

# USE OF TURBINE PERFORMANCE CURVES IN PREDICTIONS OF ENERGY PRODUCTION FOR A COGENERATION RESOURCE RECOVERY FACILITY

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## ABSTRACT

Predicting energy production for a cogeneration resource recovery facility is complex and involves the analysis of many variables affecting performance of the facility. This paper presents a methodology for modeling facility performance which incorporates these variables and facilitates analysis of the impact on energy revenue production of a change in one or more of them. The methodology utilizes the turbine performance curve for the facility, along with data on waste delivery, steam demand, and steam and electricity prices to predict energy revenue production. The methodology presented is well suited to the analysis of maximization of energy revenues.

## INTRODUCTION

The methodology presented in this paper is designed to be used by persons unfamiliar with the application of turbine performance curves in the modeling of performance of cogenerating resource recovery facilities. Most plant managers and engineers are familiar with the use of turbine performance curves and need no instruction on their use or application. However, it is frequently necessary to model the performance of resource recovery facilities in their planning stages in order to estimate revenue production, compare co-

generation to all-electric facilities, or develop an operating plan to maximize revenues. This paper is intended to aid in performing these types of analyses.

Predictions of energy production from a resource recovery facility can be difficult and complex to produce because they require simultaneous consideration of many variables. It is difficult to assess the importance in terms of energy production of any variable on an individual basis, since it is the interrelationship of each variable with all of the others that determines the level of energy production expected. This paper presents a systematic methodology for analyzing these interrelationships and for estimating energy and revenue production. Factors considered in the analysis include the turbine performance curve, quantity and timing of scheduled and unscheduled outages, prices for steam and electricity, and patterns for waste delivery and steam demand.

For a facility that produces only electricity, the results of changes in one or more of these factors can frequently be derived quite easily, and the logic involved is relatively simple and straightforward. For example, it is relatively easy to estimate the effect of reducing the waste throughput from 100% to 90% of design load. A simple assumption about boiler performance and a quick look at the turbine performance curve will yield an estimate of the effect of such a change. However, for a cogeneration facility, the result

of this change requires additional analysis. The impact of this reduction in waste throughput would be dependent upon the time of year, since this affects the level of steam demand, and the individual prices of steam and electricity, since these would determine whether it is more desirable to maximize steam or electricity sales. This is a simple example, but it illustrates why the estimation of energy production for a cogeneration facility should be carried out with care, and how this estimation process can be used to examine the effects of changes in operational and financial variables.

### FACTORS UTILIZED IN ESTIMATING ENERGY PRODUCTION

There are many factors which are utilized in estimating long term energy production from cogeneration facilities. The most important aspect in determining energy production, however, is the interrelationship of all of these factors. For instance, the impact of a change in steam demand on energy production is heavily dependent upon the design of the particular turbine generator being considered, and upon the waste delivery pattern.

The factors involved in energy production analysis include: the performance of the turbine-generator (usually expressed in terms of a turbine performance curve); the expected patterns for waste deliveries and steam demand; the individual prices for steam and electricity; and the quantity and timing of scheduled and unscheduled downtime. In order to predict the energy production from a resource recovery facility, a model must be developed which incorporates all of these factors simultaneously. A methodology for utilizing data concerning all of these factors is presented here, and through use of examples the interrelationship of these variables is explored.

### METHOD FOR ESTIMATING ENERGY PRODUCTION

The methodology presented here for estimating energy production from a cogeneration facility revolves around the turbine performance curve. An example of such a turbine performance curve is shown in Fig. 1. This performance curve is for an extraction turbine, which is a turbine in which some of the steam is extracted for sale to a customer prior to its passing completely through the turbine. What this means is that the steam passes through one section of the turbine and exits that section at a lower temperature and pres-

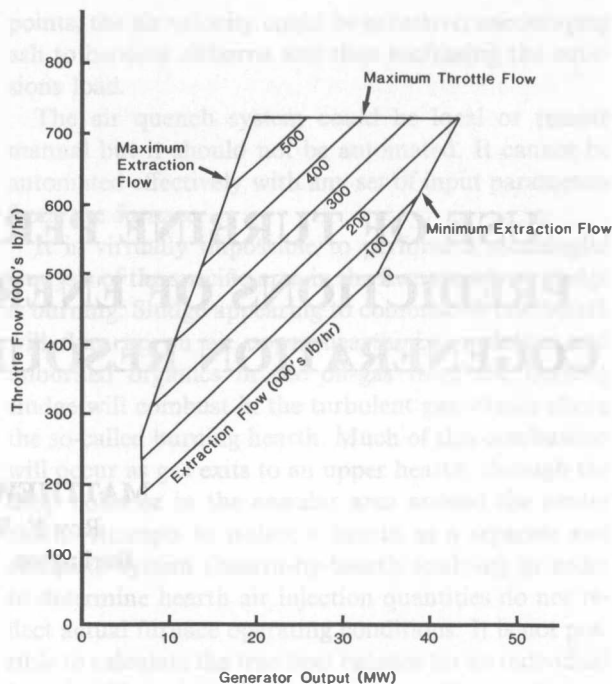


FIG. 1 SAMPLE EXTRACTION TURBINE PERFORMANCE CURVE

sure than when it entered. At this point some of the steam may be extracted for sale. Whatever steam is not sold is passed through the second section of the turbine. The steam that exits the second section of the turbine is condensed. This type of turbine is common in cogeneration facilities.

The turbine performance curve shown in Fig. 1 really consists of a set of curves. Each curve is for a given extraction flow, and shows the relationship between throttle flow (the total amount of steam fed to the turbine) and generator output. For a given extraction flow, it can be seen that the greater the throttle flow, the greater the generator output. There is a limit to how much steam can be extracted for a given throttle flow, since a certain amount of steam must always be passed through the second section of the turbine. These points of maximum extraction flow can be approximated as a line, as shown in Fig. 1.

Before detailing a method for determining energy production, it must be stressed that this is an estimating method, and as such has inherent inaccuracies. For instance, unscheduled outages will be assumed to last one day for simplicity's sake. In reality, the outage may last a few hours, or longer than a day, and so there is some inaccuracy in this assumption. For the

purpose of long-term energy production estimates, these inaccuracies are generally small enough to be acceptable. In order not to overstate the results, it is probably wise to use as conservative a set of assumptions as possible.

This method for estimating energy production consists of a set of logical steps so that it can be repeated consistently and accurate comparisons can be made between scenarios. Refinements can be made to the methodology; however, for clarity it is presented here in its simplest form.

The first step in this estimating method is to determine the interval of calculation. That is, will the calculation be done on a daily, weekly, or monthly basis? This decision depends on the level of accuracy desired, and the detail of data available regarding delivery of waste and demand for steam. The next step is to make some assumptions about boiler performance. Once again, a level of detail must be chosen. The simplest assumption is that boiler performance is constant; that the boiler will produce a certain number of pounds of steam for every pound of refuse burned. A refinement of this is to use a varying boiler efficiency, based upon the throughput. This is more accurate, as a boiler is more efficient at its design throughput than at higher or lower rates. However, in order to do this, the relationship between efficiency and throughput must be determined analytically.

In order to calculate the throttle flow to the turbine, both the boiler performance and the quantity of refuse processed must be determined. The quantity of refuse processed is determined from a projected waste delivery schedule, which will be discussed in more detail later in this paper. The maximum processing capacity of the facility must also be known, since the expected waste deliveries may exceed it, and therefore not all of the waste available will be processed.

The next step is to calculate the steam production from the boilers. The number of tons processed is multiplied by the pounds of steam per ton of refuse to yield total steam production, in pounds. If a varying boiler efficiency is assumed, the pounds of steam per ton of refuse for that particular throughput must be determined. The total number of pounds of steam is then divided by the number of hours in the time interval to determine the steam production in pounds per hour. This is assumed to be equal to the throttle flow into the turbine generator, although in reality there may be some small losses between the boilers and the inlet to the turbine.

At this point it becomes important whether steam or electricity sales are being maximized. Depending on the relative prices for these two products, it will be

more profitable to maximize the sale of one or the other. An example later in this paper will illustrate how to determine which product should be maximized based upon price. Which product is being maximized will affect how the turbine performance curve is utilized in estimating steam and electricity production.

If steam production is to be maximized, two quantities must be known. The first is the steam demand for the time period being considered (which is likely to be variable), and the second is the maximum allowable extraction flow for the calculated throttle flow. The latter quantity can be determined from the line of maximum extraction on the turbine performance curve, and the former is determined from predicted steam demand data. Once these two quantities are known, the steam sold is assumed to be the lesser of the maximum allowable extraction flow and the steam demand. In other words, if the steam demand is greater than the maximum extraction flows, then only the maximum will be extracted and sold; if the maximum extraction flow is greater than the demand, then only enough steam to satisfy the demand will be extracted for sale.

On the other hand, if electricity production is to be maximized the steam sold is assumed to be the minimum extraction flow for the calculated throttle flow, which in many cases will be zero (see Fig. 1).

With the throttle flow and the extraction flow known, it is now possible to use the turbine performance curve to determine electricity production. This is done simply by finding the point corresponding to the calculated throttle and extraction flows, and reading the gross generator output for that point. Frequently this requires interpolating between extraction flow curves. Once the gross electric production is known, the net electric production must be calculated using an assumption regarding in-plant use of electricity. In-plant use of electricity is typically estimated on a kW·h/ton basis, and thus the gross electric production must be converted to kW·h/ton before the in-plant use can be subtracted.

At the end of this procedure, the net electricity production and the steam sold are known for the first time interval. This procedure is repeated for each interval in the year. For periods in which maintenance is planned, the performance has to be adjusted to account for the fact that one boiler instead of two may be operating. In addition, adjustments must be made for periods in which unscheduled downtime occurs. A procedure for estimating downtime occurrences is discussed later in this paper.

The simplest adjustment to account for downtime in the interval being evaluated is to downrate the num-

ber of tons processed by the ratio of operating boiler-days in the interval (number of boilers operating multiplied by the number of days) to the available boiler days in the interval. A more refined procedure is to perform the calculations on a daily basis and to account for the storage of waste in calculating the number of tons processed. When storage is accounted for, frequently the loss of one boiler for a day does not significantly decrease the number of tons processed in a week. This is due to the fact that it may be possible to process waste stored during downtime later in the week by increasing the throughput, provided that the waste delivery rate is less than the throughput design capacity and that adequate storage is available.

Two of the difficulties in applying this method are the interpolation between extraction flow lines on the turbine performance curve, and the repetition of the calculations, particularly when the analysis is done on a daily basis. These two problems can be solved by deriving a mathematical formula for the turbine performance curve, and then utilizing a computer to perform the repetitive calculations. The lines of constant extraction flow can often be approximated as lines or arcs of circles, and thus equations can be derived for them. A single equation relating extraction and throttle flow to generator output can usually be derived with an accuracy of a few percent. As mentioned earlier, the points of maximum extraction flow can be approximated by a line, which is easily converted into an equation. With these formulas derived, the process of computerizing this methodology is relatively straightforward, and greatly reduces the time needed to analyze the effect of a change in any variable.

### SAMPLE CALCULATION

A sample calculation is presented here in order to illustrate the use of this procedure. The following assumptions are made in this calculation:

- (a) The time interval to be considered is a day.
- (b) 1660 tons (1506 t) of waste are delivered in that day.
- (c) Boiler performance is constant at 6500 lb steam/ton (3251 kg steam/t) refuse.
- (d) Steam demand during this time period is 500,000 lb/hr (63.0 kg/s).
- (e) Steam production is to be maximized.
- (f) No downtime occurs during the day analyzed.

With that information, the steam and electricity production can be estimated. When multiplied by 6500 lb steam per ton of refuse, the 1660 tons of refuse yields

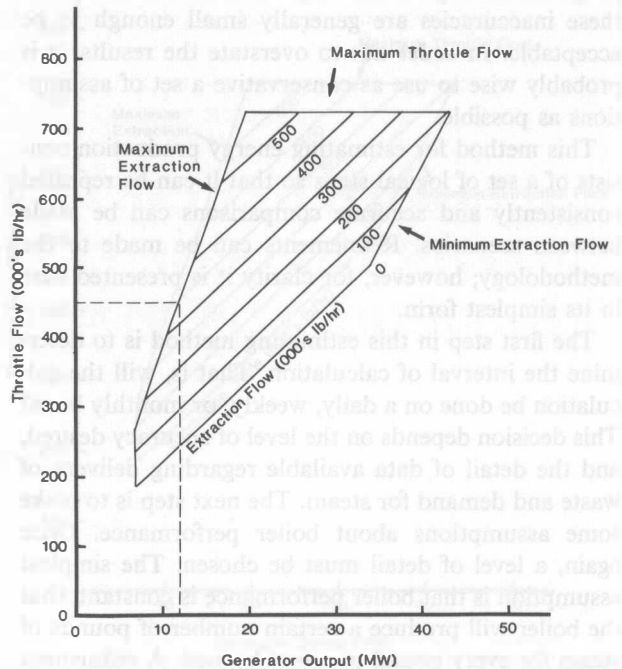


FIG. 2 EXAMPLE OF USE OF TURBINE PERFORMANCE CURVE

10,790,000 lb (4,894,236 kg) steam in a day. Dividing by 24 hr in a day, yields 449,583 lb steam/hr (56.6 kg/s). This is the throttle flow that can be fed to the turbine generator. Since steam production is to be maximized, the level of maximum extraction for this throttle flow must be known.

By looking at Fig. 2, it can be seen that for a throttle flow of 450,000 lb/hr (56.6 kg/s) the maximum extraction flow is approximately 330,000 lb/hr (41.6 kg/s). Since this is less than the demand of 500,000 lb/hr (63.0 kg/s), this is the quantity of steam that will be extracted. The generator output for 450,000 lb/hr (56.7 kg/s) throttle flow and 330,000 lb/hr (41.6 kg/sec) extraction flow is approximately 12 MW.

This example is, of course, limited since it illustrates the operation of the facility for only one day. To produce long-term estimates, the variability of each of the factors are analytically accounted for. It would be helpful, of course, if the turbine performance curve were converted into a set of equations to speed the process of estimating energy production and reduce the errors involved in reading and interpolating the graph. This conversion will be discussed in greater detail later in this paper.

**TABLE 1 COMPARISON OF STEAM AND ELECTRICITY PRICES**

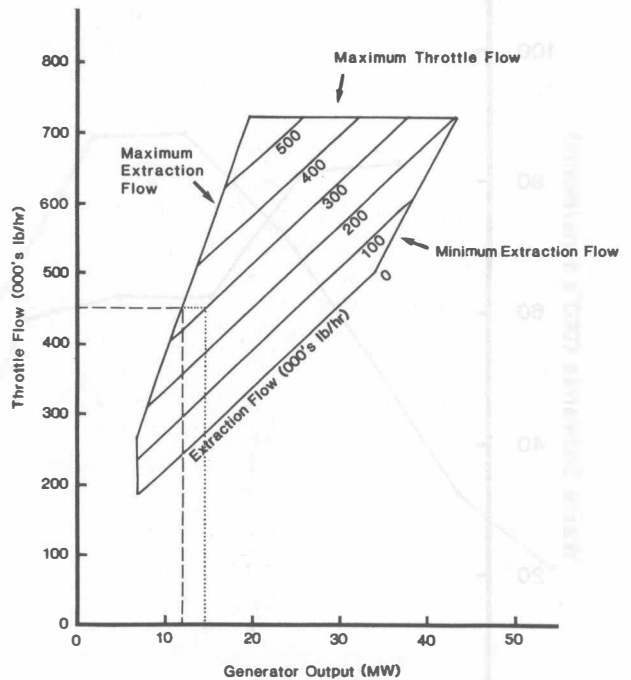
Energy Revenue - High Extraction Flow Case	
Steam Sales: 330,000 lb./hr. x \$7/1,000 lb. x 24 hr./day =	\$55,440/day
Electricity Sales: 12 Mw x 24 hr./day x \$40 Mwh =	\$11,520/day
<b>TOTAL ENERGY REVENUE</b>	<b>\$66,960/day</b>
Energy Revenue - Low Extraction Flow Case	
Steam Sales: 300,000 lb./hr. x \$7/1,000 lb. x 24 hr./day =	\$50,400/day
Electricity Sales: 15 Mw x 24 hr./day x \$40 Mwh =	\$14,400/day
<b>TOTAL ENERGY REVENUE</b>	<b>\$64,800/day</b>
"Equivalent" Price of Electricity	
Equivalent Price = $\frac{\$14,400 - \$11,520}{30,000 \text{ lb./hr.} \times 24 \text{ hr./day}}$ =	\$0.004/lb. = \$4/1,000 lb.

**COMPARISON OF STEAM AND ELECTRICITY PRICES**

For any given waste processing rate, a cogeneration facility can operate in a variety of modes. Steam production can be maximized, electricity production can be maximized, or something in between can take place. Obviously, in most cases attempts will be made to maximize energy revenues. Due to this, a comparison of the steam and electricity prices must be made if an accurate model of how a cogeneration facility operates is to be constructed.

The difficulty is that given a price for steam in dollars per 1000 lb, and a price for electricity in cents per kilowatt hour (kW·h), it is not always apparent which price is "better" since they are not expressed in equivalent units. One method for comparing prices on an equal basis is to convert both to a dollars/Btu basis. In reality, however, the comparison of prices, and a decision on which product is to be maximized must include the performance of the particular turbine generator in question. The question we want to answer is, if the turbine generator is performing at some level, would the facility generate more revenue if less steam were extracted and more electricity produced, or vice versa?

In order to answer this question it is best to look at an example. So far, one level of performance has been estimated based upon the assumption that steam production is to be maximized. If prices are assigned to steam and electricity it can be determined whether, in fact, steam production should be maximized. Assume that the price for steam is \$7/1000 lb (\$0.0154/kg) and the price for electricity is \$0.04/kW·h. Table 1



**FIG. 3 EXAMPLE OF USE OF TURBINE PERFORMANCE CURVE**

shows the revenue generated by the steam and electricity production estimated earlier. The total revenue produced is \$66,960/day.

For the same throttle flow of 450,000 lb/hr, if 300,000 lb/hr (37.8 kg/s) of steam is extracted instead of 330,000 lb/hr (41.6 kg/s), more electricity will be produced. Figure 3 shows the use of the turbine performance curve for this example, and it can be seen that the estimated generator output is 15 MW. Table 1 shows the revenue generated from this estimate of steam and electricity production. The total revenue has decreased to \$64,800/day. It can be seen that maximizing steam production does indeed maximize revenues in this case. A few cases should be examined to verify that the same conclusion is reached at different operating conditions.

A comparison of the steam and electricity prices can be made utilizing this example. This can be done by computing an "equivalent" price for electricity, in dollars/1000 lb. This price is the number of additional dollar of electricity revenue generated by decreasing the extraction flow, divided by the number of pounds of steam which were not extracted. Table 1 shows the calculation for this example, which results in an

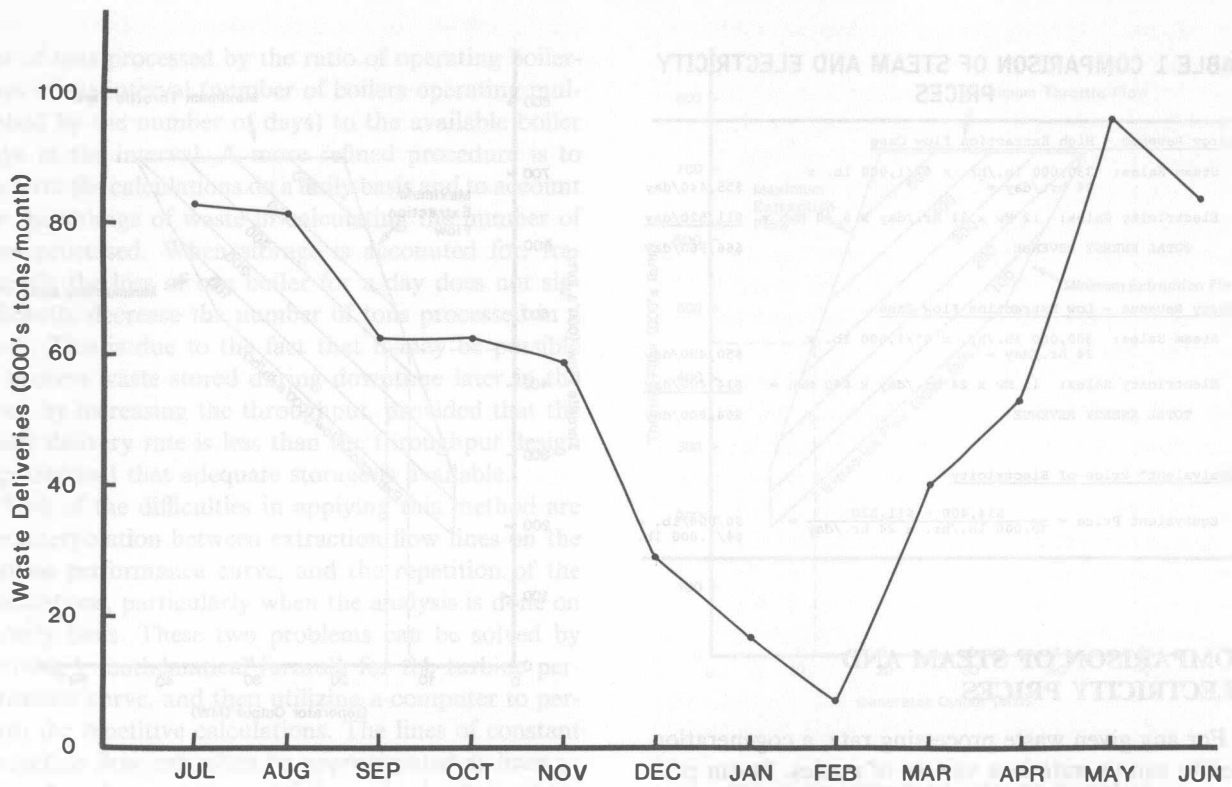


FIG. 4 WASTE DELIVERY PATTERN

“equivalent” electricity price of \$4/1000 lb (\$0.0088/kg). This shows that the \$7/1000 lb (\$0.0154/kg) is considerably better than the price for electricity. This comparison will depend partially on where in the turbine performance curve the calculation is done, but by doing this calculation at a few points, it can be seen that this variation usually does not result in a change in the conclusion that the price for one product is “better” than that for the other.

Another consideration in the comparison of prices for steam and electricity and the impact on operations is the fact that frequently electricity prices vary throughout the day, due to on- and off-peak periods. The result of this may be that at one time of the day steam production will be maximized while at another electricity production will be maximized. If this is the case, this must be included in the model of facility operations. In addition, for long-term predictions the trend of these two prices must be examined. If the prices are fixed contractually for the life of the project, then there is no guesswork in this step. If not, some projection must be made about future prices. In any case, after some prediction about long-term prices is

made, it may be necessary to check on the comparison of prices at points throughout the life of the project. It may be the case that the prices are such that steam production will be maximized in the early years of the project, but the relationship between the prices changes such that in the later years electricity production will be maximized.

#### WASTE DELIVERIES, STEAM DEMAND, SCHEDULED AND UNSCHEDULED DOWNTIME

Several other major variables must be considered in greater detail than the simple assumptions made earlier. The first of these is the schedule of waste deliveries to the facility. Frequently, the annual quantity of waste expected at a resource recovery facility is known, but the distribution of deliveries throughout the year is not. Collection of residential waste often exhibits seasonal variations, and these can have an effect on the operation of a resource recovery facility.

Figure 4 shows a pattern of residential waste collection for a city in the northern U.S. It can be seen

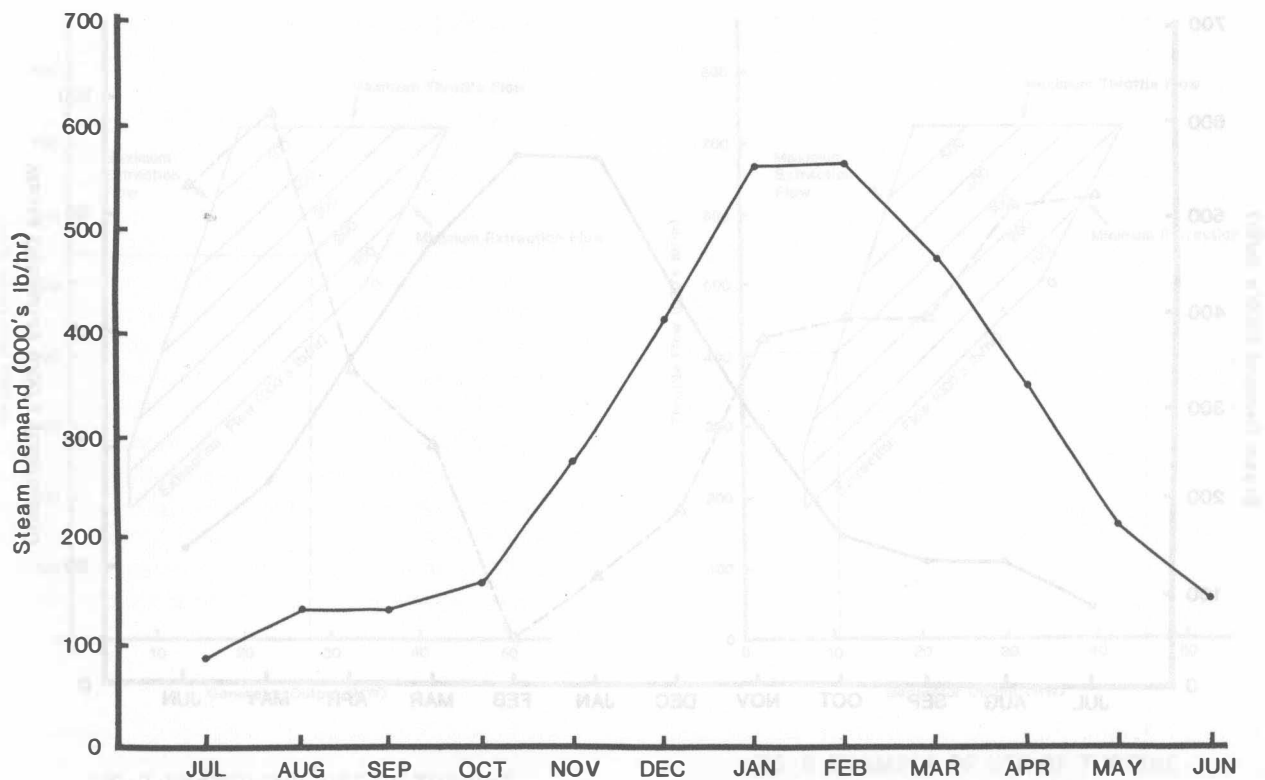


FIG. 5 STEAM DEMAND PATTERN

that the collection pattern has a strong seasonal variation. If only the total number of tons collected were known for this location and a resource recovery facility were sized based upon the "average" daily waste collected, then for a significant portion of the year the waste collected would exceed the daily capacity of the facility, and the annual quantity of waste available would not be processed.

Due to the seasonal variation in residential waste collection in many localities there may be attempts to "smooth out" the waste deliveries to the facility with the addition of commercial tonnage, and a "spot market." This spot market is simply tonnage that is not under any contract to deliver waste to the facility but may deliver there when requested. The long-term trend in waste deliveries must also be estimated, since the annual quantity of waste delivered may increase or decrease significantly over the life of a project, depending upon the local conditions. When the waste delivered to a resource recovery facility is expected to be a complex mix of community, private hauler, commercial, and spot market sources, care must be taken in developing a predicted waste delivery schedule.

Another important aspect in determining energy production for a cogeneration resource recovery facility is the pattern of steam demand. Presumably the reason a cogeneration facility is being considered is that some market for steam has been identified. Once this market is identified, it is important to characterize the market in terms of its seasonal fluctuations in demand, and the long-term trend for annual demand for steam.

If the primary use of steam from the cogeneration facility is heating in a central heating system, then the demand for steam will likely exhibit strong seasonal variations. Figure 5 shows steam demand throughout the year for a city in the northern U.S. It can be seen that while demand does not disappear in the warmer months in this particular case, it is greatly diminished. Even if the steam is to be used in an industrial process the demand for steam may fluctuate throughout the year, and it is important to predict this fluctuation when producing an estimate of long term energy production. The year-to-year trend of steam demand is obviously important as well.

It is necessary to couple the anticipated steam de-

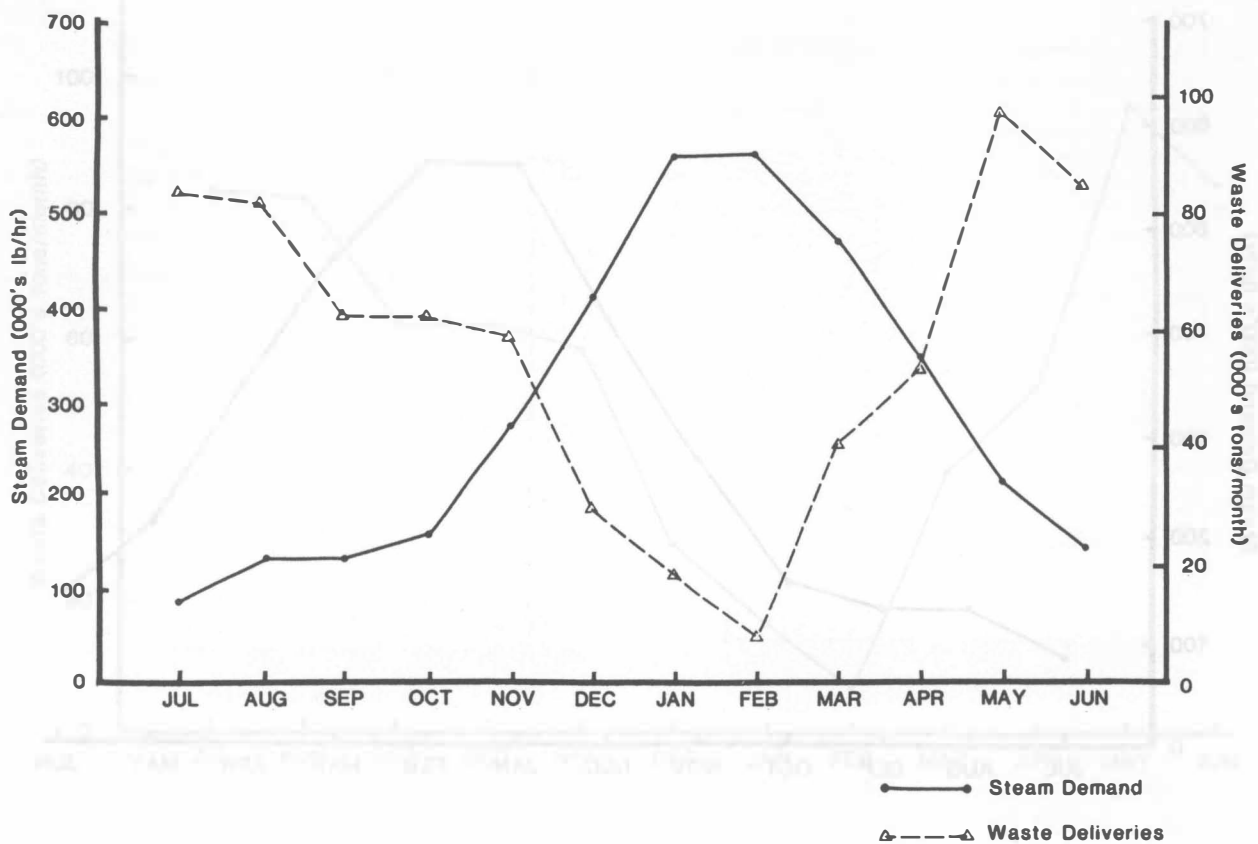


FIG. 6 STEAM DEMAND AND WASTE DELIVERY PATTERNS

mand and waste deliveries to produce the model of performance for a cogeneration facility. In Fig. 6 the steam demand and waste collection patterns discussed earlier are presented on a single graph. Both of these patterns are for the same location. It can be seen that these two patterns do not complement each other. When steam demand is high, waste collection is low, and vice versa. If steam production is to be maximized, then it can be seen that this waste collection pattern would hinder steam sales.

The interrelationship between steam demand and waste delivery patterns also affects the scheduling of routine maintenance. A typical assumption is that a resource recovery facility will experience 85% availability. That is, due to scheduled and unscheduled downtime, each boiler and/or processing train will be unavailable for waste processing 15% of the time. One reasonable assumption that can be made is that the downtime will be evenly split between scheduled maintenance and unscheduled outages. Routine maintenance will be scheduled in such a manner as to

minimize the loss of revenues. Determining when this will occur is not always a simple matter, however.

Unscheduled outages can be assumed to occur on a random basis. The average time of an unscheduled outage is difficult to determine, but since the smallest increment of time being used in this analysis is a day, it is easiest to assume that each unscheduled outage will last one day. For each boiler, unscheduled outages are distributed randomly throughout the time periods that do not involve scheduled maintenance. Thus, probability dictates that some unscheduled outages will occur for one boiler while the other boiler is being maintained, and there may be a few days a year when both boilers are unavailable due to simultaneous unscheduled outages.

The following comparison of two operating conditions reveals the interrelationship of waste deliveries and steam demand, and its effect on scheduling of maintenance. The first operating condition considered here is representative of summer operations, with a relatively high waste processing rate, and a relatively



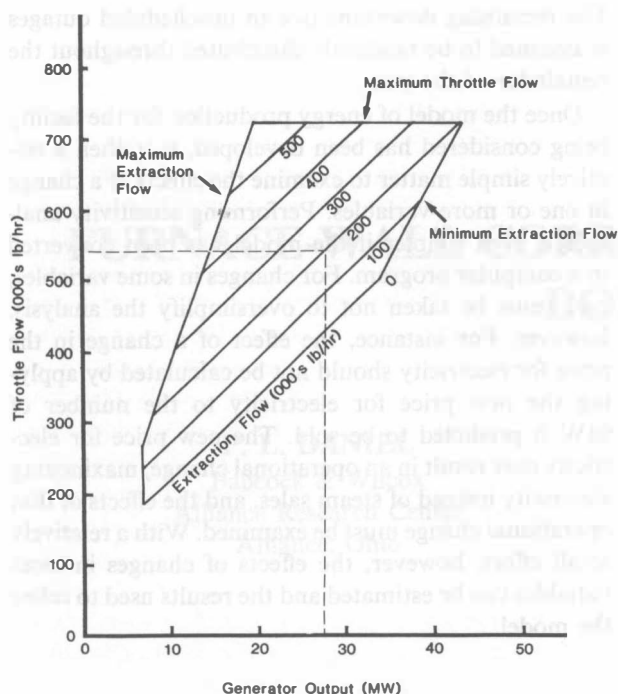


FIG. 7 EXAMPLE OF USE OF TURBINE PERFORMANCE CURVE

low steam demand. The second condition is representative of winter operations, with high steam demand and a low waste processing rate.

The conditions chosen to represent summer operations are a waste processing rate of 2000 tons/day (TPD) (1814 t), and a steam demand of 200,000 lb/hr (25.2 kg/s). Using the same assumptions as used in the previous example, the throttle flow can be calculated to be 541,667 lb/hr (68.2 kg/s). Figure 7 shows that the maximum allowable extraction flow for this throttle flow is 420,000 lb/hr (52.9 kg/s). However, since the steam demand is only 200,000 lb/hr, this is the quantity of steam that would be extracted for sale. The gross generator output for this combination of throttle and extraction flow is 27.5 MW.

Table 2 summarizes the calculations for this example. The gross electric production for the day is 660 MW·h. The in-plant use of electricity is 120 MW·h, resulting in a net electric output of 540 MW·h. Assuming the same prices for steam and electricity production as used in the previous example, the daily energy revenue produced is \$55,200.

For winter operation the processing rate is assumed to be 1500 TPD, and the steam demand is assumed to be 500,000 lb/hr (63.0 kg/s). The throttle flow is

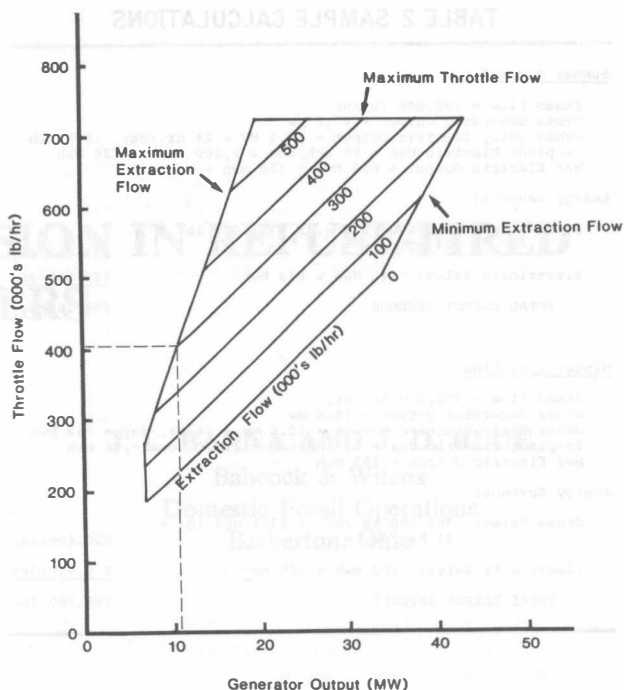


FIG. 8 EXAMPLE OF USE OF TURBINE PERFORMANCE CURVE

406,250 lb/hr (51.2 kg/s), and Figure 8 shows that the maximum allowable extraction flow is 300,000 lb/hr (37.8 kg/s). This extraction flow is less than demand, so that 300,000 lb/hr can be extracted and sold. The generator output is 10.5 MW. Table 2 summarizes the results, which indicate that the expected daily energy revenue is \$56,880.

The purpose of this comparison is to demonstrate that even though more tons are received in the summer, due to the higher steam demand in the winter, and the "better" price for steam, more revenue is generated in the winter. This example demonstrates that unexpected results frequently occur in predicting the effect of a change in a variable or variables on the expected energy production and revenue.

This type of comparison can be used to determine when scheduled maintenance will be planned. While a first guess as to when maintenance would occur would be that it would be scheduled when waste deliveries are expected to be at their lowest, this may not be the case. The above example illustrates that more revenue may be generated during periods of low waste deliveries. Therefore, depending upon what party pays for the landfilling of bypassed waste, and the exact cost

**TABLE 2 SAMPLE CALCULATIONS**

Summer Operation

Steam Flow = 200,000 lb./hr.  
 Gross Generator Output = 27.5 Mw  
 Gross Daily Electric Output = 27.5 Mw x 24 hr./day = 660 Mwh  
 In-plant Electric Use = 60 kWh/ton x 2,000 tons = 120 Mwh  
 Net Electric Output = 600 Mwh - 120 Mwh = 540 Mwh

Energy Revenue:

Steam Sales: 200,000 lb./hr. x \$7/1,000 lb. x 24 hr./day =	\$33,600/day
Electricity Sales: 540 Mwh x \$40 Mwh	\$21,600/day
<b>TOTAL ENERGY REVENUE</b>	<b>\$55,200/day</b>

Winter Operation

Steam Flow = 300,000 lb./hr.  
 Gross Generator Output = 10.5 Mw  
 Gross Daily Electric Output = 10.5 Mw x 24 hr./day = 252 Mwh  
 In-plant Electric Use = 60 kWh/ton x 1,500 tons = 90 Mwh  
 Net Electric Output = 162 Mwh

Energy Revenue:

Steam Sales: 300,000 lb./hr. x \$7/1,000 lb. x 24 hr./day =	\$50,400/day
Electricity Sales: 162 Mwh x \$40 Mwh =	\$ 6,480/day
<b>TOTAL ENERGY REVENUE</b>	<b>\$56,880/day</b>

for that landfilling, the smallest loss of revenue may occur during periods of high waste processing rates.

In order to determine the best time for scheduling routine maintenance, it is necessary to calculate potential energy revenue for at least a few times during the year. Routine maintenance is most likely to be scheduled for two times during the year for each boiler, 6 months apart. Therefore, it is necessary to determine which two time periods, 6 months apart, would result in the smallest loss of revenue if routine maintenance were performed during those time periods. A few sample calculations should result in a reasonable estimate of when these periods occur, and it can be assumed that scheduled maintenance will be performed then.

The remaining downtime due to unscheduled outages is assumed to be randomly distributed throughout the remainder of the year.

Once the model of energy production for the facility being considered has been developed, it is then a relatively simple matter to examine the effects of a change in one or more variables. Performing sensitivity analyses is even simpler if the model has been converted to a computer program. For changes in some variables, care must be taken not to oversimplify the analysis, however. For instance, the effect of a change in the price for electricity should not be calculated by applying the new price for electricity to the number of MW·h predicted to be sold. The new price for electricity may result in an operational change, maximizing electricity instead of steam sales, and the effects of that operational change must be examined. With a relatively small effort, however, the effects of changes in most variables can be estimated and the results used to refine the model.

**SUMMARY**

The estimation of energy production from a co-generation resource recovery facility involves a considerable number of variables. This paper provides a relatively simple methodology for predicting energy production, and through the use of examples explores the significance of the interrelationships between the variables used in the analysis. The application of the energy production estimation method allows the investigation of the impact of a change in one or more parameters, and allows for long term predictions of energy production as well as providing a method for identifying techniques to maximize energy revenues.