Reframing the Economics of Combined Heat and Power Projects

Creating a Better Business Case Through Holistic Benefit and Cost Analysis

One of the biggest hurdles utilities face when initiating a combined heat and power (CHP) project is the ability to communicate the costs and benefits of CHP to decision makers and the public. This is often due to the failure to use economic methods that appropriately calculate the financial outlays and long-term benefits. Without this support, decisions can be based on arbitrary factors, rather than realistically answering the simple question: Is this a good long-term investment?

Better metrics can help utilities get a more accurate picture of a project's actual costs and benefits, and ultimately make more informed decisions about moving a project forward.

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Alternative Metrics for a Better Business Case

The WERF Barriers to Biogas Use for Renewable Energy project found that most utilities are using a basic payback-period method to assess the feasibility of a CHP project – simply calculating how long it takes a project to recoup its costs. However, this method ignores long-term cash flow and the time value of money. What's more, payback periods being used are often as short as three to five years, when a reasonable timeframe could be 10, 20, or as many as 30 years, given that most assets have a multi-decade life.

These overly simplistic calculations produce incomplete information that can lead to flawed decision making. In an environment of competing demands and limited capital, this can make the difference in a biogas project being approved.

Other metrics are available that consider the full-life cycle of a potential project and create a better picture of the long-term value; they are just not as widely used. To illustrate how different financial metrics can affect decision making, WERF researchers evaluated the financial case for capturing energy at one wastewater facility using several methods.

The research team assessed the financial outcome of implementing CHP at the facility, which currently generates biogas, using the standard payback method as well as the following alternative methods:

- Net Present Value (NPV)
- Benefit Cost Ratio (BCR)
- Internal Rate of Return (IRR)
- Equivalent Uniform Annual Net Value (NUV)

Key Factors in Decision Making

When evaluating potential projects it is important to recognize that long-term investments require long-term analysis. Each of the alternative methods in this study recognizes the complete life of an asset and measures the costs and benefits over this period. Several other critical components were also considered.

Time Value of Money

Regardless of which economic method is selected for decision analysis at a utility, considering the principle of the time value of money is critical. One of the biggest shortcomings of the payback period method is that it fails to do this appropriately.

Risk Analysis

Risk analysis can improve decision making by creating a better understanding of what is driving a project's business case. Understanding and quantifying the uncertainty can add value to the process because decision makers can understand how different assumptions have more or less influence on the overall project economics. Then they can focus on those assumptions that influence the economic results most significantly.

Long-Term Sustainability

Long-term sustainability and health of both the utility and community should be the focus of any utility's business case, while also managing short-term financial constraints. By using economic analysis methods that incorporate life-cycle economics, all aspects of sustainability can be improved. Most utilities and their associated infrastructure will be in place 100 years from now, so decisions should be made in that context – not as if the utility will be going out of business in three to seven years.

The Case Study Basis for Comparison

The Orange Water and Sewer Authority (OWASA) is a public, non-profit agency that provides water, wastewater, and reclaimed water services to the Carrboro-Chapel Hill community in North Carolina. OWASA owns and operates the Mason Farm Wastewater Treatment Plant, a small- to medium-sized facility that has a permitted peak month capacity of 14.5 mgd and treats a current average of 7.5 mgd. Thickened waste activated sludge and thickened fermented primary sludge are pumped into digesters where they undergo temperature phased anaerobic digestion (TPAD) to produce Class A biosolids. The Mason Farm facility was the first treatment plant in the United States to be brought online to produce Class A biosolids using TPAD. The system started up in late 2000 and reached stable Class A operation in 2001.

The plant's four digesters are arranged in a series with biosolids passing through three digesters operated at thermophilic temperatures, followed by one digester operated at mesophilic temperatures. The mesophilic temperature is equipped with biogas storage for approximately 90,000 cubic feet. Biosolids are managed using a combination of liquid land application and composting.

Because OWASA's current practice of flaring a significant amount of biogas with useful energy value does not align with the organization's core value of being a steward of sustainable development, OWASA began to evaluate solutions to beneficially use all biogas produced at the Mason Farm facility by implementing CHP.

From an engineering study prepared for OWASA in August 2011, researchers chose one project as the preferred upgrade that would be compared to maintaining the status quo. The preferred CHP project serves as the basis for this analysis and includes the following elements:

- Installation of one, 700-kilowatt (kW) internal combustion engine in the existing engine building with modifications for sound attenuation.
- Construction of two fats, oils, and grease (FOG) receiving tanks with pretreatment and connection to existing odor control.
- Draft tube retrofits to the first-stage thermophilic digester for improved FOG handling.
- Biogas treatment, including hydrogen sulfide removal, moisture removal, digester gas pressurization, siloxane removal, and particulate removal.

Key assumptions used in the analysis include:

- The CHP project has a construction cost of $4,000,000 and an engineering cost of $500,000.
- OWASA is able to obtain a grant of $300,000 to reduce the capital expenditures for the project.
- The planning period for the alternatives is 20 years.
- The financial analyses use a 3.5% nominal discount rate based on the White House's Office of Management and Budget guideline for economic evaluation studies: Circular A94, Appendix C for 20-year investments. The nominal discount rate includes the rate of inflation, which is 1.8%.
- The engine-generator, FOG receiving, biogas treatment, and other associated equipment have useful lives of 20 years.
- Besides the initial capital investment for the CHP project, no additional capital spending for rehabilitation of the equipment is planned. Instead, engine overhauls have been included in the ongoing cost of engine maintenance.
- At the end of 20 years, the salvage value of the CHP and biogas treatment equipment is zero.

Glossary

A Breakdown of Financial Metrics and How They Apply to CHP Project Analysis

Payback Period - the time required for a project to repay its initial capital costs through annual operating savings or the time that it takes for an investment to pay for itself. Payback period is calculated by dividing the initial capital cost by the annual operating cost savings. Despite its widespread use, payback period can be misleading. Although payback period indicates the amount of time required for a utility to recoup its investment in a project, it does not present the overall net benefits or savings of a project relative to its costs. Specifically:

- It ignores the annual net cash flows after the payback period.
- It considers only the period for payback, not the magnitude and timing of cash inflows.
- It overlooks the cost of capital (the time value of money) and overemphasizes the importance of liquidity as a goal of capital expenditure decisions.

Payback period can be misleading because it does not consider the magnitude and timing of cash inflows or the cost of capital.

Net Present Value (NPV) - the value that an investment or project will deliver. Present value is the current value of future cash flows discounted at a selected discount rate. NPV is calculated as the difference between the present value of the annual cost savings (benefits) and the annual costs of an alternative. NPV is sensitive to the discount rate(s) assumed. NPV computations are a summation of multiple discounted cash flows – both positive and negative – converted into present value terms for the same point in time. A change in the discount rate can have a considerable effect on the final output. To counteract this uncertainty, NPV can be calculated for a range of expected discount rates. The alternative with the higher NPV over the expected range of rates is a better investment. Projects with an NPV of greater than zero have a total value that exceeds the value of the costs, indicating that the project should proceed.

Benefit Cost Ratio - a commonly used decision analysis process for evaluating investments based on a ratio known as the Benefit Cost Ratio (BCR). The BCR compares the present value of benefits to the present value of costs by dividing discounted total benefits by discounted total costs. It also is referred to as the savings-to-investment ratio (SIR) when the benefits are derived from the reduction of costs. When a BCR is greater than one, the benefits exceed the cost of the project and the project should proceed.

Using BCR analysis allows a utility to decide whether or not the potential benefits of a given project outweigh the actual costs. BCR calculators are available that take into consideration other factors that make the calculation more robust. Similar to NPV, BCR analysis is sensitive to discount and growth rate assumptions. Since BCR analysis uses a number of assumptions, the accuracy of the metric is a function of the accuracy of the assumptions (i.e., discount rate, project life, inflation, etc.). As BCR is a scaled measure, it provides little guidance on total value added due to a project, such as an NPV analysis would. Not all benefits are easily calculated in monetary terms. This can be a challenge in comparing BCR across alternatives where non-monetary benefits are a primary driver of project need.

Internal Rate of Return (IRR) - the return on investment for a project is calculated by determining the discount rate at which the present value of savings of an alternative is equal to the present value of its costs. The IRR is the point(s) on the curve where the NPV is zero. If the range of discount rates evaluated is fairly narrow and cash flows are relatively constant, it is likely there will be one IRR for a project. In this case, it can be determined using the IRR function in Excel. Multiple IRRs may result if cash flows shift between positive and negative outlays over the planning period (i.e., if future cash varies significantly).

IRR is most useful for evaluating one investment made now with relatively constant future cash flows. If the costs of a project occur later in its planning period, the IRR has a more limited value. For example, a project that requires significant investment at the end of the planning period would not be a good candidate for evaluation using IRR. Using IRR to evaluate such projects may be misleading in that the worse investment may have a high IRR depending on the discount rate used, because capital expenditures in the distant future are discounted heavily to bring them to the present time. Also, if the risks vary significantly between projects, the IRR may not be appropriate. If the risks are equal, the project with the highest IRR should be selected. If a project's IRR is greater than the discount rate, the project should proceed.

Using NPV in conjunction with IRR will give a more accurate assessment of a potential investment. This is because NPV looks at the total value created by an investment, not just the percentage rate of return of an investment.

Equivalent Uniform Annual Net Value (NUV) - a comparison of a project's equivalent uniform annual benefits (EUAB) and its equivalent uniform annual costs (EUAC). EUAB and EUAC are the annual costs that, if paid each year for the project period, would have the same NPV as that of the cash flows. This calculation can be performed using a levelization factor based on the discount rate and the asset life (e.g., 20 years). The PMT function in Excel gives the same result. The difference between the EUAB and EUAC is the NUV. When NUV is greater than zero, the levelized benefits of the project exceed the levelized costs and the project should proceed.

NUV is not as widely used as other financial methods, but it is beneficial when comparing alternatives that have unequal lives or where the life of a project is less than the planning period. Assuming that the alternatives are equally effective over their lives, the project with the highest NUV would be the best investment. Although many CHP alternatives are often assumed to have equal lives that match the planning period, NUV might be used on less-proven technologies with varied anticipated lives, such as a comparison between engines and fuel cells.

EUAB is an annualized notional number that can be difficult to understand. It does not reflect the estimated annual cash flows of the project, which can be important in understanding the cash flow impacts of a project within an overall utility budget. In reality, net cash flows from the project are considerably different from EUAB. The application of EUAB requires fairly accurate estimates of project life and salvage value, which are increasingly difficult to estimate in view of a changing technological and regulatory landscape.

Success Stories: Building the Case for Biogas

Some utilities have already had success reframing the economics of CHP and moving projects forward using alternative financial metrics that consider the full life cycle of an investment. By focusing on long-term economic criteria rather than simple payback, the argument for CHP is almost always more compelling.

The City of St. Petersburg used net present worth and operational savings to justify construction of anaerobic digestion and CHP. The city's digestion and CHP project has a 20-year present worth cost of $30 million less than the baseline $102 million that continued Class-B land application would have cost under future rules. In addition, the project will save approximately $3 million per year in operating costs.

In Massachusetts, a 5-mgd facility estimated that its CHP project would save $300,000 annually in electricity and biosolids management costs.

Using Metrics to Support Decisions

Using the same financial data from the OWASA case study, researchers calculated the metrics described and compared all of them to the payback period method. Alternative 1 compares current operation to the CHP project, assuming constant sludge production over the planning horizon, while alternative 2 compares the current operation to an escalated CHP project, assuming a 2% annual increase in sludge production and escalation of power costs at 1% greater than inflation. For each metric, the calculated values are shown along with a corresponding recommendation for project action. Table 1 shows the results of this comparison and what the decision outcomes would likely be.

As shown in Table 1, the payback period for both CHP alternatives is approximately 12 years. Depending on the utility, CHP projects may be viewed as marginal investments based on a 12-year payback period and may not be accepted. However, all of the other metrics appropriate for long-term project life exceed the threshold values to recommend moving the CHP project forward.

Making Decisions in an Uncertain Environment

Financial evaluation of any project depends on assumptions (e.g., discount rate, project costs, project duration). Even the best estimates have some uncertainty associated with them. The differences between alternative 1 and alternative 2 in Table 1 are assumptions about sludge production and escalation of costs. So, how can uncertainty in assumptions that affect financial evaluation be better understood?

Table 1. Financial Results for Alternative Metrics

Item	Alternative 1 – Constant	Alternative 2 – Escalated
Capital Cost	$4,200,000	$4,200,000
Annual Operating Savings	$334,257	$367,264
Payback Period	12.6 years	11.4 years
Project Action	Dependent on utility's requirements for payback period, this value can result in the project being rejected	Dependent on utility's requirements for payback period, this value can result in the project being rejected
Present Value of Savings (or Benefits)	$9,681,618	$9,929,725
Present Value of Costs	$9,299,692	$9,162,267
Net Present Value	$381,925	$767,457
Project Action	NPV > 0, so consider accepting CHP project	NPV > 0, so consider accepting CHP project
BCR	1.041	1.084
Project Action	BCR >1, so consider accepting CHP project	BCR >1, so consider accepting CHP project
Discount Rate, i	3.5%	3.5%
IRR	4.5%	5.5%
Project Action	IRR > i, so consider accepting CHP project	IRR > i, so consider accepting CHP project
EUAB	$681,209	$698,666
EUAC	$654,336	$644,667
NUV	$26,873	$53,999
Project Action	NUV > 0, so consider accepting CHP project	NUV > 0, so consider accepting CHP project

The Monte Carlo simulation method is a risk-assessment technique that can be paired with NPV, IRR, payback period, or BCR models to statistically calculate an output range based on the uncertainty of input variables. One project can be riskier than another even if they have the same NPV and BCR results. Monte Carlo simulation is used to understand the impact of various risk factors from uncertain assumptions on project benefits and costs.

Monte Carlo simulation can give insight into project uncertainty and factors posing the greatest business case risk.

Monte Carlo simulation uses a range of possible values for each risk factor by assigning a probability distribution to each. This differs from other models where deterministic or 'point estimate' inputs are used. The possible values are derived either from historic data or from a probabilistic distribution. The model can be run thousands of times within these probabilistic ranges to generate a range of outputs.

Monte Carlo simulation is often used for projects that are highly sensitive to certain risk factors. For example, the viability of a CHP project is highly dependent on the price of alternative sources of energy, which is highly uncertain in the long term. A fall in the price of power, for example, may reduce the project's NPV because the benefits of investing in biogas use decrease.

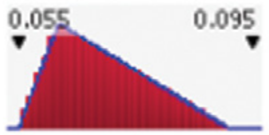
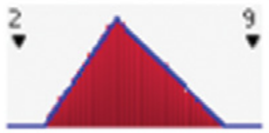
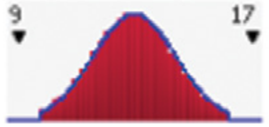
Statistical analysis results, such as those generated by Monte Carlo simulation, require a fundamental background in statistics in order to be understood. Therefore, use of this sophisticated risk analysis requires some education in order to properly interpret the results.

Additional limitations include:

- The user will not get simple formulas, which could help to understand the system.
- The user will not get exact answers – only estimates, which include uncertainty.

Table 2 lists the risk factors for the CHP project and shows the probability distribution of the risk. Figure 1 shows the frequency distribution of NPV, which results from a Monte Carlo simulation of the project NPV model from the case study. The three input risk factors described in Table 2 were modeled, and NPV was tracked to generate the probability distribution results.

Table 2. Monte Carlo Risk Factors

Item	Risk Factor	Graph	Min	Most Likely	Max
1	Cost of Power ($/kWh)		$0.057	$0.063	$0.090
2	Natural Gas Unit Cost ($/MMBtu)		$3.08	$5.00	$7.95
3	Recycle Chemicals Unit Cost ($/1,000 gal)		$10.03	$13.00	$15.99

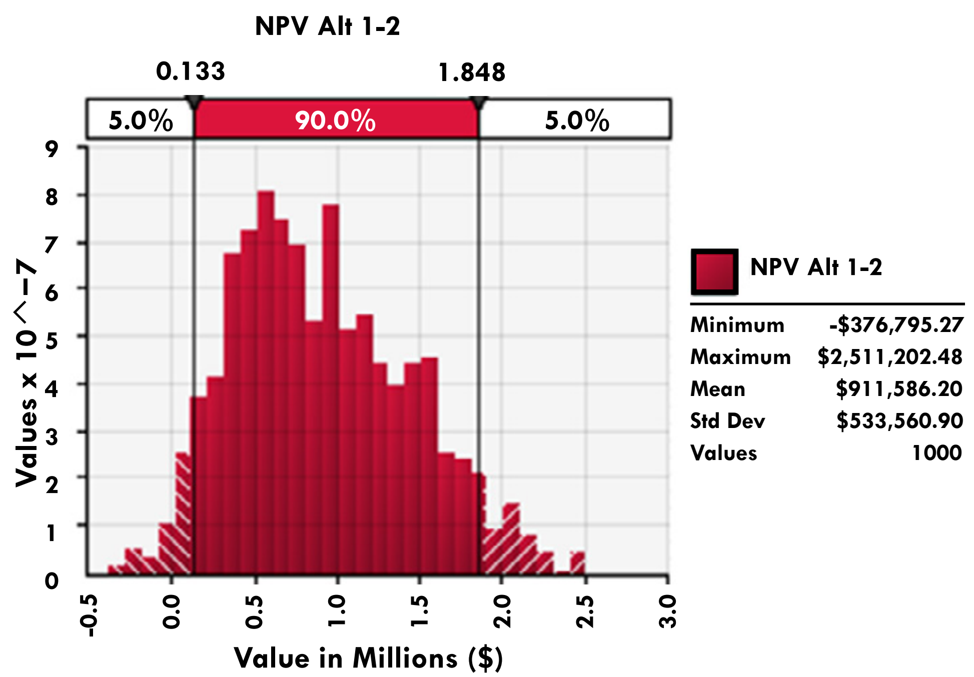
According to the Monte Carlo analysis of alternative 1, the average NPV is $0.91 million when all the likely changes in costs are taken into account. This compares to the original 'point estimate' value of $0.38 million for the same project. The results show the NPV could vary between $0.13 million and $1.85 million at a 90% confidence level. However, within the given input risk factor distributions, the NPV of the project remains positive within a 90% confidence level. The CHP project can be a good candidate for selection. There is less than 5% probability that NPV may be negative for the case study.

Monte Carlo analysis also can analyze which input assumptions cause the greatest variability in project NPV. The regression results from the project Monte Carlo simulation indicate that the NPV is most sensitive to cost of power, while cost of natural gas has almost no effect on NPV outcome.

The Monte Carlo simulation results show that uncertainty in a project's business case results can significantly impact the project's outcome. For example, the results for alternative 1 demonstrate that a risk-weighted average of the project NPV increases to $0.91 million from the original point estimate of $0.38 million due largely to the distribution assumed for future power cost. Monte Carlo simulation also can give decision makers insight into which factors pose the greatest risk to a project's business case. Those factors that are within a utility's control can be managed proactively.

While the sample calculations of Monte Carlo simulation focus on NPV, Monte Carlo simulations can be performed on most mathematical models. Whether a utility prefers NPV, BCR, or IRR for its business case evaluation metric of choice, Monte Carlo simulation can give insight into how uncertain a base estimate may be.

Figure 1. Frequency Distribution of NPV Results



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