
A-9	kW Output Setting		240.00	
A-10	Cogen Thermal Input		22.00	
A-11	Cogen Thermal Output		11.22	
A-12	Total Efficiency		0.88	
A-13	Run Hrs to Meet Thermal Need		11366	
A-14	Estimated Run Hours		7800	
	RUN HOURS EQUAL OR ARE LESS THAN HOURS			
A-15	Gas Cost Eliminated is:		68.62	$
A-16	Current kWh Consumed		4390560	
A-17	Generated kWh		1872000	
	NOTE—GENERATED KWH DOES NOT EXCEED 90% OF			
A-18	Electric Cost Eliminated is:		43	%
A-19	FERC Percentage (42.5% min.)		62.75	
A-20	Cogen Gas Rate ($/therm)		0.290	

(*Continued*)

Table 4 (*Continued*)

Line

	TAXABLE MATERIAL COSTS:	
COGENERATION UNIT:	$178,000	
HEAT EXCHANGERS:	$8,000	
DUMP RADIATOR:	$3,800	
PUMPS (2):	$1,600	
STORAGE TANK:	$0	
PIPE, VALVES & FITTINGS:	$9,000	
EXHAUST PIPING:	$300	
ELECTRICAL MATERIALS:	$9,000	
ELECTRIC METER:	$300	
GAS METER:	$0	
WATER FLOW METER:	$0	
THERMAL & METER SENSORS	$0	
MISC.	$1,000	
CATALYTIC CONVERTER	$12,000	
SUBTOTAL TAXABLE MATERIAL COST:	**$223,000**	
STATE TAX RATE.,	7.75	%
APPLICABLE STATE TAX:	$17,282.50	
ADDITIONAL TAX RATE:	0.00	%
APPLICABLE ADDITIONAL TAX:	$0.00	
TOTAL TAXABLE AMOUNT:	$17,282.50	
	ADDITIONAL INSTALLATION C	
ENGINEERING:	$8,000	
LABOR:	$10,000	
PERMITS:	$4,500	
UTILITY/INTERCONNECTION:	$35,000	
SHIPPING:	$1,500	
RIGGING:	$1,500	
SALES COMMISSION.*	$0	
G & A COSTS	$130,000	
SUBTOTAL ADDITIONAL COSTS:	**$190,500**	

Table 4. (*Concluded*)

Line			
	TOTAL COSTS (LESS TAXES):	$413,500	
	UTILITY REBATE/CREDIT AMOUNT:	$0	
	FIRST YEAR MAINTENANCE COST:	$22,000	
A-21	**TOTAL PROJECT COST:**	**$452,783**	
	PROJECTED PAYBACK (YEARS):	2.34	
	LEASE PERCENTAGE RATE:	10.00	%
	LEASE TERM IN MONTHS:	60	
	LEASE PAYMENT:	$9,620	
	DEPRECIATION TAX BRACKET:	30	%
	Monthly savings WITHOUT Dep.:	$14,041	
	Over/Under lease payment?	$4,421	
	Monthly Savings WITH Dep:	$16,305	
	Over/Under lease payment?	$6,685	

kW units is conservative. The system will not overproduce thermal energy when running 7800 hours per year. Nor will it overproduce electrical energy either. Of the 4,390,560 kW used, the cogeneration system will produce 43% or 1,872,000 kW.

Line A-19 shows a calculation of the FERC efficiency at 62.75%, well over the minimum requirement of 42.5%. It is very possible a third unit of 120 kW capacity could be added to this system with no adverse affects of overproduction or FERC efficiency. For other reasons, such as night-time loads, the analyzer decided to offer the 240-kW system consisting of two 120-kW units.

The next analysis is the comparison of the system costs versus the savings to determine what kind of return on investment the customer might enjoy if he decides to install this system.

The costs come from the manufacturer's price lists and field analysis of the engineering, plumbing, wiring, controls, overhead, etc. to determine a final proposal price. This project would carry a total turnkey price to the customer of $452,783, Line A-21. The word turnkey applies to the fact that all facets of the installation are covered in this price and no hidden or future costs will be borne by the client. The provider installs a complete system, and when finished, he "turns the key" over to the customer as the official owner.

In this case the provider has also offered a maintenance contract to the customer at a cost of $22,000 per year. This contract will cover all routine preventive-maintenance chores such as oil and filter changes, tune-ups and the like; as well as any replacement parts or *components* the system may need over the life of the maintenance contract. That includes engine, generator, pumps, controls and any other included in the provider's contract. This is a very common maintenance contract often referred to as an *Extended Warranty and Maintenance Contract*, very similar to those offered by appliance dealers and manufacturers for one's home refrigerators, air conditioners, etc.

Tables 5 and 6 are the compilation of the input data and the analysis to show the client what he can expect in the way of energy savings and their associated costs versus the cost of the installed system and maintenance contract. Section B of the First Year Cost/Savings Calculations is a repeat of the customer's utility consumption and the thermal load that the cogenerator will displace.

Section C of this analysis is a computation of the cogenerator's savings of both thermal (gas) costs, electrical-energy costs and electrical-demand costs. The analysis shows the cogenerator offsetting 87,516 therms of gas at a savings of $67,061. The 1,872,000 kW of electricity offset will save $131,040. The demand generation of 2880 kW will save another $20,160. Note in the case of demand savings, only 70% of the total demand is taken as a savings credit. The reason for this is that as is pointed out in Chapter 2, if the cogenerator should be down for any 15-minute period during the operating month, the demand credit is lost. Most manufacturers and providers account for the fact that unscheduled downtime may occur during a peak-demand period losing the demand credit for that month. Scheduled maintenance is usually done during the off-peak billing periods for obvious reasons. Even so, the demand savings of $20,160, while important, is only about 10% of the total energy savings of $218,261.

Section D shows the gas used by the cogeneration system during its 7,800 hours of operation. Note that the cost of gas per therm is only $0.29 versus the commercial rate of $0.613 per therm shown in Section B and on Line A-1. This is part of the PURPA agreement for qualified cogeneration facilities that provides the same gas cost to a cogenerator as that of the utility. In other words, the utility pays $0.29 per therm for its gas, and so shall the *Qualified* cogeneration *Facility*.

Table 5.

FIRST YEAR COST/SAVINGS CALCULATIONS

CLIENT NAME:	Business Club
SITE ADDRESS:	1000 Main Street
	Los Angeles, CA 90071
PROPOSED EQUIPMENT:	Two (2) Model ISI-120I
PREPARED:	02-Nov-98

—B—CURRENT GAS CONSUMPTION:			**—B—**CURRENT ELECTRIC CONSUMPTION:	
Annual Gas Expense	$122,152		Annual Elec Expense	$307,339
Current Gas Rate	$0.613	$/therm	Current kWh Rate	$0.0700
Annual Gas Usage	199,264	therms/yr	Annual kWh Used	4,390,560
Avail. Hot Water Load	80	%	Annual Demand Expense	$102,840
Hot Water Heater Input	159,411	therms/yr	Average Demand Rate	$10.00
Cost of Hot Water Gas	$97,722		Annual Demand kW Used	10284
—C—COGENERATION GAS SAVINGS:			**—C—**COGENERATION KILOWATT PRODUCTION:	
Heater Efficiency	80	%	Annual Run Hours	7,800
Heater Offset Required	127,529	therms/yr	Elec Output (kW)	240.0
Added Thermal Load	0	therms/yr	Annual kWh Generated	1,872,000
COGEN Thermal Output	11.220	therms/hr	Current Rate/kWh	$0.0700
Thermal Run Hrs Rqd.	11,366	hours/yr	Total kWh overgenerated	0
Max. Avail. Run Hours	7,800	hours/yr	Utility Sell Back Rate	$0~.00

Table 5 (*Continued*)

Gas Offset With Cogen	87,516	therms/yr	Value of kWh Produced	$131,040	
True Gas Offset Value	$67,061				
—D—COGENERATION OPERATIONAL DATA:			**—C—**COGENERATION DEMAND PRODUCTION:		
Max. Avail. Run Hours	7,800	hours/yr	Annual Demand Generated	2880	
COGEN Gas Input	22,000	therms/hr	Current Demand Rate	$10.00	
Annual COGEN Gas Usage	171,600	therms/yr	Est. 70% Demand credit	$20,160	
Est COGEN Fuel Rate	0.290	$/therm	Standby Charge/kW	$0.00	
Est COGEN Fuel Cost	$49,764		Annual Standby Charge	$0	
			Demand Credit Available	$20,160	
CREDITS & REBATES:			FIRST YEAR COST/SAVINGS SUMMARY:		
Displaced kWh	$0		kWh Savings	$131,040	**—E1**
Displaced Demand	$0		Demand Savings	$20,160	**—E2**
Project Rebate	$0		Gas Cost Eliminated	$67,061	**—E3**
			Cogen Fuel Cost	($49,764)	**—E4**
TOTAL CREDITS/REBATES	$0		Annual Maint Cost	($22,000)	**—E5**
Overall Efficiency	88.23	%	Credits/Rebates	$0	
FERC Efficiency	62/75	%	GENERATED SAVINGS	$146,497	**—E6**

Proposal offered by ISI and is prepared using data supplied by the individual client. ISI can not be held accountable for any inaccuracy. Client should consult their own Accountant.

Table 6.

FIVE YEAR PROJECTED COST/SAVINGS

CLIENT NAME: BUSINESS CLUB
SITE ADDRESS: 1000 Main Street
Los Angeles, CA 90071
PROPOSED EQUIPMENT: Two (2) Model ISI-120I

YEAR	ONE	TWO	THREE	FOUR	FIVE
ANNUAL SAVINGS					
ELECTRIC	$151,200	$158,760	$166,698	$175,033	$183,784
GAS	$67,061	$70,414	$73,935	$77,631	$81,513
DEPRECIATION	$27,167	$27,167	$27,167	$27,167	$27,167
GROSS SAVINGS	$245,428	$256,341	$267,799	$279,831	$292,464
OPERATING EXPENSES					
COGENERATION GAS	$49,764	$52,252	$54,865	$57,608	$60,488
MAINTENANCE	$0	$23,100	$24,255	$25,468	$26,741
TOTAL EXPENSE	$49,764	$75,352	$79,120	$83,076	$87,230
NET ANNUAL SAVINGS	$195,664	$180,989	$188,680	$196,755	$205,235
ACCUMULATED SAVINGS	$195,664	$376,652	$565,332	$762,087	$967,322

INSTALLATION COST (LESS REBATE)	$430,783
FIRST YEAR MAINTENANCE COST	$22,000
TOTAL PROJECT COST	$452,783
DEPRECIATION TAX BRACKET	30 %
ESTIMATED INFLATION RATE:	5 %
FIRST YEAR MONTHLY SAVINGS:	$16,305
RETURN ON INVESTMENT:	42.73 %
PAYBACK PERIOD (YEARS):	2.3

Section E summarizes the First Year Cost/Savings. The kWh savings are $131,040, Line E-1; the Demand Savings are $20,160, Line E-2; the gas savings are $67,061, Line E-3; for a total gross savings of $218,261. But, from these gross savings are deducted the cost of operation: fuel cost and maintenance costs for the cogenerators. Cogen fuel cost is $49,764, Line E-4 as well as D-5.

Annual maintenance costs are $22,000, Line E-5. The overall Generated *Net* Savings are $146,497 for the first year.

Table 6 shows the client what the expected savings are in the first five years of operation allowing for 5% inflation of both savings and operating expenses during those five years. One additional savings item has been added in this summary: depreciation. Since the cogeneration system will be a fixed asset of the client's property, it is allowed to be depreciated over five years and will result in a subsequent tax savings to the client. The analysis shows the client to be in the 30% tax bracket, but his accountant should have the final say in the actual depreciation savings.

The bottom line for this particular client is that for an outlay of $452,783, which includes the first year maintenance costs, he can expect savings over the five-year period of $967,322. When that number is divided by 5 years, the average annual savings is $193,464. Return on Investment is then $193,464 divided by the Investment of $452,783 to show a 42.73% ROI. This also calculates out to a simple payback of investment of 2.3 years.

This is not only a reasonable return on a clients capital investment, it is one that must be noticed and discussed very seriously within that client's management.

ABOUT THE AUTHOR

Bernard F. Kolanowski, a graduate mechanical engineer from Pennsylvania State University, has spent most of his working career in the field of application engineering of cogeneration projects. Starting in the early 70's, he became heavily involved in these projects with Ingersoll-Rand Company. He then moved into the waste-to-energy field, another form of cogeneration. Burning industrial, municipal, pathological and hazardous waste in two-stage, clean burning incinerators at over 2000°F created hot stack gases that could be effectively used in waste heat boilers to generate steam or hot water for in-plant processes.

He decided to enter the small-scale cogeneration field where market size was huge, while the machinery to serve that market was small. Representing various manufacturers in 120 to 120 kilowatt cogeneration systems, he applied that new technology in various commercial and industrial applications from the typical coin-operated laundry to the nursing home, hospital and hotel areas where hot water needs were part of everyday business.

Mr. Kolanowski joined the Capstone Turbine Corp. in 1999 to help exploit the newest technologies in MicroTurbines for on-site electrical generation and resultant cogeneration.

7221 Linden Terrace, Carlsbad, CA 92009 760-431-0930 FAX 760-431-0955 bkolanowski@capstoneturbine.com