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PROJECT EVALUATION AND IMPLEMENTATION

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Prepared by:
RCG/Hagler, Bailly, Inc.
370 L'Enfant Promenade, SW
Suite 700
Washington, DC 20024-2518

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CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE MANUAL

The purpose of this manual is to provide plant engineers with practical guidelines for the identification of opportunities for capital investments to improve energy efficiency, for the evaluation of these potential projects to check their economic attractiveness, and for the implementation of those projects which meet management criteria and are thus approved. The emphasis throughout the manual is practical: the guidelines presented here should allow a plant engineer or energy manager to present his case clearly, concisely and effectively to his plant management.

It is an unfortunate fact that many worthwhile projects are delayed or lost altogether due to poorly prepared investment cases. This manual illustrates the need for analyzing the long-term value of a project within the company strategy, and the importance of risk appraisal in presenting the case.

The manual is divided into three sections:

(A) Project identification, in which a summary of the recommended procedures is given. Extensive discussions of the technical opportunities for energy efficiency improvement are given in other manuals and books, and it is not the intention of the manual to replace these other sources of information.

(B) Project evaluation, in which various methods of evaluating and ranking potential capital investments are discussed. The methods are illustrated through comprehensive examples and case studies drawn from actual plant experiences.

(C) Project implementation, in which important aspects of the implementation of energy-efficiency projects are listed and the monitoring of the results of these projects is reviewed.

1.2 FACTORS AFFECTING THE NEED FOR INVESTMENT

There are many reasons why a need for capital investment arises. Energy efficiency improvement is only one of many factors that plant management must consider when allocating their capital budget. In general, the main factors are as follows:

- Legislative - in manufacturing industries, most regulations affecting operations concern the health and safety of the work force and the control of environmental pollution. Where a plant fails to meet the relevant legislated requirements, management has no option but to allocate funds for the appropriate investments on plant modifications or improvements. Note that investments in this category often reduce the funds available for modernization of conservation but have the highest priority.

- Preservation of market share and expansion - strategic investments to maintain a plant's markets, or to expand market share, are often viewed favorably by plant management. Investments may relate to improvements in the quantity of a product available at a given time, or to the development and manufacture of a completely new product.

- Quality - while it is true to say that all factories must make products to meet defined specifications, it may sometimes be possible to invest in new equipment to allow the plant to make higher-valued products at an enhanced specification. In some cases, an investment is made to ensure the production process meets specifications for a greater percentage of the on-stream time (i.e., less finished product is rejected for reprocessing).

- Cost reduction - this category is quite broad, and there may well be some overlap with other factors such as quality control. An improved consistency of quality, for example, has an impact on the cost of production by ensuring improved yields with less wastage, lower stock levels, less manpower for inspection and rectification of problems, etc., all of which contribute to lowering production costs.

- Productivity - this is a broad category implying the production of the same product (or more) using less resources (of materials, energy, manpower, etc.). Many energy efficiency projects fall in this category and generally they will have a favorable impact on production costs.

- Research and development - this is often a difficult area in which to make out a good justification for capital investment. Unquantifiable returns and uncertain risks are matched by claims of market needs, product development, reduced costs, and improved quality. In fact, the most difficult decision is usually not whether or not to start R&D projects, but whether and when to stop, if results are not promising.

Any or all of the above factors can have an influence on the viability of an idea for an energy conservation investment. It is important to check, at an early stage, how the proposed investment fits into company policy and how investment decisions are to be made within the company. Energy efficiency may appear attractive to the energy manager, but an investment with that objective has to be placed in the context of other investments that are competing for scarce funds. This manual provides guidelines for the evaluation of capital investments, whether for energy-related projects, or for other types of projects. The procedures are common for all cases where investment is involved: rigorous assessment is important for effective use of any resource and capital is simply one form of resource available to company management.

CHAPTER 2: PROJECT IDENTIFICATION

Before any project can be implemented, it must be identified. When the identification process is sound, half the work is done as it is likely that time spent on evaluation will be well used. In this chapter, ways to quickly identify attractive conservation projects are presented.

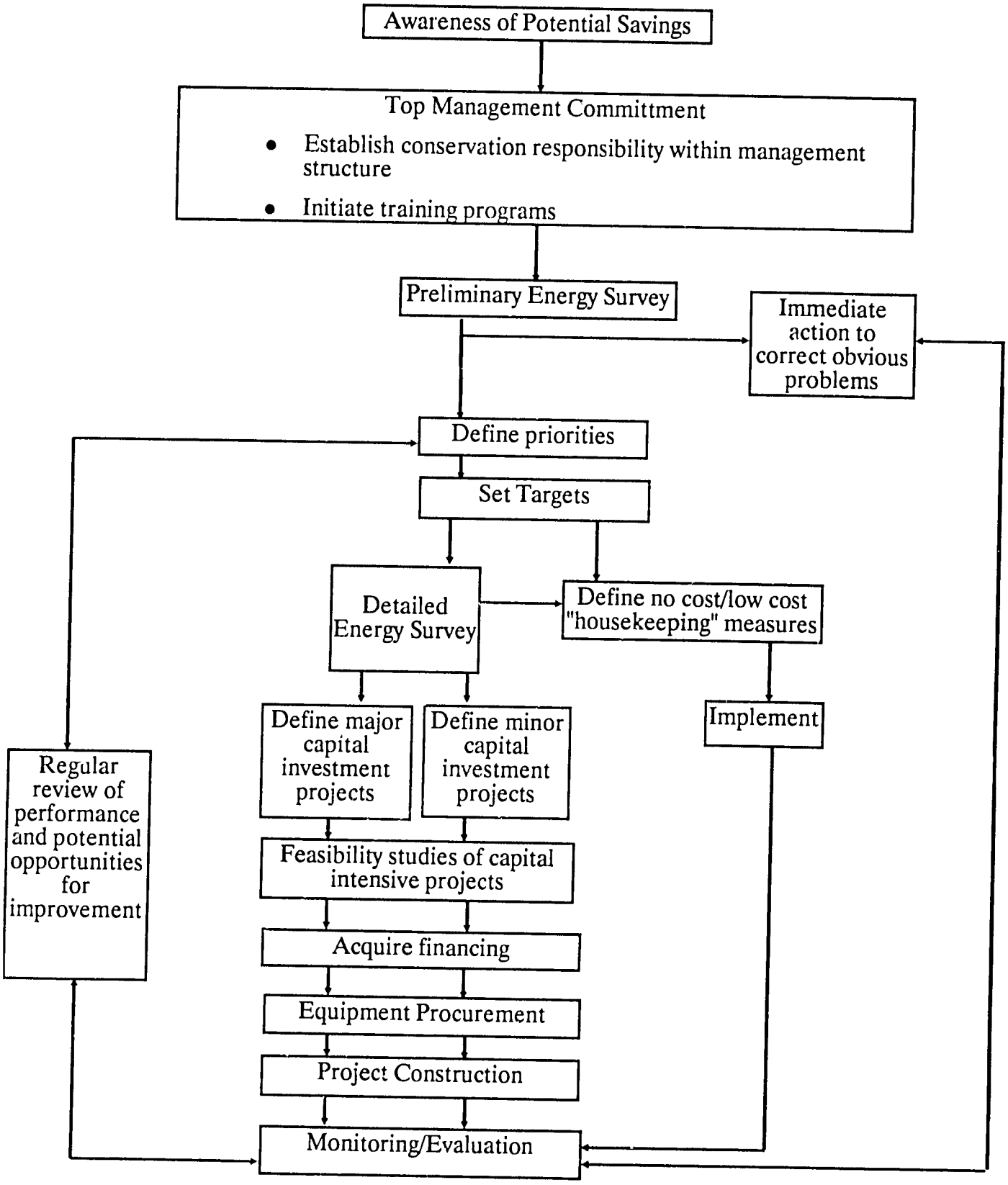
2.1 IDENTIFYING INVESTMENT OPPORTUNITIES RELATED TO ENERGY EFFICIENCY

Many reports and manuals have been written to discuss how energy-related projects may be identified. Very often, an observant plant engineer will see an obvious opportunity for improving energy efficiency and thus will develop his ideas for plant modification or replacement in line with his initial observations. At some stage, he will make an estimate of the cost involved in implementing his ideas and subsequently he will assess the economic viability of the investment. It is at this point that many opportunities are lost as many technically competent engineers lack the skills to properly communicate the financial value of a project to a "bottom line" oriented management.

Where energy efficiency improvements are not immediately obvious, a somewhat different approach becomes necessary. A rigorous "Total Energy Management Approach" is recommended in such cases, as illustrated in Exhibit 2-1. The TEM approach is best described as a logical step-wise process to identify, evaluate, and implement an effective energy conservation program. The process starts with the confirmation of a positive management commitment, an essential precursor to the activities which follow. Without an active management interest, it is most unlikely that any benefits from conservation will accrue to the plant and indeed the financial backing for some of the later activities is unlikely to be forthcoming.

The first "technical" step is usually a Preliminary Energy Survey (PES) which serves to collect basic data on processes, production activity levels, and corresponding energy

Exhibit 2-1
The Total Energy Management Process



consumption and to identify for further analysis those areas that appear to offer the best energy saving opportunities.

A Detailed Engineering Survey (DES) will follow, in which those savings that can be achieved through no cost/low cost measures are clearly identified and specific actions for their implementation are developed. The DES should also establish the scope of potential capital investment items worthy of detailed examination through subsequent feasibility studies.[2]

Where these feasibility studies indicate a good economic justification for investment, using methods such as those described in this manual, implementation will proceed through various stages, including engineering design and costing, the acquisition of financing, procurement of equipment, installation of equipment, and commissioning. Finally an evaluation of the effects of an energy conservation investment should always be made through an on-going comprehensive monitoring program.

The full TEM approach suggests that identification of measures requiring capital investment and the conduct of the relevant feasibility studies should **follow** the PES/DES steps. This may be desirable in many plants, and indeed is essential where a plant wishes to identify **all** its investment options and to rank potential projects in order of priority. However, where a useful conservation measure is readily identified, it is not essential that the complete PES/DES process be followed. Rather, a feasibility study should be conducted to determine the technical and economic viability of the proposed measure, part of which will include collection of comprehensive data relevant to the proposed change. In other words, much of the data that might otherwise be provided from the DES can be obtained as part of the feasibility study procedure where the full PES/DES process has not been conducted.

Particular care must of course be taken in conducting a feasibility study in a plant where the PES/DES process has not been completed. The PES/DES process includes implementation of no/low cost measures **before** the feasibility study step. In principle, this should ensure that the benefits of a proposed measure are estimated from the correct base line. For example, the benefits of automatic oxygen trim control on a

2 Such energy audits studies may be divided into two stages, knows as Prefeasibility and feasibility studies (See Section 2.4)

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boiler should be based on improvements over and above the best operation attainable with manual control (and routine flue gas testing on a regular basis). The benefits cannot be claimed from the baseline of the existing, as-found, operation where there may be no attempt at excess air control whatsoever. Thus the feasibility study must recognize where some measures might be adopted before implementation of the specific measure in question and that the benefits attributable to capital investment may have to be estimated from a hypothetical baseline (or a baseline representing future operating conditions). The subsequent evaluation of the effect of the measure when implemented will not be realistic unless the no/low cost items have themselves been implemented.

2.2 ENERGY SURVEYS (AUDITS)

An effective energy management program must be related to numerical objectives and must specify in detail the actions required, and by whom, to achieve the objectives. To define plant programs, it is therefore necessary to determine accurately the types and quantities of energy used in each stage of the manufacturing process. It is also necessary to establish procedures for recording energy use on a systematic and continuing basis. The collection of data is followed by data analysis, and the definition of conservation opportunities. The combination of data collection, data analysis, and the definition of conservation activities, is frequently called an "energy survey", also know as an "energy audit". A detailed description of energy audit procedures is outside the scope of this manual; the reader is referred to other publications, such as the Industrial Energy Auditing Manual, prepared by RCG/Hagler, Bailly, Inc. as part of the USAID Energy Conservation Services Program.

In summary, however, there are may levels of energy audit, ranging from simple data surveys to detailed examinations of existing data coupled with special plant test runs designed to provide new data. The time taken to conduct an audit depends on the size and type of facilities, but priority should be given to the departments or sections of a plant that are the greatest energy consumers.

A preliminary energy survey or initial audit can be carried out in as little as one or two days for a simple plant, although significantly longer is required in more complex plants.

The initial audit will review briefly the condition and operation of important energy-using equipment (e.g. boilers, steam systems) the extent of energy-related instrumentation, the existing data collection and analysis procedures, and management control of energy costs.

The initial audit is most useful for defining improved housekeeping measures, for exposing data collection and analysis problems, and for identifying the important energy consuming parts of the plant with potential for improvement which should be examined in detail at a later date.

A detailed energy survey or audit usually follows the initial audit. Depending on the nature and complexity of the plant, a comprehensive audit can take from several weeks to one or two months to complete. Detailed studies to establish and investigate energy and material balances for specific plant departments or types of process equipment are carried out. Checks of plant operations may be carried out over extended periods of time. The audit report typically includes a description of energy inputs and product outputs by major department or processing function and evaluates the energy efficiency of various stages of the manufacturing process and utility systems. Means of improving these efficiencies are identified and assessments of the costs and economics of capital investment improvements are prepared. At this stage, a cost estimate with an accuracy of 25 to 30 percent is usually adequate.

Comprehensive audit work may be followed at regular intervals by less detailed surveys in order to monitor plant performance and to check on progress being made to raise efficiency.

The procedures used in conducting audits will vary according to the scope of work and the size and type of facilities. In general, the following steps are involved for conducting a detailed energy audit:

1. Plan the entire project. This includes setting audit objectives, dividing the facility into operating departments (or cost centers, as appropriate), selecting the audit team members, assigning responsibilities.

2. Collect basic energy consumption and production data from the departments/costs centers, using standard forms or questionnaires.

3. Carry out plant test runs to gather additional data on the operating performance of specific equipment, departments or cost centers.

4. Calculate energy balances and equipment efficiencies.

5. Identify improved energy management procedures and estimate energy savings if appropriate. Projects in this category might include, among other things, improved record keeping, modification of purchasing agreement.

6. Identify improved maintenance and operating procedures, estimate obtainable energy savings, and assign responsibilities to specific individuals for implementing all worthwhile measures. Projects in this category will generally have a simple payback of less than 1 year.

7. Identify minor cost improvements, estimate the cost of implementation to within 25 or 30 percent, calculate the energy-saving potential, and prepare schedules for implementing all attractive capital investments (specify who will do what, and when). Projects are considered to be in this category when simple paybacks of 1 to 3 years are calculated.

8. Identify major cost improvements, estimate cost to within 25 or 30 percent, calculate the energy saving potential, and prepare detailed schedules of items showing attractive paybacks. When simple paybacks of more than 3 years are expected projects are placed in this lower priority category.

9. Prepare a report to management summarizing the findings and recommendations of the audit and including all data collected and procedures used in technical appendices. The report may include recommendations for energy efficiency improvement targets, based on the data gathered during the audit work and the analyses performed.

It should be noted that an important part of an energy audit frequently consists of the preparation of accurate energy and material balances. Without such data, it is rarely possible to carry out the quantitative analysis needed to identify the size and value of potential energy savings.

Experience has shown that many plants do not possess adequate instrumentation for the preparation of energy and material balances. It is necessary therefore to supplement the data obtained from plant instruments by additional readings from specialized portable instruments. These instruments include combustion gas analyzers, thermometers, clip-on voltmeters/ammeters, and power factor and load meters.

2.3 TYPICAL OPPORTUNITIES FOR IMPROVING ENERGY EFFICIENCY

Experience shows that valuable energy savings can be achieved in three main categories:

1. Housekeeping measures - the improvement of the operating efficiency of existing processes and equipment through measures that require little or no capital investment and can be effective in the short term. Examples include:

    - better monitoring and control of energy use
    - closer control of process temperatures and pressures
    - improved maintenance
    - elimination of leaks
    - improved scheduling of operations
    - better combustion control on furnaces, kilns and boilers.

2. Minor capital investments - relatively simple modifications to plant or equipment through which savings can usually be obtained in the short to medium term. Examples include:

    - additional insulation of process and steam lines and vessels
    - installation of improved instrumentation
    - steam condensate recovery
    - installation of high efficiency electric motors.

3. Major capitol investments - substantial replacement or modification of plants with the latest energy-efficient technologies, through which savings can be obtained in the medium to long term. Examples include:

   - additional heat exchangers to recover waste heat
   - higher efficiency lighting
   - combustion air preheating
   - replacement of boilers
   - replacement of process plant, reactors, distillation columns, etc.
   - conversion to a completely different process.

Housekeeping measures are generally successful in the short term and will lead quickly to measurable savings. However, lack of attention to even the simplest housekeeping activities can lead to the savings being lost equally quickly. Good supervision of operations is essential.

This manual provided guidelines for project evaluation and thus addresses the evaluation of energy efficiency measures falling into the minor and major capital investment categories.

2.4 FEASIBILITY STUDIES

Where the information developed in the detailed energy survey indicates a number of interesting project candidates with attractive payback periods, there may well be a case for carrying out a short prefeasibility study to verify the data reported and the conclusions reached. The prefeasibility stage can help avoid the situation where a fully comprehensive feasibility study is conducted on a project that has poor economics and is therefore unlikely to be adopted. When a plant has limited funds, prefeasibility studies may be used to select only the most promising ideas for future study.

The prefeasibility work can, of course, be conducted as the initial phase of a feasibility study itself. Before implementing a project involving any sizable capital investment,

company management will normally require a detailed feasibility study. Such a study will verify the technical and financial bases of the proposed project, including a thorough appraisal of the risks involved. The study may often be a prerequisite of the bank that is being asked to extend a loan.

A prefeasibility study is a relatively short investigation of a potential capital investment. Areas of uncertainty should be explored. These can include uncertainties in the data collected and the technical benefits anticipated; in the value of the benefits; and in the magnitude of the capital investment itself. Estimates with an accuracy of 15 to 20 percent are usually adequate at this stage. A prefeasibility study will thus address all these topics and provide quantified recommendations to management on the desirability of proceeding with the project.

A feasibility study has a number of steps, the first being to conduct a technical analysis. The objective of this analysis is to quantify the potential savings from a capital investment. The capital project under consideration will typically be a major project that has more than one technically-feasible solution. For example, a boiler plant may have a low efficiency, and options will include measures to renovate the existing plant by installing heat recovery systems, for example, or to replace it with a new boiler (with or without fuel switching).

A typical feasibility study should therefore proceed as follows:

1. Define each technical option to be studied.
   Prepare initial flow diagrams where appropriate.

2. For each option, define the specific data that describe plant operations before project implementation. These data will typically include:

   - existing production levels (relevant to the plant operation under investigation, e.g. steam production)

   - daily/weekly/seasonal variations in production levels

   - current operating schedules (e.g., hours worked per day/month, time of operation, number of shifts, etc.)

- current energy use, by fuel type, for the relevant plant operation including peak demands if appropriate
- current fuel costs and tariff schedules
- current process-related parameters (e.g., temperatures, pressures) current operating and maintenance costs for the relevant plant operation
- current operating efficiency of relevant equipment (and associated heat and material balances).

3. Define the specific data that will describe plant operations after implementation, such as

   - anticipated production levels
   - anticipated operating schedules
   - future energy requirements by fuel type
   - anticipated operating parameters
   - operating and maintenance needs, including training
   - estimated useful life or any new equipment.

4. For the subsequent financial analyses, the following data will be needed:

   - marginal tax rate of the company
   - usual terms and conditions available to the company for financing capital projects, including terms of a loan, associated grace period, interest rate, required debt to equity ratio
   - required rate of return for the proposed project.

5. At this stage, it is normal to visit the plant to check all data requirements have been defined and to discuss the work planned with plant management.

6. Prepare a work plan for the site work of the feasibility study team, indicating responsibilities and schedules for data collection and analyses. Note that for some cases, most if not all the data may have been collected during a previous detailed energy audit and therefore further plant work may be unnecessary.

7. Where necessary, collect the data at the plant, measuring key operating parameters over a period of time, e.g., one week or more if appropriate. Check plant records for major variations or trends in key parameters. Look for indications of seasonal variations and any evidence of strong dependence on throughput, for example.

8. Where appropriate, check the current operating parameters and efficiency of relevant equipment. If possible, modify operating conditions to achieve improved performance before recording key parameters for use in the feasibility study analyses (e.g., reduce boiler excess air to optimum level before collecting data for the calculation of heat and material balances and operating efficiency).

9. Determine all costs associated with the implementation of the various options, including

   - equipment design costs
   - engineering design costs
   - capital equipment and installation costs (estimates with an accuracy of ± 10 percent are necessary at this stage)
   - operating and maintenance costs.

   Note that some projects may require imports of equipment and spares. Therefore the foreign exchange component of each cost element must be specified. Relevant import duties must be determined.

10. Analyze data and estimate potential energy savings associated with the implementation of the proposed options. Where the size of equipment can

be varied (e.g., heat exchanger surface area), several options may need to be evaluated using incremental analyses of costs, savings, and rates of return (see Section 2.14 of this manual).

At this point, the financial analysis is conducted to determine the probable effect on the company of implementing each technical option. This will enable the company to determine which option should be implemented. The analysis should give, for example, the simple payback or the internal rate of return for the investment (see Section 2.11 also). In addition, areas of risk should be clearly pointed out. Note that the financial analysis results are intended to give support for funding by banks (or possibly donor institutions such as the World Bank).[2]

The feasibility study proceeds as follows:

11. Conduct the financial analyses using methods described in this manual.

12. Conduct sensitivity analyses for the most attractive options. Typical sensitivities will include the effect on project rates of return of changes in

    - energy savings actually achievable (i.e., based on different baseline data assumptions or on equipment performance)
    - capital cost of equipment
    - construction/implementation schedules
    - foreign currency proportion
    - future energy costs
    - cost of loads (interest rates, grace periods, etc.)
    - operating and maintenance costs.

2 A so-called "economic analysis" may be conducted to examine the value to the national economy of project implementation. The economic analysis will usually give a different result from the financial analysis because of various divergences in the treatment of items such as energy costs. A discussion of difference between public sector and private sector approaches is given in "Economics of Energy Conservation at the Enterprise Level", M. Fisher, RCG/Hagler, Bailly, Inc. prepared for the Office of Energy (ECSP), USAID, January 1985.

A comprehensive feasibility study report should be prepared. A typical format is presented below for guidance:

SUMMARY

1. Introduction

   - Brief description of the project
   - Funding requirements

2. Purpose of the Project - this section should set the non-technical background for the particular project including its objective and its relevance to plant profitability or operability.

3. Justification of the Project - This section should give the estimated benefits (and disadvantages) of the proposed project, quantified if possible (otherwise the reason for not quantifying should be stated). Where there may be a choice of alternative technologies, e.g., different means of waste heat recovery, justification should be given for the particular technology chosen. In compiling this section it is essential that attention be paid to the company criteria for approval of projects (such as required rate of return). Base line data describing current operations should be provided.

   This section could be organized in the following manner:

   - Technical options
   - Cost and performance assumption for each option
     - Investment cost, including design/engineering costs
     - Operating and maintenance costs
     - Energy savings and non-energy benefits

- Financial analyses
    - Financial and tax circumstances of the company
    - Financial analysis of project performance (for each option), including rates of return, cash flows, sensitivity analyses results and implications
    - Analysis of Foreign currency requirements
    - Recommendations.

4. Description of the Work - Based on the recommended option, this section would include a concise description of the equipment to be purchased and the work involved (e.g., design, engineering, modification of existing plant, installation, and commissioning). A management plan (e.g., bar chart) should be provided, showing accomplishment milestones with estimates of time and cost to reach each milestone.

5. Monitoring and Assessment - Details should be given of monitoring requirements and an indication of how the project performance will be evaluated once the equipment is commissioned.

Appendices

These should contain background, technical, economic, or marketing information that support the undertaking of the project. This could include, for example, key technical specifications, details of any feasibility study already conducted, detailed results of the financial analyses, etc.

CHAPTER 3: PROJECT EVALUATION

3.1 INTRODUCTION

From a financial viewpoint, energy conservation can be achieved by two different approaches:

a) By implementing housekeeping or related measures that optimize the efficiency of existing plant and equipment. Investment is not required. If the operating costs of the measures adopted are less than the energy savings achieved, then the program is attractive economically.

b) By investing in new plant and equipment.

All investment, whether for energy conservation or not, should be subject to a systematic system of capital appraisal with two goals in mind:

a) To provide a basis for the selection or rejection of projects by ranking them in order of profitability.

b) To ensure that investments are not made in projects that earn less than the cost of capital, which is frequently expressed as a minimum rate of return.

Various appraisal techniques are available for ranking competing projects on a systematic basis. These are described in the following sections.

When carrying out the evaluation of capital investment in energy efficiency projects, the energy manager or engineer should keep the audience in mind. The evaluation report should be addressed to the decisionmakers, who are generally plant managers or company directors concerned with overall company performance. Investment appraisal and decision making by management should focus on discerning, from the many claims that will be made on scarce resources, those projects that will best meet the company's goals.

In proposing a capital investment project, three important considerations should be recognized by the energy manager:

(1) The decisionmaker should be identified so that his needs can be satisfied.

(2) The project evaluation should be presented in a form that satisfies the decisionmaker. Company policy may dictate the use of a particular format, or the decisionmaker may prefer a one-page summary.

(3) As far as possible, a format should be adopted that sets out clearly the following points:

- Why the project is being considered.
- What the project is intended to achieve.
- What the financial and other benefits should be.

3.2 KEY QUESTIONS

When conducting a project evaluation and subsequently developing a project proposal, the energy manager should bear in mind a number of important questions:

- Does the proposal fit in with the declared energy policy and with the other business plans?

  For example, the energy policy may state "the company will keep its energy consumption at the 1985 level for the next three years". The business plan may show a 5 percent per year increase in production over the same period. In this case a furnace modification giving a 7 percent increase in production for the same energy consumption fits in ideally.

- Is the investment proposal being launched from a sound position?

  Has an energy audit been carried out and do metering and monitoring facilities exist such that any claimed improvements can be validated?

- Have most of the simple no-cost or low-cost measures identified through an energy audit been successfully implemented?

  These items should be carried out first because the amount of energy to be saved from a large project may be totally different after their implementation and its viability may be affected. The simple things should be done first.

- Is this proposal the logical next step?

  In addition to an energy policy, a progressive company needs to develop an energy efficiency plan and to keep it regularly updated. The plan may contain several energy efficiency projects in chronological order, albeit with flexibility in some areas. For example, changing the recuperator on a billet reheating furnace to operate with a current waste gas input temperature of 450°C should not be considered before a furnace geometry change that may drop the waste temperature below 450°C.

- What is the market forecast for the products affected by the project?

  It is essential to know the projected trends in the sales volume of the plant product. The viability of most projects is closely related to throughput, so this must be considered not only in the financial justification but also in the risk analysis. Also, long term market trends may have an impact on the viability of a specific project.

- How does the proposal rank in terms of cash needs, return on investment, etc., with other schemes demanding cash?

  Information should be presented in such a way that it can be compared directly with competing investments on both a long and short-term basis. In this respect, the total demand for investment capital has to be considered. At times of severe capital constraint, it may be preferable to consider a small scheme rather than a large scheme that may be rejected because of lack of cash. There is considerable advantage in knowing what capital limits are being imposed by company management on individual projects or on overall expenditure.

- Can the scheme pay for itself in less than one year and be paid for from the revenue account?

  In many early investments in energy saving measures, paying for measures from revenue is a feasible approach because returns are high. In some companies this may mean that different people are responsible for decision making regarding the use of the revenue account. This will generally apply at the lower end of the investment range.

- Is the proposal clear, concise, and numerate - i.e , can the results be accurately monitored and assessed?

The importance of this item for gaining acceptance of a proposal cannot be over-emphasized. The proposal should contain a clear statement of the intention of the project, what it will cost, and how much it will save, together with a description of how success will be measured. Over-lengthy technical descriptions, inaccurate calculations, and lack of clarity in argument are the main reasons projects are rejected when cash is available.

3.3 COST ELEMENTS

In evaluating the financial benefits of a proposed project, it is important that all relevant capital and operating costs be taken into account. Project costs must therefore include the following:

<u>Capital and associated costs</u>

1. Cost of preliminary studies
2. Cost of planning work
3. Cost of engineering and design
4. Cost of the equipment itself, including procurement costs
5. Cost of additional materials, such as supporting steelwork or civil works

6. Cost of production downtime during plant modification

7. Cost of modification or repair of existing equipment

8. Cost of commissioning, including adjustments and "debugging"

9. Freight costs, import duties and taxes.

Recurring (operating) costs include:

1. Additional maintenance

2. Extra utilities (fuel, electricity, cooling water, compressed air, etc., needed to operate the proposed equipment)

3. Extra labor costs

4. Extra chemicals for corrosion control, chemical cleaning, etc.

5. Additional insurance costs.

Some of these costs may be difficult to estimate without assistance from equipment manufacturers or their representatives. Capital costs may be estimated using data for comparable equipment. The Energy Equipment Cost Directory, prepared under the USAID Energy Conservation Services Program by RCG/Hagler, Bailly, Inc., is also available to help plant engineers develop realistic capital costs estimations for potential energy-saving investments.

The cost for such items as civil works, production downtime, modification of existing equipment, and costs for commissioning are, to a greater or lesser extent, specific to the plant in question and can only be estimated by an engineer with good knowledge of the plant.

Costs for the various preliminary studies and design work can also vary significantly from project to project and plant to plant. The cost of an energy audit is not directly related to the level of investment and can represent a large proportion of the potential

capital cost for new or modified equipment. As a rough guide, costs for detailed audits are likely to fall in the following ranges:

Small plant	$15 - 35,000
Medium plant	$25 - 50,000
Large plant	$50 - 100,000

The complexity of the process and utilized systems can greatly increase the cost of an audit: a small plant with 3 or 4 boilers on-line can cost as must to audit as a much larger plant with only 1 boiler.

Other costs can be expected to fall into the following ranges (expressed as percentages of the proposed capital investment):

	Size of Investment (Thousand Dollars)		
	Small	Medium	Large
	< 100	100-500	> 500
Prefeasibility study	20-50%	5-10%	3-6%
Feasibility study	8-30	7-20	5-10
Detailed engineering study	5-8	17-15	5-1
Approx. total for studies	15-40%	15-35%	10-20%

Note that the accuracy expected of cost estimates varies according to the type of analysis being carried out. In general, the accuracy should be in line with the following guidelines:

Audit reports (with recommendations)	25 to 30%
Prefeasibility studies	15 to 20%
Feasibility studies	± 10%

Most operating costs will have to be estimated with the help of manufacturers or their local representatives. Utility requirements, for example, should be given in manufacturers' literature. Maintenance costs may be estimated based on the experience of the plant itself (an allowance of 4 percent to 8 percent of the capital cost

of equipment is reasonable). Insurance costs are likely to be about 1 percent of the capital costs.

3.4 BENEFITS

Savings resulting from project implementation will include energy benefits and other savings. The magnitude of energy savings will depend directly on the expected utilization of the new equipment. The value of the energy saved will depend on the projected price scenario.

The other benefits accruing from a project are obviously site-specific. In some cases, environmental benefits can be attributed to an energy efficiency improvement, and the avoided cost of pollution control equipment should be considered as a benefit. Reduced maintenance costs for existing equipment may also be relevant in some cases, as may be increased plant throughput. These benefits must be carefully calculated as the assumption that the extra production can be sold may not always be valid.

For each case, the total benefits associated with the project should be used in the calculations of payback or return on investment. In the sections of this manual that discuss calculation methods, it is understood that this approach will be adopted. In some cases, there may be "intangible benefits", including improved working conditions within the plant, improved safety of operation, and higher quality products (i.e., beyond the basic specification limits). In these cases judgment will have to be used when interpreting the results of a project evaluation whenever intangibles are clearly a factor in the decision, particularly when attempting to rank projects in order of desirability.

3.5 PROJECT EVALUATION BY THE SIMPLE PAYBACK METHOD

The most basic appraisal method is simple payback. At its basic level this looks at the capital outlay required and takes the forecast revenue savings based on current energy costs, providing a time in which the capital should be recouped:

$$\frac{\text{Capital investment}}{\text{Annual Savings at current energy costs}} = \text{Payback (in years)}$$

The shorter the payback period, the better the investment. Payback times of three years or less are commonly acted on, although the exact value depends on the availability of company funds and thus on company policy. An example of the simple payback method is as follows. A project is developed for the installation of a furnace recuperator that costs $10,000 to purchase and install, $300 per year on average to operate and maintain, and is expected to save, by preheating combustion air, an average of $3,400/year in fuel expanses. The simple payback period is as follows: -

$$SPP = \frac{\$10,000}{\$3,400 - \$300} = 3.2 \text{ yr.}$$

The simple payback method has a number of serious disadvantages:

- It does not give consideration to cash flows beyond the payback period, and thus does not measure the efficiency of an investment over its entire life.
- It ignores the time value of money.
- It does not reflect changing energy prices.
- It usually ignores the effect of taxation.
- It usually assumes a continuation of the status quo in terms of production and other relevant variables.
- It ignores any residual value of capital assets.

In short, the simple payback method gives attention to only one attribute of an investment (i.e., the number of years to recover costs) and, as often calculated, does not even provide an accurate measure of this investment cover time. It is a measure that many firms appear to overemphasize, tending toward shorter and shorter payback requirements. Firms' preference for very short payback to enable them to reinvest in other investment opportunities may in fact lead to a succession of less efficient, short-lived projects.

Despite its limitations, the simple payback period has some advantages. There are several situations in which the simple payback method might be particularly appropriate:

- A rapid payback may be a prime criterion for judging an investment when financial resources are available to the investor for only a short period of time.
- The speculative investor who has a very limited time horizon will usually desire rapid recovery of the initial investment.
- Where the expected life of the assets is highly uncertain, determination of the break-even life (i.e., payback period) is helpful in assessing the likelihood of achieving a successful investment.
- Simple payback may be used for a rapid screening of a large number of projects, with, for example, those project showing paybacks under 4 years being retained and subjected to further, more sophisticated analyses.

"Simple Payback" is admittedly not a sophisticated method of risk assessment, but in practice many decisionmakers feel that a short payback period provides comfort. Certainly a question asked by many companies when considering an energy saving scheme is "how quickly will I get my money back?"

3.6 PROJECT EVALUATION BY THE RETURN ON INVESTMENT METHOD

The return on investment (ROI) or return on assets method calculates average annual benefits, net of yearly costs such as depreciation, as a percentage of the original book value of the investment:

$$\text{Return on Investment (ROI)} = \frac{\text{(Average Annual Net Benefits)}}{\text{Original Book Value}} \times 100$$

For example, the calculation of the ROI for an investment in waste heat economizer is as follows:

Original book value - $15,500

Expected life = 10 years

Annual depreciation, using a straight-line method = $15,000/10 = $1,500

Yearly operation, maintenance, and repair cost = $250

Expected annual fuel oil savings = $5,000

$$ROI = \frac{\$5,000 - (1,500 + \$250)}{\$15,000} \times 100 = 22 \text{ percent}$$

Like the payback method, this method does not take into consideration the timing of cash flows, and therefore may incorrectly state the economic efficiency of projects. The advantages of the return on investment method are that it is simple to compute and is a familiar concept in the business community.

3.7 THE CONCEPT OF LIFE CYCLE COSTING

The "payback" and "return on investment" methods are relatively easy to apply but it is rare that all applicable costs are taken into account. For a proper evaluation of a project, the concept of "life cycle costing" should be understood.

Life-cycle costing (LCC) is a method of expenditure evaluation that recognizes the sum total of all costs associated with the expenditure during the time that it is used. Initial costs and all subsequent expected costs of significance are included in the calculations, as well as disposal value and any other quantifiable benefits to be derived. The LCC technique is justified whenever a decision must be made on the acquisition of an asset that, over its lifespan, will require substantial operating and maintenance costs relative to its first cost.

For these investments, five components stand out as requiring careful consideration. These are:

1. Initial capital investment costs
2. Annual operating and routine maintenance costs
3. Major repairs and component replacements

4. Complete item or system replacement

5. Residual values.

A sixth consideration is time. The timing factor is used to judge when costs or benefits occur and when replacements are needed. Combining the six elements together results in a "life cycle" for an investment decision.

3.8 THE CONCEPT OF THE TIME VALUE OF MONEY

One of the major weaknesses of the simple payback method of project analysis is the failure to differentiate properly between projects with different lives and whose benefits may vary from year to year. In addition, no consideration is given to what happens after the end of the payback period.

Consider the following two projects, each of which has a payback period of two years:

		A	B
Investment		$20,000	$20,000
Savings, year	1	10,000	$10,000
	2	10,000	10,000
	3	8,000	10,000
	4	8,000	10,000
	5	6,000	10,000
	6	6,000	10,000
	7	-	10,000
	8	-	10,000

The simple payback method simply does not address the differences in the benefits obtainable from A and B. Since the purpose of analyzing investment opportunities is to measure the productivity of current expenditures against future benefits derived from project implementation, the simple payback method is clearly inadequate. The decisionmaker is not given enough information to evaluate alternatives in which the timing of benefits varies widely.

The concern of the time value of money leads to the conclusion that immediate benefits are preferable to benefits obtained later in time, even if risk and uncertainty are comparable. This is because, if a consumer must wait to obtain a sum of money in benefits derived from an investment, he is losing the opportunity to invest the funds elsewhere during the interim period. Stated another way, money has value distinctly related to the timing of its receipt and disbursement, and this value is determined by the opportunity to earn from normal investment activity. This concept is referred to as the opportunity cost and may be expressed as the interest rate.

Studies in engineering economics are concerned with the most economical alternatives in the long run. Since the alternatives to be considered are expressed in terms of money flowing at different times, the time value of money must be recognized and taken into account in any realistic system of project evaluation.

As a matter of convention, it is normally assumed that all cash flows occur at the end of a time period (for example, at the end of a month or year). End-of-period cash flows will be used henceforth in this manual. In addition, interest rates used for most engineering calculations are the effective annual rate.

3.9 INTEREST RATE AND DISCOUNT FACTORS

The time value of money is reflected in the interest rate. Interest may be viewed as money paid for the use of money, or as the return[1] obtainable because of the productive

[1] "Return" is the short form of "return on investment".

use of assets. Thus, if the interest rate is 8 percent per year, 100 dollars will become 108 dollars at the end of the year:

$$100 \times (1 + \text{rate}) = 100 \times 1.08 = 108$$

Conversely therefore, receiving 108 dollars after one year is equivalent to receiving 100 dollars today, provided the interest is 8 percent. The present value P of a future sum of money F is given by the following equation:

$$P = F \times \frac{1}{(1 + \text{Rate})}$$

$$\text{e.g. } 108 \times \frac{1}{1.08} = 100 \text{ dollars}$$

The factor which is used to multiply F to calculate P is known as the "discount" factor, and is calculated as follows for a specified interest rate (i) and number of years (n):

$$\text{Discount Factor} = \frac{1}{(1 + i)^n}$$

Exhibit 3-1 is a table of discount factors for various values of i and n. It may be used to calculate the present value of a sum of money to be received in the future. For example, suppose a heat recovery project is expected to provide savings of 500 dollars in 4 years time. For an interest rate (or "discount rate") of 16 percent, the present value of the 500 dollars is computed as follows:

$$500 \times 0.552 = \$276$$

[Discount factor for 16%, 4 years]

A similar energy saving in 7 years time (interest rate 16 percent) is equivalent to much less today:

$$500 \times 0.354 = \$177$$

[Discount factor for 16%, 7 years]

Exhibit 3-1
Discount Factors for Future Payments

Years Hence (n)	Interest rate per year (i)											
	1%	2%	4%	6%	8%	10%	12%	14%	15%	16%	18%	20%
1	0.990	0.980	0.962	0.943	0.926	0.909	0.893	0.877	0.870	0.862	0.847	0.833
2	0.980	0.961	0.925	0.890	0.857	0.826	0.797	0.769	0.756	0.743	0.718	0.694
3	0.971	0.942	0.889	0.840	0.794	0.751	0.712	0.675	0.658	0.641	0.609	0.579
4	0.961	0.924	0.855	0.792	0.735	0.683	0.636	0.592	0.572	0.552	0.516	0.482
5	0.951	0.906	0.822	0.747	0.681	0.621	0.567	0.519	0.497	0.476	0.437	0.402
6	0.942	0.888	0.790	0.705	0.630	0.564	0.507	0.456	0.432	0.410	0.370	0.335
7	0.933	0.871	0.760	0.665	0.583	0.513	0.452	0.400	0.376	0.354	0.314	0.279
8	0.923	0.853	0.731	0.627	0.540	0.467	0.404	0.351	0.327	0.305	0.266	0.233
9	0.914	0.837	0.703	0.592	0.500	0.424	0.361	0.308	0.284	0.263	0.225	0.194
10	0.905	0.820	0.676	0.558	0.463	0.386	0.322	0.270	0.247	0.227	0.191	0.162
11	0.896	0.804	0.650	0.527	0.429	0.350	0.287	0.237	0.215	0.195	0.162	0.135
12	0.887	0.788	0.625	0.497	0.397	0.319	0.257	0.208	0.187	0.168	0.137	0.112
13	0.879	0.773	0.601	0.469	0.368	0.290	0.229	0.182	0.163	0.145	0.116	0.093
14	0.870	0.758	0.577	0.442	0.340	0.263	0.205	0.160	0.141	0.125	0.099	0.078
15	0.861	0.743	0.555	0.417	0.315	0.239	0.183	0.140	0.123	0.108	0.084	0.065
16	0.853	0.728	0.534	0.394	0.292	0.218	0.163	0.123	0.107	0.093	0.071	0.054
17	0.844	0.714	0.513	0.371	0.270	0.198	0.146	0.108	0.093	0.080	0.060	0.045
18	0.836	0.700	0.494	0.350	0.250	0.180	0.130	0.095	0.081	0.069	0.051	0.038
19	0.828	0.686	0.475	0.331	0.232	0.164	0.116	0.083	0.070	0.060	0.043	0.031
20	0.820	0.673	0.456	0.312	0.215	0.149	0.104	0.073	0.061	0.051	0.037	0.026

$$\text{Discount factor} = \frac{1}{(1+i)^n}$$

The discounting process is important in project evaluation because it permits the translation of future values to present values. If the total cost of owning an asset is its initial cost and all subsequent costs, the latter must first be discounted to the present value before they are combined with the initial cost to calculate a life-cycle cost. It would obviously be erroneous to ignore the timing of the future costs and merely add them unadjusted, to the initial cost.

Finally, it is necessary to discuss the differences between real and nominal interest rates. Real interest rates do not include the rate of inflation. Nominal interest rates include the effect of inflation. As an approximation, the nominal interest rate equals the real interest rate plus the inflation rate. In the case of very high real or inflation rates, however, it is best to be rigorous. In the case of an 8-percent real interest rate and a 12-percent inflation rate, the nominal rate is 21 percent (and not 20 percent), calculated from the equation below:

$$\left(1 + \frac{\text{nom. rate, \%}}{100}\right) = \left(1 + \frac{\text{real rate, \%}}{100}\right) \times \left(1 + \frac{\text{inflat. rate, \%}}{100}\right.$$

Thus:

$$\left(1 + \frac{\text{nominal rate\%}}{100}\right) = \left(1 + \frac{8}{100}\right) \times \left(1 + \frac{12}{100}\right)$$

$$= 1.08 \times 1.12$$

$$= 1.21$$

The difference between real and nominal rates is very important when conducting project evaluations. When projecting the annual operating costs or potential energy savings to be derived from the installation of energy-efficient equipment, it is important to specify if those projections are in real or nominal terms. Real cash flows are discounted at real interest rates; nominal cash flows are discounted at nominal interest rates. When there is difficulty in projecting inflation rates, it is usually best to use real cash flows discounted with r interest rates.

3.10 PROJECT EVALUATION BY THE NET PRESENT VALUE METHOD

Two widely used methods of estimating the profitability of a project take into account the time value of money: these are the "discounted cash flow rate of return" (DCFRR) and "net present value" (NPV) method. The DCFRR is also called the "internal rate of return", or sometimes the "profitability index" or the "investor's rate of return".

To evaluate projects by these methods, actual cash flows are first calculated for each time period being studied. In the majority of practical cases, the time period taken is one year. Savings from an energy efficiency investment are taken as positive cash flows: these are offset by negative cash flows which represent operating costs and any capital expenditures in the year in question. At the end of the life of the proposed investment, there may be a scrap value of the equipment to include in the calculation as a positive cash flow.

The calculated net cash flows for each time period are then "discounted" to give their equivalent present values.

The example below for a waste heat recovery project illustrates the principles involved.

Example:

Initial investment	$25,000
Annual energy savings	$8,500 in the first year of operation
	$12,000 per year thereafter
Additional maintenance costs	$1250 per year
Additional labor	$3,000 per year
Additional chemicals	$500 per year
Residual scrap value	$3000 after 6 years useful life
Project construction time	1 year

Cash flows:

Year	0	1	2	3	4	5	6	7
Capital Investment	(25000)	-	-	-	-	-	-	-
Energy Savings	-	8500	12000	12000	12000	12000	12000	-
Maintenance	-	(1250)	(1250)	(1250)	(1250)	(1250)	(1250)	
Labor	-	(3000)	(3000)	(3000)	(3000)	(3000)	(3000)	
Chemicals	-	(500)	(500)	(500)	(500)	(500)	(500)	-
Scrap value	-	-	-	-	-	-	-	3000
Net Cash flow	(25000)	3750	7250	7250	7250	7250	7250	3000

These cash flows occur at different times over the whole life of the equipment[2]. By convention, it is assumed that the cash flows take place at the end of the year in question. Each of the actual cash flows is now "discounted" to calculate its equivalent present value. This is done by multiplying the actual cash flows by the corresponding discount factor, calculated using an assumed interest rate i. For the end of the second year, for example, the calculation is as follows for i = 10 percent:

$$\text{Discount factor } \frac{1}{(1+i)^n} = \frac{1}{(1.10)^2} = 0.826$$

Actual net cash flow = $7250
Present value = 7250 x 0.826
= $5989

The present value ($5989) is also known as the "discounted cash flow". To speed up calculations, discount factors may be read off Exhibit 3-1.

The discount factor is, of course, dependent on the value of the interest rate i. By using a value that represents the current cost of capital to the company, the projected cash flows may be expressed as their present value. The total of these discounted cash flows

2 Note that the values of the net cash flows are very important to a company. Even though a project may show a high rate of return overall, periods of negative cash flows can occur and these require the company to have sufficient reserves to pay out cash over perhaps long periods of time, before returning to a net cash inflow position.

is called the "net present value" (NPV). If the NPV is positive, the investment will pay for itself and should therefore be considered favorably by plant management.

For our waste heat recovery example, the NPV is calculated as follows for an interest rate of 10 percent:

Year	0	1	2	3	4	5	6	7
Net cash flows For i = 10%	(25000)	3750	7250	7250	7250	7250	7250	3000
Discount factors	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.512
Discounted cash flows	(25000)	3409	5989	5445	4952	4502	4089	1539

Net Present Value(NPV) = discounted cash flows = + $ 4925

3.11 PROJECT EVALUATION BY THE INTERNAL RATE OF RETURN METHOD

The NPV is clearly sensitive to the value chosen for i, and an interest rate can be chosen to make the NPV equal to zero. The value for i may be found graphically or by an interactive procedure, the latter being used when a programmable calculator or computer is available. The value of i that makes NPV zero is known as the "discounted

cash flow rate of return (DCFRR) or "internal rate of return" (IRR). For our waste heat recovery example, the IRR may be calculated as follows:

Year	0	1	2	3	4	5	6	7
Cash Flow	(25000)	3750	7250	7250	7250	7250	7250	3000
For i = 15%								
Discount factors	1.000	0.870	0.756	0.658	0.572	0.497	0.432	0.376
Discounted cash flows	(25000)	3263	5481	4771	4147	3603	3132	1128
Net Present Value = + $ 1653								
For i = 16%								
Discount factors	1.000	862	743	6441	552	476	410	354
NPV = - $245								
F i = 15.7%								
Discount factors	1.000	864	747	646	558	482	417	360
Discounted cash flows	(25000)	3240	5416	4684	4046	3495	3023	1081
NPV = - $15								

For the example, the IRR is therefore very close to 15.7 percent. If the cost of capital to the company is 10 percent, the project is attractive. If the cost of capital is 20 percent, the project is clearly unattractive.

The IRR's of a series of potential investments may therefore be calculated and the projects may be ranked in order of the IRR, the highest value being the most attractive. A value for the cost of capital to the company can be used as the "cut-off" point, those projects with an IRR under the set value being discarded.

3.12 A COMPARISON IF NPV AND IRR METHODS

Since the IRR is a single percentage it has the advantage of being readily understood. The NPV has the disadvantage of being a sum of money and so additional information (e.g., the rate of interest) is needed before its significance can be fully appreciated. However, when a company is considering investing in a portfolio of projects, the individual NPVs have the advantage that they can be added together. This cannot be done with individual IRR's.

It must be remember that an NPV or IRR estimation can be no better than the accuracy of the predicted cash flows over the life of the project. Obviously, it is likely that cash flows will be predicted more accurately for two or three years ahead than for nine or ten years ahead. However, since the cash flows in the later years are discounted to a greater extent than for the earlier years, the later years have less effect on the overall estimation.[3] Nevertheless, the difficulty of predicting cash flows in later years and the inherent lack of confidence in these predictions is a disadvantage of the IRR method. In this respect, NPVs are more useful since they are calculated for each year of a project. Thus a project with a positive NPV after only a few years is normally viewed favorably by management.

3.13 SENSITIVITY AND RISK ANALYSES

In formulating the financial justification for a project, it is necessary to make a number of assumptions. Some of these may have a high degree of certainty attached, others will not. Typically, it will be the cost of a proposed project that will be more certain than the benefits. To reach a well informed decision on the proposed project therefore requires some assessment to be made of the project's viability if the central assumptions are varied.

This requires an assessment of the sensitivity of the return to changing assumptions and a statement of the likely degree of risk. The return in this context is likely to be the payback period and/or the IRR. In order to assess sensitivity it is necessary to determine which factors are key to providing the level of forecast benefits. The factors

3 For most practical purposes, a project life of 15 years is adequate. Indeed, a life of 10 years is quite commonly used for the purpose of calculations.

will depend on the project and can usually be chosen by inspection; that is to say, by varying each assumption in turn it is possible to see which has the larger impact. At this stage, the project evaluation is thus open to fairly straight-forward mathematical manipulation.

There is, however, a danger at this point that even if key assumptions are properly identified, the degree to which they are varied assumes a simplistic style which divorces the result from any likely reality. For instance, it is easy just to change all assumptions by 10 percent or 20 percent, and calculate the resulting return. Such an approach ignores the fact that some assumptions are inherently more certain than others. The present cost of fuels, for instance, will be known, and short-term future costs of most fuels (excluding perhaps oil) can often be estimated fairly closely. The usage of fuel for a given production level may however be less certain, particularly in untried equipment. Similarly, the production levels themselves may be far from certain in even the relatively short term. There is unfortunately no easy solution to this problem. It is a matter of applying judgment based on experience and of obtaining the maximum amount of relevant real-life data.

The objective remains to set the central case in a context of risk. At one end there will be an estimate of the maximum return that is considered feasible. At the other end there will be an estimate of the minimum return. The central case presented will obviously be somewhere between these two extremes, the extent to which it differs from each being an indication of the relative risk.

As an example of a sensitivity analysis, let us again consider the heat recovery example. Suppose the energy saving benefits are not a great as expected; what will the IRR

become if energy savings are 10 percent less than calculated? The calculation is as follows:

Year	0	1	2	3	4	5	6	7
Capital Investment	(25000)							
Scrap value	-	-	-	-	-	-	-	3000
Energy Savings	-	7650	10800	10800	10800	10800	10800	
Maint., labor & chemicals	-	(4750)	(4750)	(4750)	(4750)	(4750)	4750	-
Net Cash Flows	(25000)	2900	6050	6050	6050	6050	3000	
For i = 10% Discount factors	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513
Discount Cash flows	(25000)	2636	4997	4544	4132	3757	3412	1539

NPV = + 17

The IRR is now close to 10 percent, compared with 15.7 percent previously.

The IRR may be recalculated for other changes: for example, the construction time of a project may be raised, as may the time taken to achieve full benefits. Capital costs can also be varied to examine the sensitivity of the IRR to cost overruns.

3.14 THE IMPACT OF TAXATION AND FINANCING MECHANISMS

So far, the examples of project evaluations have been computed without taking into account the effect of company taxation. In fact, for the purpose of ranking competing

projects, this is usually not important: provided all projects are evaluated on a consistent basis, the final ranking is unlikely to be altered.

However, a rigorous calculation should include tax and any offsetting "benefits", such as depreciation, which will reduce the tax payable. In addition, there may be special incentives for investing in new plant and equipment; examples are investment tax credits and accelerated depreciation (sometimes allowable in the first year or two of a project).

It should be noted that depreciation is not a cash cost, although it must be included in the calculation of tax liability. The opposite occurs for equity payments, such as the initial investment or repayment of principal on any debts; these items affect the cash flow situation for a company but do not enter into the calculation of taxes to be paid.

The calculation of cash flows, profits, and taxation must be carried out using the appropriate regulations of the country concerned. It should be noted that there will usually be a one year "delay" in applying the tax; that is, a profit in year x will result in a tax bill payable in year (x + 1), following the completion of the usual tax returns and in accordance with local regulations.

In the initial years of operation of a project there may be losses; in this situation, no tax is normally payable, and there may be loss carryovers allowed in the tax code.

A typical calculation of after-tax cash flows and the after-tax IRR proceeds as follows:

<u>Example</u>

Investment	$18,000	
Net savings	$6,200/year	
Useful life	6	years
Depreciation schedule	40%	first year of investment
	20%	for next 3 years
Tax rate	50%	
Unlimited loss carryover		

Tax payment made in the year following corresponding operations.

Cash flows and calculations:

Year	0	1	2	3	4	5	6	7
1 Capital Investment	18000	-	-	-	-	-	-	-
2 Net savings	-	6200	6200	6200	6200	6200	6200	-
3 Net Cash flow before tax	(18000)	6200	6200	6200	6200	6200	6200	-
4 Depreciation	(7200)	(3600)	(3600)	(3600)	-	-	-	-
5 Profit/loss (2)-(4)	(7200)	2600	2600	2600	6200	6200	6200	-
6 Loss carryover	0	(7200)	(4600)	(2000)	-	-	-	-
7 Taxable income	(7200)	(4600)	(2000)	600	6200	6200	6200	-
8 Tax[4] 0.5x(7)	0	0	0	0	(300)	(3100)	(3100)	(3100)
9 After-tax cash flows (3)-(8)[5]	(18000)	6200	6200	6200	5900	3100	3100	(3100)
Recapitulation								
3 Before-tax cash flows	(18000)	6200	6200	6200	6200	6200	6200	-
IRR = 25.7% before taxes								
8 After tax cash flows	(18000)	6200	6200	6200	5900	3100	3100	(3100)
IRR = 18.1% after tax								

For the above example, the IRR is reduced from 25.7 percent before tax to 18.1 percent after tax. With the calculation procedure programmed for computer use, it becomes

4 In some countries, special tax credits or tax exemptions may be given for approved energy efficiency investments. These special 'rules' must be included in the calculation.

5 After-tax cash flows are particularly important to a company to check if significant reserves are needed to survive periods of negative cash flows.

easy to investigate the sensitivity of the IRR to changes in tax rates, depreciation rates, loss carryover provisions, etc.

Finally, it is appropriate at this point to mention some of the different possibilities for financing projects. It has been assumed in all the examples so far that the capital cost of a project has been met by company funds, that is, by a cash payment. Many companies may not have the full amount of money available and some companies may choose to borrow a proportion of the required funds. If a project is not to be paid for by 100 percent equity from the company reserves, a different debt/equity ratio can be used in the project evaluation calculation.

In general, the calculation method is similar to that already discussed in this manual. However, in addition to the normal line items, it is necessary to introduce into the cash flow calculation the effect of interest paid on the debt portion of the capital investment, and the effect of repayments of the principal in accordance with some agreed debt repayment schedule. The precise terms of the loan must therefore be established. Some lenders will charge a fixed rate of interest on the balance outstanding and will allow a moratorium on principal repayment for the first 3 years. Some loan terms include a total moratorium on interest and principal payment for 2 years. Based on the exact terms available, the interest and capital repayments can be introduced into the cash flow calculation and the interest payments will normally decrease the profit that is subject to taxation. Although the calculation may seem complex, the rigorous, logical method used in the previous example may be extended relatively easily to incorporate the impact of debt (and the associated interest payments) on the before-tax and after-tax internal rates of return.

3.15 COMPUTER MODELS FOR PROJECT EVALUATION

From the examples given in this manual, it is clear that the calculations are easily made using micro-computer spreadsheet software, such as Lotus 123. Changes in one or more parameters can be introduced and the impact on net present value and IRR observed rapidly. Tedious calculations, especially those involving taxation, are avoided and the risk of error is much reduced.

Ready-made software programs for project construction, before and after tax and to different depreciation schedules, are available. Two examples are the Energy Conservation Project Investment Evaluation (ECPIE) Model, written under the USAID ECSP and RCG/Hagler, Bailly's EFAP model. Both were developed by RCG/Hagler, Bailly. Both programs allow the user a broad range of flexibility to set investment values, project lives, dept/equity ratios, levels of benefits, tax and depreciation rates, etc. Using these models, sensitivities and risk analyses may be performed rapidly and accurately. For small projects with few uncertainties, manual calculations are normally adequate. For large projects where sensitivities must be explored, use of a microcomputer and the ECPIE Model (or a similar model) is strongly recommended.

3.16 INCREMENTAL ANALYSIS

For many projects it is frequently found that several alternative designs are available and it is necessary to decide which alternative is best economically. In particular, it may be found that energy efficiency may be increased in stages by increased investment. For example, a heat recovery system may be installed with either a small heat exchanger or a range of increasingly larger exchangers: larger heat exchangers recover more energy but require greater investments. It is important to define at which investment level the optimum economic results will be achieved.

The principle of incremental analysis is used for this purpose and may be applied with both simple payback and IRR calculations. The principle is explained as follows.

For each project, a base case is defined. Usually this will represent the minimum investment alternative. The project return (e.g., simple payback or IRR) is calculated. The next increment of investment, from more expensive equipment, is then estimated and the return on the incremental investment is calculated. This return is calculated based on the additional savings only that are generated by the incremental investment. Providing that the base case return is attractive, it will be attractive to continue to add incremental investment until the return on the last increment of investment added is the minimum acceptable. When the incremental return falls below the minimum acceptable, then the particular case under study is not the optimum.

An example of incremental analysis will show the principles involved. Let us assume a heat recovery project is being investigated. There are four configurations that are technically feasible, A being the smallest heat exchanger and D the largest.

	A	B	C	D
Cost ($)	10,000	15,000	20,000	25,000
Energy Savings ($/yr)	6,200	9,000	11,600	13,900

It is also known that the plant management evaluates projects on the basis of simple payback and a project with a simple payback period of under 2 years is normally acceptable. Which option should be installed?

The procedure to evaluate the four options is as follows:

(1) Calculate the payback period for each option:

	A	B	C	D
Payback (years)	10,000	15,000	20,000	25,000
	6,200	9,000	11,600	13,900
	1.61	1.67	1.72	1.80

From this calculation, it appears that all options meet the "less than two years" criterion for an acceptable payback.

(2) Calculate the incremental investments, incremental savings, and the payback for each increment:

	A	—	B	—	C	—	D
Cost($)	10,000		15,000		20,000		25,000
Increment($)		5,000		5,000		5,000	
Savings($)	6,200		9,000		11,000		13,900
Increment($)		2,800		2,600		2,300	
Payback(yrs)	1.61		1.67		1.72		1.80
Incremental payback(yrs)		1.79		1.92		2.17	

From this calculation, it is clear that the incremental investments have paybacks under two years except for the final increment, C to D. By the incremental analysis, Option C is acceptable but Option D should not be installed because the incremental payback does not meet the management criterion.

The incremental investment of $5,000 should not be spent on this project but a more attractive project should be sought that will meet the requirement of a 2 year payback.

3.17 GOVERNMENT POLICIES TO INFLUENCE INVESTMENT DECISIONS

A number of government policy measures are available for altering the way a company views energy conservation investments. Some examples are as follows:

1. Measures to improve the terms of access to debt capital, e.g., by reducing debt costs. These measures can increase the rate of return of a project. By providing more flexible terms of repayment, cash flows can be made more acceptable to prospective borrowers.

2. Measures that reduce the capital cost of a project, such as direct grants, cost-sharing, investment tax credits or other capital subsidies.

3. Measures that reduce taxes, such as special conservation tax credits and accelerated depreciation of investments.

4. Measures that reduce risk, such as performance and load guarantees.

The impact of government policies on the payback and IRR of a project should therefore be taken fully into account in the evaluation of projects.[5]

3.18 SUMMARY OF RECOMMENDED EVALUATION PROCEDURES

There are many methods of evaluating potential capital investments. Two methods are considered to be particularly useful, simple payback and IRR (using the discounting

5 A comprehensive discussion is given in "The Economics of Energy Conservation at the Enterprise Level", prepared by M. Fisher (RCG/Hagler, Bailly, Inc.) for the USAID Energy Conservation Services Program, 1985.

technique). It is therefore recommended that the following procedure be used to rank and evaluate potential capital investments:

1. Ensure all capital and associated costs are available. Calculate the benefits (energy and other). Check the basic guidelines for analysis, such as maximum acceptable payback and IRR (or cost of capital). Project lives should be established.

2. For all projects, calculate the simple payback period.

3. Rank projects in order of payback period. Projects with a long payback (e.g., greater than 5 years) should be rejected, unless there are special reasons for considering them further. The management of few plants will be willing to accept such long payback periods. On the other hand, projects with a short payback period (e.g., less than 2 years) should be proposed to management and, hopefully, approved and implemented. Management will often accept payback periods of 2 years or less while demanding relatively little financial analysis, unless the capital investment is particularly large (e.g., over $200,000)

4. For all projects with intermediate payback periods (2 to 5 years), the IRR should be calculated. The IRR can be used to rank the projects and to compare with the company's cost of capital. Projects whose IRR exceeds the cost of capital (by a margin of a percent or two, depending on management criteria) should be presented to company management for consideration, together with the results of Step 6.

5. All projects in which a "phased" approach can be adopted should be subjected to incremental analysis to determine the optimum options.

6. For attractive projects, the appropriate risk analyses should be conducted to assess the sensitivity of the IRR results to changes in costs or benefits. The findings of the risk analyses should be included in the final project proposal that is presented to management for the approval of capital investment.

Finally, some important points to be noted are the following:

1. The working lifetime of a project requires careful consideration, and a realistic value should be chosen for the IRR calculation. However, the typical length of a project is around ten to fifteen years, with an IRR requirement of 20 percent or more. The discount factors for this situation are quite low after a few years. This means that the contribution of the later years to the NPV (and IRR) is rather small and therefore the exact lifetime of the project is not critical in most cases.

2. If a potential project is particularly innovative or involves a large capital investment, a careful evaluation of the risks is essential. The risk or sensitivity analysis must include a "pessimistic", a "realistic", and an "optimistic" scenario for consideration. Uncertainties should be included in the pessimistic picture to ensure that management is made fully aware of any difficulties involved. When a project is to provide data for other production equipment, it is most important to monitor it carefully and completely. A decision on the eventual replication or development of the system depends on accurate data being collected.

3. In practical situations in a factory, there are often many unpredictable variables. The rigid application of financial analysis is therefore only to be used as a tool to ensure the whole picture is considered. Judgments have to be made before the financial analysis takes place; a rigid analysis can then be applied. In some evaluations, the effect of operational problems is ignored in the IRR analysis. Attempts should always be made to quantify all the variables involved and, where there are uncertainties, carry out a proper sensitivity analysis.

4. Although it is sometimes difficult to identify the ancillary benefits of a project, it is essential to consider these marginal areas when the project is difficult to justify using the more easily identified factors. However, in any project, an attempt should be made to include as many of these benefits as possible, particularly in the sensitivity analysis. Basically, the nearer a

project is to the borderline of acceptance, the more effort should be put into the clarification of doubtful areas.

5. In some countries there may be severe foreign exchange shortages and yet certain items of equipment must be improved. In such cases, it is usual to carry out project evaluations using the same general methods described in this manual, but identifying clearly the foreign exchange and local currency elements of the capital investment. Sometimes foreign exchange can be obtained from a country's central bank, but a premium may have to be paid above the normal exchange rate; the project evaluation must take this added cost into account.

CHAPTER 4: PROJECT IMPLEMENTATION

4.1 INTRODUCTION

Following approval of funding for a project, implementation may proceed. This process can be divided into several major activities:

1. Planning
2. Detailed Engineering Design
3. Procurement of Equipment and Services
4. Construction
5. Commissioning
6. Monitoring Project Performance

4.2 PLANNING

Planning entails reviewing the feasibility study and all other previous work, verifying important data, and developing a complete work plan that includes time schedules, detailed design procedures, drawings, arrangement of financing, and clear directions regarding project responsibility.

At the beginning of the planning phase, the plant management should appoint a project manager and select a team. The project manager must be aware of the skills and financial and material resources existing within the company and plant. Where these resources are lacking, they will have to be provided from outside. The project manager must therefore be knowledgeable concerning these outside resources available within the country, such as construction services, equipment supplies, and consulting organizations.

One of the first actions of the project manager and his team will be to draw up a list of all activities necessary to implement the project. Each activity has an associated time frame which is dependent, to a greater or lesser extent, on the completion of previous activities.

To ensure that any construction project is completed in a timely manner and within budget, a schedule of activities must be developed. Various project management computer programs are now available for microcomputer use, based on such techniques as Critical Path Method (CPM) or Program Evaluation and Review Technique (PERT). These programs help the project engineer to keep track of all activities, their scheduled start and completion times, the resources required for each activity, and to identify any specific activities that might delay project completion so that additional resources can be brought to bear if necessary. Most computer software will present project activities in both tabular and graphical formats.

4.3 DETAILED ENGINEERING DESIGN

For virtually any project, however simple, a detailed design of the proposed plant modifications must be completed. On the basis of this design, the equipment can be ordered from the manufacturer or local suppliers. Where a small project is contemplated, such as the installation of a heat exchanger to recover heat from boiler blowdown, the design calculations are often quite simple and are done in-house. Installation drawings will also be needed to guide the civil works (for equipment foundations, supports, etc.) and the mechanical installation. In some cases, instrumentation drawings will also be needed. For small projects, most of the preparation of drawings can often be carried out in house. Where the plant lacks the necessary skilled engineering personnel, an outside engineering consulting will be commissioned to do the work.

In the case of complex projects, especially those involving new technologies or novel equipment designs, a great deal of assistance can be required from the manufacturer. In extreme cases, pilot plant testing may be needed, or data on key parameters may be sent to the manufacturers for use in sophisticated, proprietary computer models for optimizing the detailed process and equipment design.

In fact, the design of process systems and equipment is often carried out on microcomputers. Popularly known as computer-aided design (CAD), software is available for many process and equipment design exercises, and the same (or related) software can be used to produce any necessary drawings. However, the typical small to medium-sized plant in a developing country will not need such software very often, and it is best to utilize manufacturers or specialized consultant skills and experience when the need arises. Indeed, much of the best software is proprietary and is regularly updated to take into account new designs and new design methods that are developed from proprietary research.

Although specialized programs are needed for some aspects of process and equipment design, a plant engineer may find a microcomputer useful for carrying out routine design calculations such as pipeline pressure drops, line sizing, and pump or compressor selection. Depending on frequency of use, a heat exchanger design program might also prove useful, as might HVAC design programs. Software may be obtained from private companies, from computer dealers (suppliers), and through professional societies Information on microcomputer software is often provided in professional journals published in the United States and Europe. In an extreme case, a plant-specific program could be written by the plant energy manager, perhaps with the assistance of local university staff.

4.4 PROCUREMENT OF EQUIPMENT AND SERVICES

The procurement process is the acquisition of all the outside services and materials necessary to implement a project. It is important to ensure that the most cost-effective services and equipment are obtained, that is, the lowest price should be paid, consistent with the required quality and delivery dates specified by the plant.

Some plants may have an experienced purchasing department that can undertake the procurement activities. In some cases these activities will be left to a plant engineer or the project manager. For equipment, the procurement process consists of the following steps:

- Determine equipment availability and estimated cost, prepare lists of qualified suppliers.

- Prepare specifications and bid documents.
- Obtain bids from several equipment suppliers.
- Evaluate bids and select equipment to be purchased.
- Where necessary, report the process to select an installation contractor.
- Contract for the equipment purchase and installation services.
- Arrange for delivery of equipment to the site.

Before undertaking the purchase of outside equipment or services, there are several basic items that the project manager must consider. These include:

- In most cases, procurement from local sources should maximized, subject to quality and availability, to keep costs to a minimum. In some countries government regulations may prohibit importing certain categories of equipment.
- Local conditions and in-plant skills should be assessed carefully before procurement decisions are made.
- Equipment must be ordered well in advance of the estimated time of need.
- Competitive bidding should be used whenever practical to minimize costs and maximize quality.
- Careful attention must be paid to the impact of tariffs and customs clearance time on the cost of equipment and the time schedule.
- Future maintenance and training in operations should be provided for during the procurement phase.
- Appropriate insurance must be provided at various stages of equipment purchase and installation.

Assuming that basic guidelines for such items have been established as company policy, the procurement process may be started. With respect to equipment availability and costs, the project feasibility study should have provided at least rough estimates of equipment and construction costs and the availability of contractor services. These data are a good starting point with which to assess supplier and contractor responses.

Comprehensive and clear specifications must be assembled and the corresponding bid documents prepared. For equipment, duties and dimensions should be provided to bidders in as much detail as possible. Operating conditions should be given (temperatures, pressures, hours of operation, continuous or intermittent operation, etc.) and, if appropriate, hazardous or corrosive environments should be identified. For construction services, the bid documents must specify exactly what work will be required, the time period allowed for the work, and any other conditions that must be met. Bid documents should also specify the format for responses. This will permit the evaluation of responses on a common basis. In general, a package of bid documents will contain at least the following items:

- A formal invitation to bid
- Instructions to bidders
- Bid forms
- General conditions of the contract
- Detailed specifications of the equipment or services requires
- Any relevant drawings.

Once bids have been received, they must be evaluated and the bid that provides the required equipment or services at least cost to the plant (within the desired time limitations, of course) must be identified promptly. Where necessary, bid prices must be adjusted to include freight costs, insurance, and import duties on a common basis. Suppliers will often quote factory gate, or Freight on Board (FOB) prices, based the port of shipment in the country of origin.

Contracts for equipment and services must be carefully written to specify the exact items covered, the relevant time schedules, facilities or services to be provided by the plant (if any), the schedule of payments to be made, the extent to which costs may vary in case of unforeseen circumstances, any inspection or quality control procedures that must be met before final payment is made, and details of any after-sales services, training, and performance guarantees.

Equipment should be inspected on delivery. Inspection of large items to ensure specifications are met and the equipment is in good condition is often a task entrusted to specialized companies. The first such inspection will normally be completed at the port (or airport) of delivery, possibly in conjunction with customs inspection and clearance.

Finally, the engineer responsible for procurement must consider the delivery of equipment to the site. Heavy equipment, in particular, may pose logistical problems. In addition, some items may require special storage conditions (e.g., humidity and temperature-controlled conditions for electronic instruments).

4.5 CONSTRUCTION

The construction phase is, of course, the installation of equipment on-site. Simple projects will be completed by plant personnel but construction of large or complex equipment may need to be contracted out to a specialist firm.

Planning plays a major role in the construction phase. In particular, it is important that normal plant operation proceeds with as little disruption as possible while equipment is being installed. Often it is possible to erect new equipment adjacent to existing systems so that a short shutdown is all that is required to tie in the new equipment (and, if appropriate, disconnect the old system). In some cases, removal of the old equipment is essential before the new equipment is installed. A longer shutdown may therefore be needed, and careful options planning is essential to minimize the value of lost production (through pre-shutdown inventory building, for example).

Effective monitoring of the construction progress is important to ensure that schedules are met, that items of equipment are delivered to the site at the right time, and that the right resources of manpower and construction equipment are in place when required.

4.6 COMMISSIONING

Once the new system has been installed, it must be started up, operated and checked. Often this will be the responsibility of the construction contractor, possibly working in conjunction with manufacturers representatives who have specific responsibilities for certain items of equipment and the appropriate plant operations staff who will be responsible after commissioning. Performance testing should also be carried out to check that equipment and systems meet the contractual specifications and performance guarantees. When necessary, adjustments to the equipment should be made before formal acceptance by the plant management. In particular, closed-loop control systems may need fine-tuning by experts. This process might take several days.

Finally, as part of the commissioning phase, any necessary training for operators or maintenance technicians should be completed. Emergency shutdown procedures should be covered. Long-term arrangements for spare parts should be reviewed with engineering and maintenance departments.

4.7 MONITORING PROJECT PERFORMANCE

Once a capital investment has been made, it is important that the subsequent plant performance be monitored to see if the projected benefits are actually achieved. Plant management will wish to check that the estimated payback or IRR is met, or that the actual payback or IRR at least meets the company criteria. Where actual performance falls short of that predicted, the explanation should be sought so that corrective measures can be taken to improve the situation.

Data on energy consumption and plant production should be collected as a routine procedure. Hopefully, good plant records will be available to assess performance <u>before</u> the implementation of a particular project. It is important to relate energy use

to production and thus calculate the specific energy consumption for the plant or process (that is, the energy used per until of output).

For many factories, where output can be expressed in terms of one major product, a plot of energy use against production rate can reveal a great deal about the efficiency of the process. Exhibit 4-1 is a typical graph showing two components:

(1) energy related to production (mP)

(2) energy not related to production (e)

For example, in a simple factory utilizing only electricity, "mP" could be the electricity used to operate machines while "e" could be the electricity used for various purposes which are not directly related to production, such as lighting, ventilation fans and air conditioning. Examination of the graph of energy against production will thus reveal the extent of the energy used for "services" or standing losses from equipment, in contrast to the energy actually used for production purposes.

An item that should be monitored by plant managers is the "specific energy consumption" (SEC), which is the energy used per unit of output:

$$SEC = E/P$$

For the typical factory, whole performance is indicated in Exhibit 4-1,

$$SEC = E/P = e/p + m$$

A plot of SEC against production rate (P) is given in Exhibit 4-2. This characteristic curve shows that energy efficiency, as measured by the energy consumed per unit of output, will generally decrease (and decrease quite significantly) as throughput is dropped.

It is therefore extremely important to relate the energy consumption per unit output (SEC) with throughput or capacity utilization. In Exhibit 4-2, for example, point A represents an improvement in energy efficiency compared with the average performance while point B shows a deterioration, even though the actual value of B is lower than A.

Exhibit 4-1

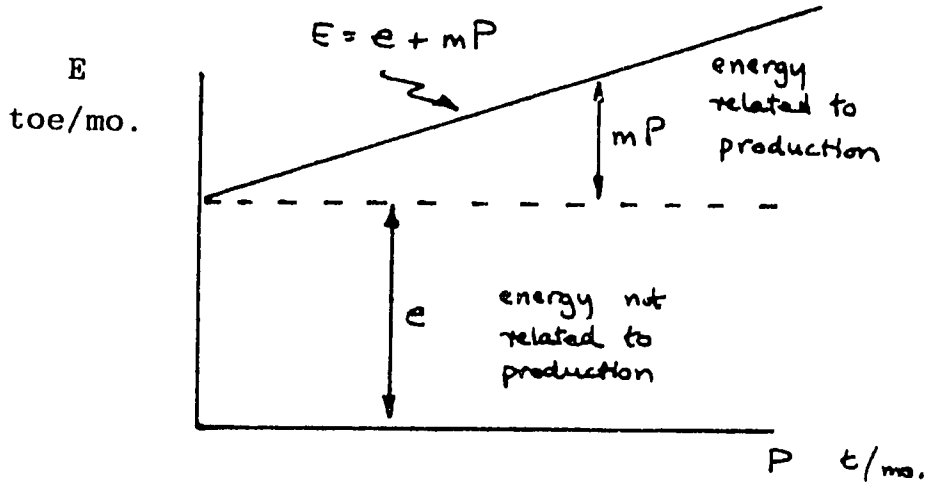


Exhibit 4-2

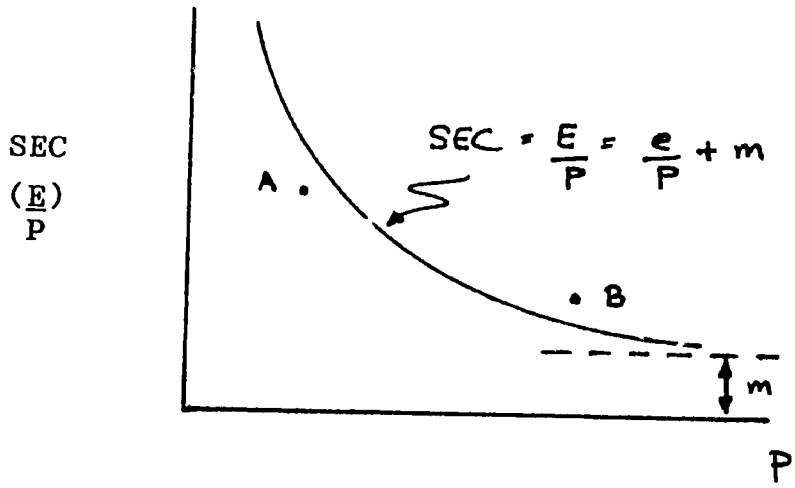
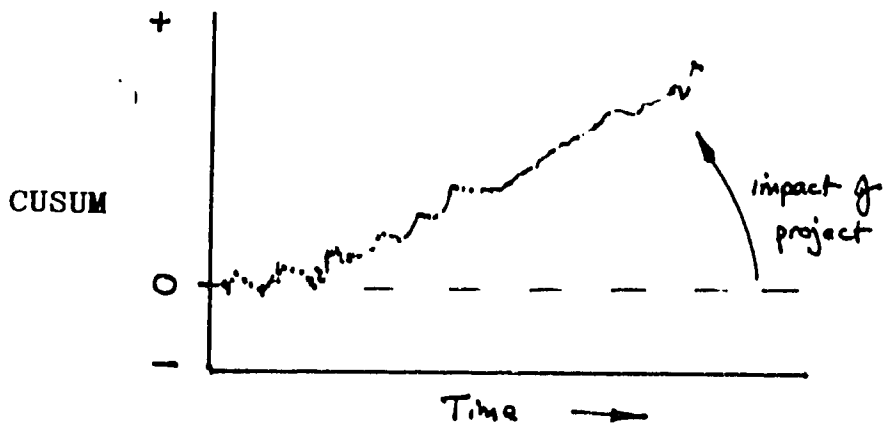


Exhibit 4-3



This gives one means of checking if plant performance has changed after implementation of an investment project. Historical data can be used to establish the typical SEC curve and new data (taken after project implementation) should indicate if energy efficiency has improved. Similarly, the graph of E against P should also indicate improvements.

Another method of highlight energy efficiency improvements is to develop an equation to predict energy consumption using historical data. After project implementation, the actual energy use is measured and compared with the predicted energy use for the same plant output. If there has been any improvement in energy efficiency, there should be a measurable difference between these two quantities:

$$E \text{ predicted} - E \text{ Actual} = \text{Savings}$$

The actual energy use should be measured over specific periods of time, for example every week, and the savings calculated by comparison with the predicted energy use for the same production. A graph of the "cumulative sum of savings" (CUSUM) drawn against time should soon reveal the trend, if any, towards greater energy efficiency (See Exhibit 4-3). This method allows for the fact that there may be some periods when the savings are negative, due to random functions in plant operations, to errors in readings and/or calculation of energy use, or to inaccuracies in the estimation of the predicted energy use. Over a reasonable period of time, the CUSUM curve should show a distinct trend toward greater energy efficiency if indeed the project has had any beneficial effect.

Of course, these methods of monitoring plant energy efficiency may not be sensitive enough to the improvements made by a small energy saving project. Heat and material balances around the new or modified equipment may also be used to check performance and to compare it with performance prior to implementation.