ENERGY
MANAGEMENT
SERIES

FOR INDUSTRY
COMMERCE
AND INSTITUTIONS

Energy Accounting

Energy, Mines and Resources Canada   Énergie, Mines et Ressources Canada

Canada

PREFACE

Much has been learned about the art and science of managing energy during the past decade. Today, energy management is a seriously applied discipline within the management process of most successful companies.

Initially, in the early 1970's, energy conservation programs were established to alleviate threatened shortages and Canada's dependency on off-shore oil supplies. However, dramatic price increases quickly added a new meaning to the term "energy conservation" — reduce energy costs!

Many industrial, commercial and institutional organizations met the challenge and reduced energy costs by up to 50%. Improved energy use efficiency was achieved by such steps as employee awareness programs, improved maintenance procedures, by simply eliminating waste, as well as by undertaking projects to upgrade or improve facilities and equipment.

In order to obtain additional energy savings at this juncture, a greater knowledge and understanding of technical theory and its application is required in addition to energy efficiency equipment itself.

At the request of the Canadian Industry Program for Energy Conservation, the Commercial and Institutional Task Force Program and related trade associations, the Industrial Energy Division of the Department of Energy, Mines and Resources Canada has prepared a series of energy management and technical manuals.

The purpose of these manuals is to help managers and operating personnel recognize energy management opportunities within their organizations. They provide the practitioner with mathematical equations, general information on proven techniques and technology, together with examples of how to save energy.

For further information concerning the manuals listed below or material used at seminars/workshops including actual case studies, please write to:

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1 - INTRODUCTION

1.1 - Value of Energy Management

Energy management is a sound investment. It offers investment opportunities with attractive payback periods and above-average returns to plant and building owners. Put another way, energy management can be thought of as a low-cost source of energy, capable of supplying a plant or building with substantial volumes of conserved or reclaimed energy, well under the cost of purchased fuel and electricity. Moreover, from a national perspective, energy management conserves energy resources and improves the balance of international payments.

1.2 - Monitoring Energy Productivity and Performance

To realize the full economic potential of energy management, plant and building energy managers should be capable of tracking and comparing the energy efficiency or productivity of their operations. Just as financial management involves the measurement and reporting of financial indicators, so energy management should include the monitoring of energy productivity and performance. Both gross and net energy performance need to be monitored. Gross energy performance is the change over time in the quantity of energy used to produce a given amount of output. Net energy performance refers to changes in energy productivity resulting from conscious energy management efforts. Note that not all changes in energy productivity are the result of decisions based on energy management considerations.

1.3 - Objectives and Organization of the Energy Accounting Manual

This manual is intended to assist Canadian firms and organizations in the industrial, commercial and institutional sectors in their efforts to design and implement an appropriate energy accounting system capable of monitoring energy productivity and performance. This system will help management to identify opportunities for improvements in the efficiency of energy utilization. The manual provides a standard accounting format applicable to both single- and multi-unit organizations. The accounting format is presented through the use of text, forms and numerical examples.

The fundamentals of energy accounting are provided in Section 2. These include the basic concepts and approach relevant to energy accounting (Section 2.1); reporting considerations (2.2); the measurement of production outputs and energy inputs (2.3 and 2.4); and the measurement of **energy productivity** (2.5).

Section 3 extends this basic approach to show how changes in energy productivity may be translated into a measure of **net energy performance** through the use of adjustment factors. The limitations of using unadjusted **gross energy performance** figures are discussed in Section 3.1 and the various factors affecting energy productivity are noted in Sections 3.2. and 3.3. The method for measuring net energy performance, as applied to single reporting centres and to company, organization or industry levels of aggregation is described in Sections 3.4 and 3.5.

Section 4 turns to the ultimate goal of energy management — the achievement of cost savings — and shows how the financial impact of saving energy is measured and reported.

Section 5 provides a numerical example for industrial operations and buildings, including completed forms and calculation procedures showing the various components of an energy accounting system. Appendices A to D provide, in order: a glossary of terms; calorific contents of energy commodities; metric conversion factors and prefixes; and the set of blank forms that make up the energy accounting system.

2 - FUNDAMENTALS OF ENERGY ACCOUNTING

This section describes the basic concepts and approach involved in energy accounting. Particular attention is paid to showing how energy productivity may be measured at the plant or building, company or organization, and sectoral levels of aggregation.

2.1 - Basic Concepts and Approach

2.1.1 - Concepts and Approach

Energy productivity is defined as energy consumption divided by output.[1] This definition can be applied to a single energy consuming unit such as a plant or building, to a group of such units, or to an entire industry, industrial sector and the economy as a whole.

Energy productivity trends are monitored by measuring current energy productivity and comparing the result with those for one or more selected reference or **base periods**. Of course, comparisons may also be made at any one time between the energy productivities of two or more consuming units. This type of comparison has been frequently made at the international level; the results of such comparisons typically show that Canada's energy use per unit of national output is among the highest in the world.

If the energy productivity trends of a single plant or building alone were the only interest, it would be sufficient simply to measure the energy-output ratio at two points in time and calculate the percent difference. However, in practice, there is often interest in the aggregate energy productivity of a group of reporting centres, each of which may produce different types and quantities of goods and services. Aggregating energy-output ratios across such centres is feasible only if similar products or services are produced in each. As the outputs of various reporting centres may well be dissimilar, a different approach is necessary. This involves the comparison of actual energy consumption in the current period with **base period equivalent energy** or imputed energy consumption. Imputed energy consumption is defined as the amount of energy that would have been consumed in the current period if energy productivity as measured for the base period remained constant. The percent difference between imputed and actual energy consumption measures the change in energy productivity or **gross energy performance**. As later sections will show, it is straightforward to sum actual and imputed energy use across various reporting centres to calculate the aggregate change in energy productivity.

2.1.2 - Overview of Calculation Procedure

Figure 1 provides an overview of the steps involved in calculating changes in energy productivity. The step-by-step procedure is summarized as follows (subsequent sections discuss in greater detail each of these steps):

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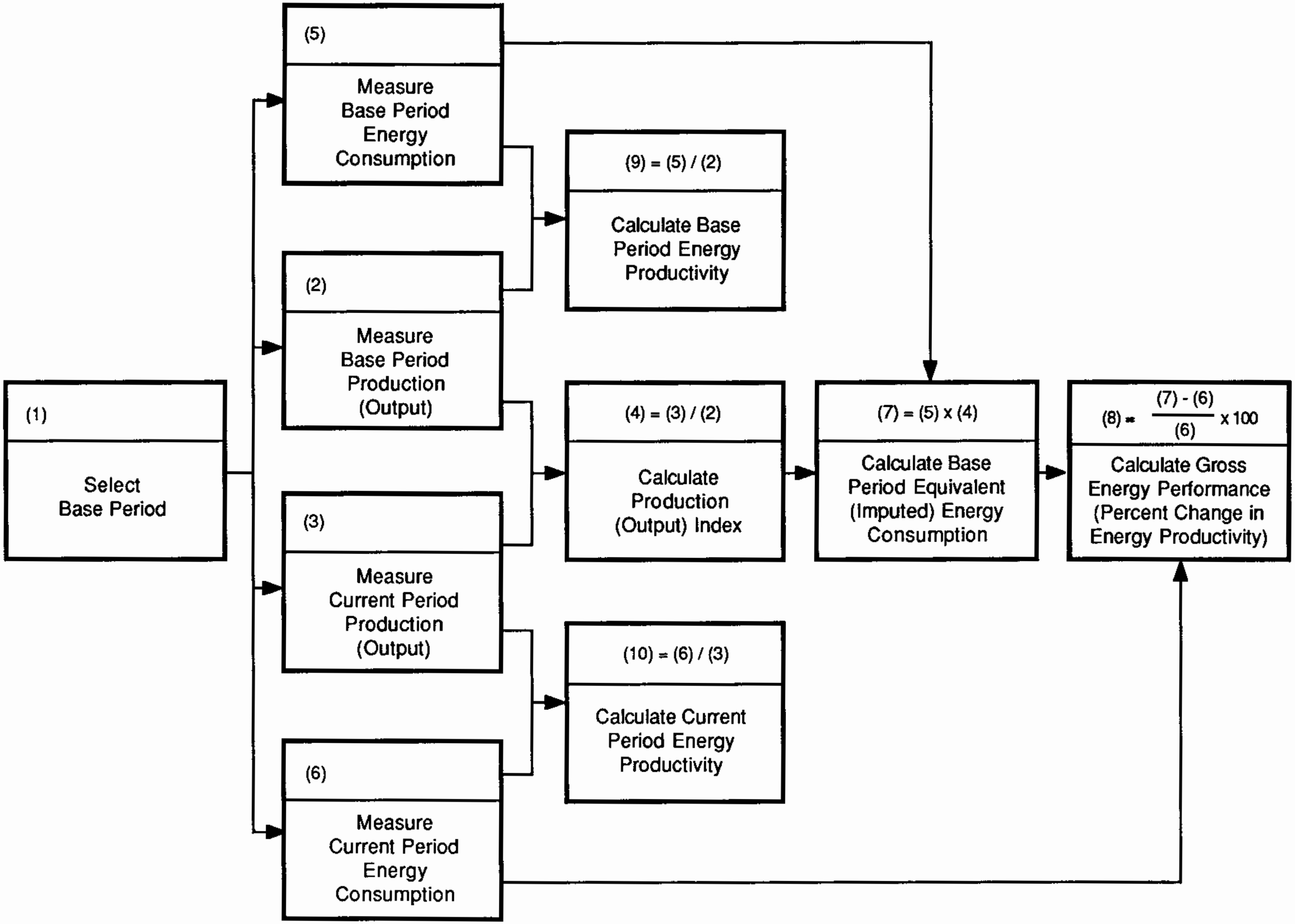
[1]This measure may also be denoted as *energy intensity*, *energy-output ratio* or *energy coefficient*. For definitions of these and other terms the reader is referred to the Glossary in Appendix A.

Figure 1

Energy Productivity Accounting
OVERVIEW OF CALCULATION



1. Select base period (see Section 2.2.3).
2. Measure base period production or other indicator of activity (see Section 2.3).
3. Measure current period production (see Section 2.3).
4. Calculate production index (see Section 2.5.4).
5. Measure base period energy consumption (see Section 2.4).
6. Measure current period energy consumption (see Section 2.4).
7. Calculate imputed current period consumption (see Section 2.5.4).
8. Calculate change in energy productivity (see Section 2.5.4).

If the plant or building manager is also interested in the absolute levels of energy productivity, the same raw data may be used to derive these indicators as follows:

9. Calculate base period energy productivity (base period energy use divided by base period production).
10. Calculate current period energy productivity (current period energy divided by current period production).

The energy productivity figures calculated in steps (9) and (10) are not required for energy accounting per se. However, they do afford comparisons of energy efficiency at a point in time, among similar plants and buildings within Canada or internationally.

2.2 - Reporting Considerations

Thoughtful and consistent attention to data collection will ensure useful, reliable energy productivity and performance measures. Figure 1 shows how the various steps in energy accounting are connected. The practical execution of each step must be carried out according to the individual characteristics of an organization and within an organization according to the particular type and circumstances of operation. The purpose of this section, and the two that immediately follow, is to set out guidelines that will help in the establishment of an energy accounting system that is tailored to the organization's specific conditions.

2.2.1 - Selection of Energy Accounting Reporting Centres

An organization may produce one product, operation or service from a simple process, or several complex, interrelated processes could be involved. Bearing in mind that energy productivity relates the quantity of energy going into an activity to the output of the activity, it is clear that the more closely this relationship can be identified, the more accurate the measure of energy consumed per unit output. More importantly, it will be easier to relate the calculated energy productivity to specific operations, and thereby determine the potential for making improvements in energy performance.

It may be possible to set out the operation of the organization schematically, including all production processes, and identify stages at which measured energy use can be related most closely to quantities of output passing through each stage. These locations of measurement are called **reporting centres**.

In general, the longer and more complex a process, the more opportunity there will be for improvements in energy performance by identifying as many reporting centres as possible. In this way, even organizations producing a variety of outputs from interconnected processes in a number of locations can obtain meaningful energy performance information from energy accounting.

Often, organizations keep financial records pertaining to the operation of discrete divisions. As energy bills would likely be accounted for in this regular financial monitoring, these operating divisions can be good places to locate energy reporting centres. In this way, costs and related output and energy use information can accurately be recorded over time. This is the key, as noted above, to good energy accounting. This manual is written assuming the normal metering points. As the number and specificity of measurements are increased, management will have more information, be able to make more accurate decisions, be better able to identify energy saving opportunities, and save more energy and money.

2.2.2 - Timing and Frequency of Reports

To facilitate tracking and planning energy performance improvements, data from reporting centres must be recorded on an ongoing basis, and at specified intervals. The timing of these intervals can be fixed according to periods at which both energy and output can be measured conveniently. For example, natural gas consumption is metred for billing purposes at one month intervals. Output is often measured per year, quarter or month, allowing a choice of alternative reporting intervals, since gas consumption can be summed over periods that are multiples of the one month billing period.

Care must always be taken to ensure that, whatever the reporting interval chosen, energy consumption as measured is actually used in the production of measured output. For example, invoices may be received on a monthly basis for deliveries of heavy fuel oil used to fire a boiler. If production over a previous period was less than capacity, a relatively small amount of fuel will be shown on the invoice. Over the subsequent production period however, this new fuel and the inventory of fuel oil already in the tank could be used to produce output at a rate above that registered for the preceding period. In this case, the actual amount of fuel consumed in producing the measured amount of output can only be determined by dipping the storage tank at the beginning of the reporting period, after the new fuel oil is added, and at the end of the reporting interval. The difference between the first and last reading, when added to the fuel bought, gives the amount of fuel consumed over the interval.

While it is appropriate to collect data on energy consumption and output at intervals that are best suited to focusing on the relationship between the two, comparing these measures of energy productivity may best be done at longer intervals. The operating circumstances of a plant may vary over time for reasons other than those directly related to energy use efficiency. As will be discussed in greater detail in Section 3, variations in output relative to design capacity, seasonal, meteorological or daylight hour changes should be allowed for; where such considerations are relevant, longer accounting periods may be necessary. The more frequently energy productivity tallies are made, the more insight can be obtained into the role of energy in the process.

2.2.3 - Choosing a Benchmark or Base Period

The base period is simply the first interval over which energy consumption and process output data are collected. An inventory must be made of the factors that for technical or other reasons may have affected energy productivity measured in that benchmark period. This list could include the fact that a work stoppage took place, meteorological conditions were markedly abnormal, a major alteration was affected to the production process, etc. The base period can, of course, be changed. In fact, it may be advisable to compare energy productivity in any current reporting period with that of the period immediately preceding, as well as with the base period.

2.2.4 - Reporting Responsibilities

Having described in general terms the objectives of energy accounting and the outline of how it is accomplished, the next step for a company or organization to take involves the selection of personnel most appropriate to undertake the work. Should an 'energy manager' already be employed by a firm, it remains only to delegate responsibilities as to the gathering of energy information for reporting centres selected. Staff closest to the reporting centre's processes should be involved, if only in an advisory capacity, for the purposes of gathering data, and to add insight on the performance of individual pieces of equipment, changes in operating conditions, and proposals designed to bring about energy efficiency improvements.

Finally, the persons involved in energy accounting should be close enough to energy efficiency decision-making to ensure maximum utilization of the management information they gather.

2.3 - Measuring Production Outputs

Energy productivity is measured by identifying the relationship between energy inputs and production outputs. This latter category includes all goods — from automobiles to zirconium — and all services — from massage clinics to message centres (where services are concerned, energy productivity is usually left to the owner of the building space the firm occupies). Reporting centres, then, might record data for 'output' measured in units like tonnes of product per month, cubic metres of throughput per quarter, square metres of space occupied, etc. Choosing the unit of measurement for production is a relatively simple matter where a reporting centre encompasses a large, distinct production process. A reporting centre may be chosen, however, that contains only a single component of the overall production process, in which case the unit of output is an unfinished good, used in the next stage of production. It is important in these cases to ensure that output can be measured accurately, even if such measurement is indirect (e.g. there exists a known fixed relationship between the quantity of finished goods produced —which is counted— and the quantity of intermediate product associated with that amount of output which is not counted, but can therefore be inferred for reporting centre purposes).

When choosing a unit of measure for production, it is advisable to start with those quantities that are currently recorded for other management accounting or production performance measures. If a unit is chosen for which records are not currently kept, data collection for energy accounting will necessarily involve increased costs for record keeping.

It may be the case that certain inputs are more closely related to energy use than any measure of output. If so, then the units applicable to the raw material in question can be used for energy accounting purposes, including labour or machine time used (number of hours or shifts). In the latter case, care must be taken not to confuse the measurement with changes in general productivity.

Where the majority of energy consumption is for building heating, cooling and lighting, it may be simplest to use the number of hours the facility is open as an energy accounting unit of 'production'.

2.3.1 - Examples of Units for the Industrial Sector

Table 1 lists some typical units of production that would be used in energy accounting. These are suggestions only; each organization should adopt units which measure the production of those segments of its operation most amenable to, or in need of, energy productivity improvement.

2.3.2 - Examples of Units for the Commercial/Institutional Sector

As is the case in the industrial sector, choosing a unit of output for an operation that consists of one or more buildings may not be straightforward. The chart also lists examples of such units, but individual organizations should use common sense when choosing the unit most appropriate to them. The most common unit of output is floor space. In some instances, energy may be consumed largely in relation to the total space occupied. For example, domestic hot water and lighting may account for the majority of energy consumed. In these cases, a measure of area in use could be selected, such as occupied beds (in hospitals) or occupied rooms (in hotels). Monetary units as measures for energy inputs or outputs is not recommended in energy accounting in order that the necessity of adjusting for price fluctuations is avoided.

2.4 - Measuring Energy Inputs

Useful energy accounting is also predicated on accurate measures of energy consumption. This section will show how easily each particular energy form can be accounted for and converted into common energy units of measurement.

2.4.1 - Types of Energy Commodities

Energy requirements are usually met in the form of natural gas, fuel oil, and electricity. Less common but equally relevant are coal, wood and waste, propane and purchased steam. Some industries, like petroleum refineries, purchase inputs the majority of which are used for raw materials, but some of which are used for process energy. Note that the focus of the manual is on the efficient use of

TABLE 1

TYPICAL UNITS OF PRODUCTION

Industrial Sector

Chemicals	- Weight of product
Vehicle Manufacturing, Farm and Industrial Machinery	- Number of finished machines or parts, weight of parts in cases such as castings, direct labour hours or shifts worked
Ferrous Metals	- Weight of raw steel as poured or cast
Food and Beverage	- Number of cases/containers, weight of product or weight of a key raw material
Electrical and Electronics	- Completed units, direct labour hours or shifts worked
General Manufacturing	- Completed units, weight, length, area of product, quantity of key raw material used, direct labour hours or shifts worked
Petroleum Refining	- Cubic metres of crude oil processed
Plastics	- Weight, length or finished units, machine hours
Pulp and Paper	- Weight of finished product
Industrial Minerals	- Volume or weight of raw material or finished product
Textiles	- Weight of material input or finished units

Commercial/Institutional Sector

Office Buildings	- Floor area (m^2)
Warehouses	- Floor area, building volume (m^3)
Shopping Centres	- Floor area
Hotels/Motels	- Floor area, rooms occupied
Supermarkets	- Floor area
Restaurants	- Floor area, capacity, meals served
Hospitals, Nursing Homes	- Floor area, beds occupied
Schools, Colleges and Universities	- Floor area, number of full-time equivalent students

purchased fuel and electricity. Energy from waste (wood, refuse, etc.) is excluded by certain industries in accounting for energy productivity and performance. The accounting method adopted should be consistent with the standard for the particular industry. In any event, the method should be uniform time.

2.4.2 - Types of Measurement

Energy consumption is generally measured in terms of the physical quantities of the types of energy in question. Typically, purchases are measured in litres, cubic metres, tonnes or kilowatt hours. These are the basic units recorded in energy accounting, and these are the units that will be used when designing courses of action aimed at improving energy performance.

Overall energy performance, however, can only be examined on the basis of a generic energy unit into which the various physical energy measures can be converted. The most commonly used energy unit that standardizes all of these fuel-specific units is the **joule (J)**. Expressed in terms of their energy content, information on consumption of all energy forms can be combined to yield a measure of total energy used.

Some organizations, in order to get a better understanding of energy use in terms that are easily translatable to current prices, may prefer to measure energy inputs in terms of a numeraire, or energy equivalent unit, for example, barrels of crude oil equivalent.

For convenience, a table setting out the energy content of several common energy types is provided in Appendix B.

2.4.3 - Measuring Energy Consumption

Energy consumption measurements may be made at different levels of detail, depending on the objective. Gross consumption data will be available from financial records, and may suffice for many purposes. However, for more detailed investigative work in complex situations, more refined measurements are required. The use of energy balance concepts to round out an energy measurement program is also reviewed in this section. For greater detail concerning the information in the discussion to follow, the reader may refer to Module No. 15 of this Energy Management Series, entitled *Measuring, Metering and Monitoring.*

(a) *Gross Consumption*

Gross consumption data by billing period for the major utilities (gas, heating oil and electricity) can be valuable, particularly to smaller organizations where the applications of each energy source may be limited to one major end use area. An office building, for example, may use electrical energy primarily for lighting and burn gas or oil for space heating. An industry may operate a single furnace or kiln that accounts almost exclusively for a single type of energy. In these circumstances, the gross consumption records may be adequate for most purposes.

(b) *Specific Consumption*

This manual is written to allow organizations to both calculate a single energy productivity factor for a year for the whole organization and to calculate many energy productivity factors for each managed activity of a complete organization.

Specific consumption data will be required where an organization is operating a number of different equipment items or processes from the same energy supply. The measuring equipment required may be permanently installed, or may be installed temporarily to rate typical performance characteristics of the equipment or process. Examples where different approaches are used are as follows:

- Electrical process (variable demand): A watt-hour meter can be permanently installed. Electrical process heat is usually delivered with negligible losses, simplifying measuring requirements.

- Electrical process (constant demand): Lighting in a commercial building, an essentially constant load in most applications, is an example. Where applicable, energy consumption can be inferred from the hours of business.

- Combustion furnace: The efficiency of combustion has a marked effect on energy use. While combustion efficiency can be checked by permanent instrumentation, regular maintenance is required to ensure the correct calibration of that instrumentation. A more cost-effective approach is to have furnaces tested for efficiency by a qualified technician. Testing should be repeated regularly so that combustion efficiency is always known to the desired precision. Elapsed time or fuel usage metering will then give complete information about fuel usage and energy delivered.

(c) *Energy Balance Accounting*

Measurements of energy may be balanced, either as a quality check on the data obtained or to extend the data. Obviously, in the second case the quality of the data should be verified by alternate means as far as possible. The following are examples where energy balance methods may be applied:

- A commercial building may use electrical energy for heating, lighting, domestic hot water and air conditioning. Monthly electrical energy is known from energy billings. Lighting energy is constant for each month and is known from the total wattage installed (including ballast losses, typically 15 to 20 per cent of the lamp rated power). The constant lighting energy can be subtracted from the monthly billed energy to obtain the heating plus domestic hot water in the winter months, or the air conditioning plus domestic hot water in the summer months. The domestic hot water load may be estimated from the 'shoulder' months, where neither heating nor air conditioning is used. Higher energy requirements should be anticipated in the winter and spring months, when the incoming water is cold.

- A hot water boiler is instrumented for measuring flow of water, incoming and outgoing temperature, and fuel usage. The boiler losses can be calculated from the difference between the energy contained in the fuel, and the energy contained in the heated water.

Supplementary data required for performing heat balance calculations can be obtained from Module No. 15, *Measuring, Metering and Monitoring.*

(d) *Energy Equivalence*

The purpose of measuring energy consumption is to determine if performance objectives are being met, and possibly to determine if alternate practices, procedures or energy sources should be introduced. It is first necessary to select the appropriate method of accounting for energy. The following are the principal options:

- Thermal Equivalence. This approach is useful in applications such as the evaluation of substituting natural gas for oil in a boiler. Referring to Appendix B, the fuels have the following energy contents:

Natural Gas	37.20 MJ/m^3
Heavy Fuel Oil	40.5 MJ/l

where MJ refers to one megajoule (one million joules) of energy (see Appendix C).

If the cost per MJ of natural gas is lower than the cost per MJ of oil, then it may be worth considering a fuel substitution. Note, however, that the combustion (energy conversion) efficiency will be different (typically lower) with the natural gas fuel, and therefore the cost comparisons should be in terms of useful or output energy. The cost per useful MJ of energy is simply the per MJ cost of a purchased energy type, divided by its combustion efficiency.

- Energy Quality. The thermal equivalence of a fuel does not by any means say everything about a fuel. Electricity is the highest quality commercial fuel, since it may be used for heat, light or mechanical work with a minimum of losses. If it is converted into heat, then the conversion can involve major losses depending on the temperature of the heat. The quality of energy is not always reflected in the price of the fuel. In general, a high quality fuel should be considered for applications where mechanical work or high temperatures are required. For space heating or low temperature drying operations, a low temperature waste heat stream should be considered when this is available. Refer to the Module *Waste Heat Recovery,* of this Energy Management Series, for a review of specific energy management opportunities.

2.5 - Measuring Changes in Energy Productivity (Gross Energy Performance)

Having considered the means by which energy contributes to production, the forms of energy used, the best locations for measuring energy inputs and product outputs, and the most sensible time period over which to collect data, energy productivity measurements can now be taken.

This section explains the procedures of basic energy accounting, that is, recording the two fundamental types of data required, and then calculating the relationship between them. Blank energy accounting forms are presented in Appendix D. They are designed for use by a generic organization that has chosen data recording intervals of one month duration and an energy performance calculation frequency of one year. Section 5 will show how these forms are to be used in practice; for now it will suffice to explain the concepts and relationships involved that will enable those charged with energy accounting to best tailor these sample recording forms to their individual needs.

2.5.1 - Recording Production Data

The choice of production units having been made (in Section 2.3.1), it remains to ensure that actual output over the period is counted, rather than sales or net change in inventories of the item in question. Moreover, be aware that, over the reporting period, there may be a planned physical change in the design of the product that could affect the amount of energy used per unit output. In some instances it may be best to start, or restart the base reporting period at the point at which this change took place [see Section 3.3.7 (4)]. Alternatively, allowances could be made in the form of an adjustment to the recorded quantity of output. All of these considerations having been accounted for, output quantities can be entered in column 8 of Form 1.

2.5.2 - Recording Energy Consumption Data

Measured quantities of energy consumed are recorded in columns 1 through 7 of Form 1. The appropriate volume of gas, oil, electricity, etc., to record for energy accounting purposes is not, as noted in Section 2.4, always straightforward. Electricity and natural gas are flows of energy, metered at the reporting centre 'gate'. The quantity of energy used between any two meter readings is easily determined by subtracting the latest reading from the earlier. If production can be measured over this same period, the process of relating electricity or natural gas use per unit of output becomes a relatively simple matter. If the meter reading dates on bills do not coincide with a reporting period chosen on the basis of its relationship to output measurement, special readings must be taken. Fuel oil, on the other hand, may be delivered in specific quantities at regular intervals, but because it is maintained as a stock and is not usually metered at the reporting centre 'gate', special attention should be paid to dipping the tank at the beginning and end of the reporting periods, and taking account of the quantities delivered in between. The same holds true for any analogous fuel (e.g. propane). Energy accounting requires information on actual energy consumption, not simply expenditures on energy. It may be that the only use an organization will have for utility bills in the energy accounting process is to keep track of energy prices. The adjustment for changes in stored quantities of fuel can be made at the end of the reporting period or at the end of the entire interval over which energy productivity is calculated.

When filling in the amounts of energy consumed, care should be taken to note certain details that could be useful when evaluating results. For example, grades of fuel oil should be accounted for separately, as should the quality of coal burned.

Total energy use for any single reporting centre employing more than one fuel type can only be calculated by first converting physical quantities of fuel to units of energy (MJ). This is a simple matter involving multiplication of the physical quantity consumed per reporting period by the appropriate conversion factor (from Appendix B, or from supplier information in cases where fuel quality can vary). This will yield energy consumption measured in MJ for each fuel type, the sum of these being the total amount of energy consumed over the reporting period. Form 2 provides a convenient framework for these calculations.

2.5.3 - Calculating Energy Productivity

Energy productivity — the average quantity of energy consumed per unit of output — is obtained for the reporting centre by dividing the total amount of energy consumed (MJ) by the total quantity of output from that energy. This yields a productivity figure expressed in MJ per unit of output. A single organization may wish to aggregate information from all of its energy accounting reporting centres in order to produce a measure of overall energy productivity. While this measure is useful for observing changes in the organization's efficiency with respect to energy use over time, it is only possible where all reporting centres are concerned with the same type of uniformly measurable output. Overall energy productivity can, then, be derived by assigning to the productivity measure calculated for each reporting centre a 'weight' to be used in the estimation of the total, where this weight is equal to the reporting centre's share of the total amount of energy consumed.

As noted earlier, organizations that produce a number of different outputs and therefore have several identifiable reporting centres, cannot aggregate simple measures of energy productivity. An overall estimate of gross energy performance — defined as the change in energy productivity measured in the current year over that calculated for the base year — can, however, be made.

2.5.4 - Calculating Changes in Energy Productivity Over Time

The energy efficiency trends of a reporting centre are gauged by the changes in calculated energy productivity over time. Once a benchmark reporting period has been established, each subsequent reporting period is considered the 'current period' for comparison purposes. The objective of calculating energy performance is to measure changes, over time, in the relationship between energy input per unit output that result from efforts to improve energy productivity.

Gross energy performance (EP_g) refers to changes in energy productivity over time. It can be estimated in both absolute and relative terms. To obtain a relative measure, a simple percentage change in a reporting centre's energy-output ratio between the base period and the current period can be calculated, yielding a figure for EP_g. To express EP_g in absolute terms, energy-output ratios can be compared (e.g. if the base period energy-output ratio is 243 MJ/unit and currently it is 212 MJ/unit, then the absolute change is a reduction of 31 MJ/unit). A better alternative, set out in Form 3, where an organization producing several different outputs is concerned, can be calculated in terms of the amount of energy used in the current period and the amount that would have been used in the current period if the base period energy-output ratio had remained unchanged.

This latter amount is called the imputed or base period equivalent energy (E_{be}). It is derived by multiplying the quantity of energy consumed at the reporting centre during the base period (E_b) by the quantity of output measured for the current period (Q_c), but after taking pains to express this latter quantity as a percentage or multiple of output in the base year (Q_b). To illustrate, if 2 units of output were produced in the base period, and production increased to 4 units for the current period, then current output expressed in terms of base period output (the so-called production index) would be 4/2 (or 2.0). If energy consumed in the base period was 10 MJ (making for an energy-output ratio of 5 MJ/unit output), then the base period equivalent energy would be 20 MJ (10 MJ, multiplied by 2) — it would have taken 20 MJ to produce the current period's output if the energy-output ratio had remained at its base period level.

Of course, the actual quantity consumed in the current period could be more, or less, than this base period equivalent amount. The EPg, expressed as the percentage difference between current energy consumption and the base period equivalent is identical to that calculated above using energy-output ratios.

It was stated earlier that base period equivalent energy measures could be used to calculate EPg for organizations that have more than one reporting centre, and more than a single measure of output. It should be clear that in such circumstances, energy-output ratios cannot be aggregated to the organization level in any way (e.g. weighted averaging) since the units of output are not all the same — a classic case of 'mixing apples and oranges', although approximations can be derived by assigning dollar values to develop weights. The EPg for an organization or an entire sector can, however, be achieved by calculating the percentage difference between the sum over all reporting centres of current period energy consumption and the sum, again over all reporting centres, of energy consumption expressed in base period energy equivalent terms. The format for such a calculation is shown on Form 4.

3 - REFINING ENERGY ACCOUNTING DATA: THE USE OF ADJUSTMENT FACTORS

The purpose of this section is to show how the basic data and results of energy accounting as described in Section 2 can be adjusted in order to exclude those influences on energy productivity that are outside the control of energy managers. Calculations involving adjustment factors are shown on Form 5.

3.1 - Interpreting Energy Performance Measures

Gross measures of energy performance (EP_g) give a good view of changes in the energy productivity of a reporting centre, plant, building or organization over time. The accuracy of these gross measures, and hence the associated confidence in the result, is critically dependent upon the degree to which the reporting centre environment changes over time. It was mentioned in Section 2 that seasonal or other regular fluctuations in output should be acknowledged when fixing the duration of reporting periods. In order to allow for different energy requirements for heating purposes as a proportion of the total energy picture, an adjustment to the E_b is required. The same consideration holds true for changes in the quality of raw materials, in the quality of products or services, in the type of energy used or the energy mix used, in the rate at which output is produced, in capital stock related to safety or environmental concerns, in the proportion of energy devoted to inputs produced 'in house', plant disruptions, expansions, the addition of new product lines and the deletion of others, etc. The essential purpose of adjusting the measurement of gross energy performance to derive **net energy performance** is to exclude those influences on energy productivity changes that are outside the control of the energy manager, or cannot be attributable to the management of energy. Knowledge of changes in adjusted energy productivity will assist the energy manager to evaluate the effectiveness of steps planned or implemented that are designed to bring about improved energy productivity.

3.2 - Isolating Types of Energy Consumption for Diagnostic Purposes

In order to facilitate the description of how to make energy accounting adjustments to compensate for influences on energy productivity beyond the control of the energy manager, it is useful to segregate energy consumption at a reporting centre into two distinct components: 'fixed' and 'variable'.

Fixed energy is that which is consumed even when the process covered by the reporting centre is in a stand-by or idle (shutdown) condition. This would include energy for heating, lighting and ventilation, for support services like maintenance shops, laboratories, office, cafeteria and warehouse space, and for equipment that must be kept running (e.g. to maintain temperature levels) even when the facility is not operational (i.e. in the case of a building, when it is standing empty). In general, however, weather has the largest effect on fixed energy consumption.

Variable energy consumption is that which changes in the same direction — but perhaps not at the same rate — as the rate of output when this rate is measured on a per minute or per hour basis (i.e. under constant, normal operating conditions). For many industries, as output per unit time rises, energy consumption rises, with the first unit produced in a time period usually causing the greatest rise variable energy consumption. As the rate of output rises, energy consumption associated with each incremental increase also rises, but by smaller and smaller amounts as the **process rate of output** is approached. The process rate of output is determined technologically and logistically, and is defined as the optimum or design amount of output the process can produce under normal operating conditions per unit time (sometimes expressed in units/minute or units/hour). Exceeding this threshold often causes the energy-output ratio to rise. Graphically, the relationships among fixed, variable and total energy consumption and between these and the rate of output relative to the process rate of output are represented in Figure 2.

In practice, distinguishing between fixed and variable energy consumption is not easy. If it is possible to obtain meter readings when production processes are idle, these would constitute fixed energy consumption. Once the reporting centre is in operation, any meter readings taken would necessarily be measuring both fixed and variable energy, such that by subtracting fixed energy as previously metered, variable energy would be obtained.

Of course, it is not always possible to obtain meter readings when the facility is idle, nor are all energy sources measured by meters. Another way of determining the fixed energy component is from the 'boiler plate' specifications of process equipment. Organizations with sizeable, complex plants that consume large amounts of energy may wish to conduct a detailed audit of energy use to determine the variable component of their total energy consumption. Organizations with processes characterized by easily identifiable energy use areas may not need to do so.

It may be the case that the total of fixed and variable energy consumption estimated by the above means is not equal to measured total consumption. The difference should be allocated judgmentally (assuming that the best possible estimates were obtained from specification data) to either fixed or variable consumption. If a new machine is added to the process, or production is altered in some other way that might affect the fixed/variable energy split, it should be taken into account.

Ultimately, the isolation of the fixed and variable components of total energy consumption will help the energy manager trace the origins of observed changes in the energy-output ratio. Not only will optimal rates of production (where optimal is defined in terms of variable energy consumption per unit output) be discernable, but specific energy-consuming elements within the reporting centre may be focussed upon as potential targets for retrofit or replacement in order to improve energy productivity.

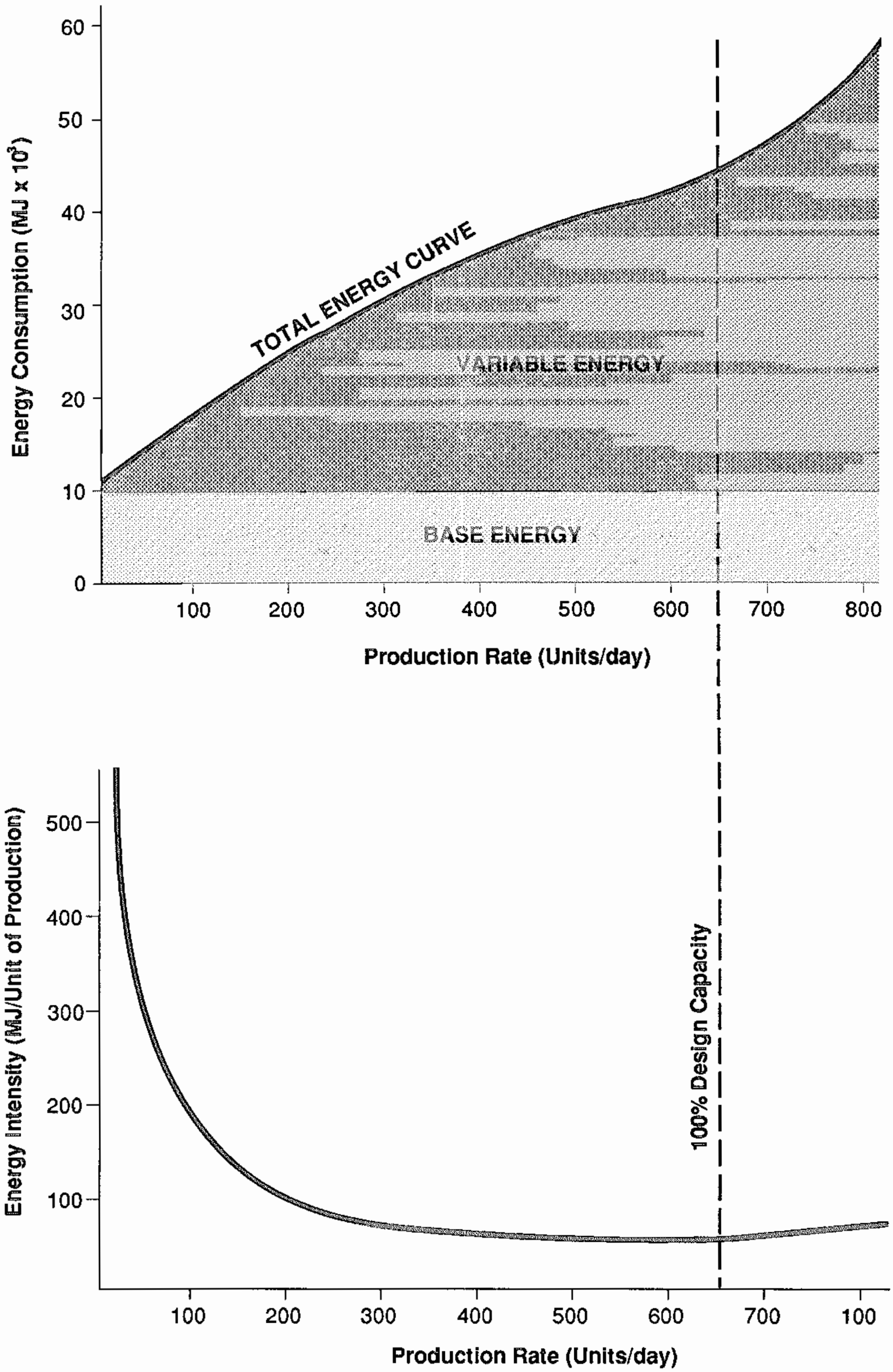
3.3 - Adjustment Factors

Influences on the energy-output ratio, and hence observed energy productivity of any reporting centre can be, as noted earlier, of either external or internal origin. Adjusting for the external influences so as to produce energy performance figures that are as unbiased as possible should be done consistently, so as not to render energy accounting results incomparable over time.

The following chart summarizes the types of adjustments that should be considered by organizations in the industrial, commercial and institutional sectors, and indicates those for which the manual provides formulas.

Figure 2

TYPICAL CURVES SHOWING PRODUCTION RATE VERSUS ENERGY CONSUMPTION AND ENERGY INTENSITY



NOTE: THE ABOVE CURVES ARE ILLUSTRATIVE ONLY

Situation Calling for Adjustment	Relevance to Industrial Facilities	Buildings	Formula Provided
1. Changes in the quality of raw materials or inputs	X		Yes
2. Externally dictated interfuel substitution	X	X	Yes
3. Changes in the process rate of output	X		Yes
4. Changes in safety and/or environmental regulations	X	X	No
5. Make/buy decisions	X	X	No
6. Weather	X	X	Yes
7. Production disruptions	X	X	No
8. Plant/building expansion	X	X	No
9. New plants/buildings	X	X	No
10. New products/services	X	X	No
11. Change in product/ service quality	X	X	No

3.3.1 - Changes in the Quality of Raw Materials or Inputs

Sometimes good inputs are hard to find. The amount of energy normally required to process a given quantity of raw material may depend, to a large extent, on certain qualities of the material. If these characteristics vary depending on the time of year, the source, different grades from the same source, degree of pre-sale processing, etc., then the energy-output ratio of a reporting centre, plant or firm can vary.

Where a change in input quality can be detected by a change in the quantity of that input required per unit output, a simple adjustment can be made to account for this change, such that the current period and base period measures of energy consumption are rendered comparable.

Note that a decrease in input quality could raise or lower the E_c of the reporting centre, and when all other production cost effects are accounted for, could result in a lowering of the unit cost of production. All of these consequences should be considered when evaluating adjusted EP_g information.

To adjust for changes in input quality, merely multiply the quantity of raw material used in the current period (Qi_c) by the change in variable energy (VE) consumed per unit of raw material used between the current period (period C) and the last period (period C-1). This will yield the amount (in MJ) by which base year equivalent energy (E_{be}) should be adjusted to account for the change in raw material quality.

$$\text{Input Quality Adjustment} = [VE_c/Qi_c - VE_{c-1}/Qi_{c-1}]$$

This formula automatically establishes whether the adjustment is positive or negative.

If quality changes occur regularly or repeatedly, simply add each new adjustment factor to the cumulative (net) total of previous adjustments (see worked example in Section 5).

3.3.2 - Interfuel Substitution

Similar adjustments can be made in order to accommodate differences in the end-use efficiency or materials handling requirements associated with individual types of energy, which become relevant when one energy source is substituted for another. These same considerations hold for buying steam instead of generating it on site (or vice versa), establishing a cogeneration process, or commencing to use renewable (solar, wind, geothermal) energy sources.

Note that where an energy type changeover takes place for reasons beyond the control of the reporting centre (or organization), an adjustment is required to normalize the current year's energy consumption with the base year. If the change is the result of a conscious decision (to improve security of energy supply, insure against price fluctuations, cut handling costs, or reduce overall unit costs) an adjustment is not called for, because current year energy consumption should reflect all changes in the energy-output ratio due to efforts to enhance the production process.

To make an adjustment for a change in the type or mix of energy used, the first step is to calculate the **energy utilization efficiency** (U_i) of the types of energy (where energy type is specified by a number: i = 1,2,3... , each number being a different energy type) involved. Purchased process steam, for example, is 100 per cent efficient because it does not have to be converted into another energy form in order to be utilized. Bunker C fuel oil, on the other hand, may lose 20 per cent of its energy when used to generate process steam, such that its utilization efficiency is only 80 per cent. Energy utilization efficiencies depend on the fuel and process in question. The energy manager is well advised to seek the guidance of a process engineer when estimating these efficiencies. Once they have been determined however, it is a simple matter to calculate an adjustment factor. The quantity of energy consumed (e) by utilizing the type of energy used (type i) in the current period (Period c) — ei_c — multiplied by the ratio of its energy utilization efficiency (U_i) to that of the previous energy type (U_j, where energy type j is not the same as energy type i) will yield the amount of energy that would have been input to production in the current period had the old energy type been used. This amount, subtracted from the actual amount of energy consumed in the current period, yields a quantity of energy that represents the difference between production with the old energy type and the new.

Interfuel Substitution Adjustment (MJ) = ei_c - [ei_c x U_i/U_j]

The resulting adjustment figure should then be added to the base period equivalent energy (E_{be}) prior to calculating changes in energy productivity.

Calculate the interfuel substitution adjustment every year, using the same energy utilization efficiencies, even if process improvements have altered these efficiencies for the current period. If, in such a case, the actual efficiency is used to make the adjustment, the EP_g improvement due to the process change would not be visible in the energy accounting results.

3.3.3 - Changes in the Process Rate of Output

Normally, the energy-output ratio will improve as the rate of output is increased toward the process rate of output because the base energy requirements are being spread over more output units. Just as total energy consumption often accelerates at production rates beyond the process rate, the energy-output ratio often rises once the process rate of output is exceeded. Altering the rate of output relative to the process rate then, can have an effect on the energy-output ratio. If this is done solely for the purpose of conserving energy, then no adjustment is necessary. If it is undertaken for other reasons (e.g. in response to changes in market demand for output), then an adjustment should be made so as not to bias the EP_g results.

As was the case with interfuel substitution, the adjustment for a change in the rate of production relative to the process rate of output is easily made. In the simplest case, the rate of output over the entire current reporting period is constant, as was the rate of output over the base period. The difference between the energy-output ratio for the current rate of production (E_{cr}) and that associated with the base period (E_{br} calculated in analogous fashion), when multiplied by the quantity of output in the current period (Q_c), yields the production rate adjustment in MJ:

Production Rate Adjustment (MJ) = Q_c x [E_{cr} - E_{br}]

The result is added to the base period equivalent energy estimate, such that a positive result means that the current average rate of production is more energy intensive than in the base period, whereas a negative result signals an improvement in the energy-output ratio. A more complex case would be where the rate of output varies over the current period (or the base period), such that the energy-output ratio varies over the period as well. In this case, a weighted average energy-output ratio must be taken that accounts for each identifiable rate of output and the associated energy-output ratio. Each rate of output (measured in units/time period) is multiplied by the corresponding number of time units for which it prevailed during the reporting period to obtain the total number of units produced at that rate. The energy-output ratio related to each rate of output (as determined from estimates described in Section 3.2 above) is, in turn, multiplied by the number of units produced at each respective rate to obtain the total amount of energy consumed at each intensity. Summing over the number of units produced at each output rate yields the total output produced during the reporting period; summing over the amounts of energy consumed at each rate of output yields total energy consumption. These figures can then be used to determine the E_{cr} (or E_{br}) used in the production rate adjustment equation shown above.

3.3.4 - Changes in Safety and/or Environmental Regulations

Changes to safety and environmental regulations, to the extent that these entail the purchase of new equipment or the altering of processes, can result in a raising of the energy requirement per unit of output. Clearly, no single adjustment can be used to accommodate every possible influence of this type. In general, however, an adjustment would consist of a calculation of the amount of energy associated with the change in the regulatory environment, with the objective of modifying the E_{be} measure in order to simulate current operating conditions in the base period. Care should be taken to recognize, in the energy accounting process, the possible long-term influences of the regulatory changes. It may be the case that a new regulation will have a constant effect from the year in which it is promulgated onward. On the other hand, the effect could be to increase the energy-output ratio gradually or in steps over several reporting periods.

3.3.5 - Make/Buy Decisions

Of all the inputs used to produce the finished output at a reporting centre, some may be made "in-house", that is, within the reporting centre boundaries, while the balance are obtained from external sources. From time to time a change may be required in this input mix, perhaps due to the disappearance of external sources, or the interruption of supplies of material with which to produce the input in-house. Adjusting the base period energy for this type of change involves the estimation (or calculation) of the amount of energy required to produce one unit of the input. Multiplying this figure by the number of units of the input used in the current period will yield the amount of the adjustment (in MJ) to be applied to the E_{be} calculation. If the input was made in the base period and purchased in the current year, this quantity is subtracted from the E_{be} figure. If it was bought in the base period and is now being made in-house, the adjustment factor is added to the E_{be} number.

The energy use and production rate associated with the input, as recorded in the first full reporting period of the change, should be used for all subsequent reporting period comparisons.

3.3.6 - Weather

The effect of weather on energy consumption in a given period is primarily through changes in temperature. The **heating degree-day** is the standard measure used to estimate energy use for heating purposes. Data for degree-days over a given period is readily available from Environment Canada and most fuel suppliers.

Adjusting raw energy accounting data for changes in temperature involves comparing the energy required for heating in the base and current periods. First determine the number of degree-days in the current period (D_c) and base period (D_b) from Environment Canada data. Then calculate the simple growth between the two periods and multiply this amount by the amount of energy used for heating in the base period (HE_b). This gives the quantity of heating energy that would have been used in addition to that actually assumed in the base period if the number of degree-days experienced then had been identical to that for the current year:

$$\text{Degree-day heat energy adjustment (MJ)} = HE_b \times [(D_c - D_b)/D_b]$$

If current period degree-days are higher than was the case in the base period, the adjustment will be positive. If degree-days were lower, the adjustment will be negative. In either case, the adjustment should simply be added to the E_{be} to simulate current period temperature conditions in the base period.

In processing industries, a small portion of the total energy used is directed at space heating or heating raw materials from ambient to working temperatures. If the temperature variation is only a few per cent from year to year, the impact on overall energy productivity will be quite small.

Of course, in buildings where a substantial fraction of energy is used for space heating, this effect can be considerable.

Significant proportions of fixed energy may be used for air conditioning purposes. In such cases, an adjustment for **cooling degree-days** would be required, analogous with that described above for heating degree days. Unfortunately, adjustment for cooling is much more difficult than for heating, since the effects of humidity, sunlight, etc. on cooling systems must be included in the accounting. It is recommended that where cooling energy is important, specialists be consulted on the appropriate adjustment for a given reporting centre.

3.3.7 - Other Factors that Must be Accommodated

While perhaps not requiring specific adjustments in the same way as the factors described above, there remain certain types of events the effects of which have to be considered in energy accounting.

1. *Production Disruptions* - Not all breaks in the production process occur on a routine basis. Unlike shutdowns for plant re-tooling at the beginning of a new model year or for a scheduled vacation period, there are exceptions to the normal course of events, beyond the control of energy managers: strikes, natural disasters, power blackouts and the like. Even if a plant or building is open over these periods (and consuming at least fixed energy), production is not occurring. Therefore any energy consumed during such idle periods should be excluded from the period total, in order that the energy-output ratio not be negatively affected.

2. *Plant/Building Expansion* - Construction at an existing plant or building site uses energy that is not directly involved in the production of output. Similarly, when new facilities come on stream, it is normal for energy requirements to rise temporarily over what they will be when the new processes are operating normally. To account for these two events, it is best to exclude

from both energy consumption and output measures figures representing the portions of periods during which either construction or commissioning, or both, take place.

3. *New Plants/Buildings* - New capital, whether used to supplement or substitute for the output of old equipment and facilities, almost always embodies a greater degree of energy efficiency than existing plant. Such is the case that should an entire new plant or building be constructed, the organization's energy performance results will be affected. This type of change is, of course, the result of conscious business decisions to improve production, so no adjustments need be made to energy accounting data to correct for it. New replacement facilities producing the same products should continue to calculate base period energy equivalents at the efficiencies that existed at the old plant or building. New facilities that represent incremental additions to productive capacity should be added in to overall organization energy performance calculations, where the effect of their greater energy efficiency will be factored in.

   If both new and old plants or buildings coexist, and an organization wishes to continue to use the same base period in order to capture the energy improvements embodied in the new facility, it will be necessary to render the new plant's energy productivity characteristics in terms that reflect the 'state of the art' for that type of facility in the base period. In other words, estimates must be made of energy-output ratios that would have occurred had the new plant or building been constructed, fully commissioned and operational over the base period. This way, the new facility's energy performance will include improvements resulting from the higher energy efficiencies embodied in the new equipment and processes. Of course, the relatively high initial energy performance results will be attributable largely to the design of the new plant and equipment rather than to prudent energy management. Changes in performance over subsequent periods will, however, highlight energy management decisions.

4. *New Products/Services* - Whether produced from new or existing facilities, new products and services have distinct effects on energy-output ratios. First, care must be taken to ensure that the unit of measure previously chosen to record quantities of output is still applicable. If not, a new measure must be chosen along the same lines described in Section 2.3 above. It may be advisable to re-start the energy accounting process after the introduction of a new product, beginning the first reporting period only once the equipment commissioning phase is complete.

5. *Change in Product/Service Quality and/or Features* - Adjustments are necessary if changes in product/service quality or features are beyond the control of the energy manager and the modified process reflects changes in energy-output ratios. These adjustments to base year equivalent energy consumption should be negative if producing the modified product/service requires less energy than before, and positive if it requires more energy than previously.

3.4 - Reporting Centre Net Energy Performance

Any and all adjustments undertaken in order to reflect more accurately the changes in an energy-output ratio that are due to conscious efforts to conserve energy can be amalgamated and then added to (whether positive or negative) the E_{be} to obtain what can be called the **adjusted base period equivalent energy** or E'_{be}. This figure can then be used to calculate the final **net energy**

performance or EP_n of a reporting centre as shown on Form 6. The energy efficiency benefits derived from energy management activities should, after all of the above mentioned adjustments have been taken into account, be readily discernable via energy accounting. The final net energy performance measure expresses any improvement in energy efficiency as a percentage of the E'_{be}, and allows for ongoing comparison based on a single standard.

3.5 - Organizational Net Energy Performance

Summary data from each reporting centre in an organization can be combined to permit the calculation of net energy performance at the plant or organizational level as set out in Form 7. An E'_{be} for the entire organization is derived from the E_{be} and E'_{be} data calculated for all reporting centres. From this, a measure of the magnitude of any changes in energy efficiency can be obtained as follows. The ratio of the difference between the E_{be} and the E_c for the organization and the E'_{be} gives the proportionate size of the change in energy performance for the entire organization between the current period and the base period (multiplying by 100 renders this as a percentage improvement).

$$\text{Net Energy Performance (\%)} = [(E'_{be} - E_c)/E'_{be}] \times 100$$

These measures can be compared with other organizations within the sector or across sectors at the regional or national level.

4 - FINANCIAL IMPACTS OF SAVING ENERGY

As noted earlier, the paramount value of energy management and energy accounting is reflected in the cost savings, rather than simply energy savings, accruing to an organization. To provide a means of tracking these financial impacts of energy management, the following procedures are suggested. Although industrial and building managers may adopt particular methods of accounting for energy cost savings, this approach will be a useful starting point.

1. *Determine energy savings in the current period relative to the base period.* This figure is calculated as the difference between imputed and actual energy consumption in the current period as defined in Section 2.1 and Figure 1. If warranted, adjusted figures should be used in recording imputed energy consumption, as discussed in Section 3.

2. *Calculate the current period average cost of energy ($/MJ).* This figure should be calculated as the weighted average cost of energy, using as weights the shares of each type of energy in the reporting centre's total energy (MJ) consumption.

3. *Apply the average cost as computed in step 2, to the quantity of energy saved in the current period, as computed in step 1.* The result represents the dollar value of energy savings in the current period. It is useful to add these savings over time to show the cumulative total dollar value of the organization's energy management activities. Note that this simplified approach assumes that the mix of energy forms saved equals that currently consumed by the organization.

Form 8 provides a worksheet that can be used to calculate these financial impacts of energy management. Section 5 provides numerical examples to illustrate the calculation procedure, including completed examples of Form 8.

5 - APPLYING THE CONCEPTS: NUMERICAL EXAMPLES

5.1 - ABC Manufacturing Inc.

ABC is a manufacturer of industrial chemicals with three plants across Canada, each producing a different product. In the base year, plant A used electricity and heavy fuel oil (HFO) and plants B and C used electricity and natural gas. In the current year, plant A switched from HFO to natural gas while in the other plants there was no change in the types of energy used. Table 2 shows the base and current year data and summarizes the energy productivity calculations. Completed Forms 1 to 4 and 5 to 7 provide details of how ABC calculated its gross and net energy performance respectively.

Note that in this example, adjustments made to translate from gross to net performance were based on changes in raw material quality, fuel mix and rate of output.

Form 8 presents the calculations to determine the financial cost savings stemming from energy management activities between the base and current years. Note that two sets of figures are shown corresponding to cost savings from improved gross (unadjusted) performance and net (adjusted) energy performance.

5.2 - Canada Office Plaza

Canada Office Plaza is a high-rise office and retail building. In both the base and current years, 'output' is 20,000 m^2 of floor space. Electricity and natural gas are the energy forms used in the building. Table 3 shows the building data for the base and current years and summarizes the energy productivity calculations. Completed Forms 1 to 4 and 5 to 7 provide details of calculations to measure gross and net energy performance respectively. Note the adjustment for changes in heating degree-days — this factor accounts for the differences between the gross and net energy performance indicators.

Form 8 presents the calculation of cost savings associated with the building's energy management activities between the base and current years. The two sets of figures represent cost savings from improvements in gross and net energy performance.

TABLE 2

CASE STUDY EXAMPLE: ABC MANUFACTURING INC.

	Plant A	Plant B	Plant C	Total
Base Period				
1. Production (tonnes)	20 000	10 000	30 000	
2. Electricity Use (kW.h)	800 000	420 000	1 000 000	
3. Natural Gas (m^3)	—	100 000	250 000	
4. Heavy Fuel Oil (litres)	160 000	—	—	
5. Total Energy Consumption (MJ)[1]	9 360 000	5 232 000	12 900 000	27 492 000
Current Period				
6. Production	28 000	15 000	39 000	
7. Electricity	1 042 000	580 000	1 235 000	
8. Natural Gas	229 000	138 000	309 000	
9. Heavy Fuel Oil	—	—	—	
10. Total Energy Consumption (MJ)[1]	12 270 000	7 221 600	15 940 800	35 432 400
11. Production Index (= 6/1)	1.4	1.5	1.3	
12. Base Year Equivalent (Imputed) Current Year Energy Consumption (at Base Year Energy Intensity) (= 5 x 11)	13 104 000	7 848 000	16 770 000	37 722 000
13. Gross Energy Performance (Change in Energy Productivity) $(= \frac{12 - 10}{12} \times 100)$	+ 6.4%	+ 8.0%	+ 5.0%	+ 6.1%

[1]Total energy consumption in MJ is calculated as electricity use (kW.h) times 3.6 MJ/kW.h, plus natural gas use (m^3) times 37.2 MJ/m^3, plus heavy fuel oil use (litres) times 40.5 MJ/litre.

ENERGY CONSUMPTION AND PRODUCTION RECORD
Form 1

Organization: ABC MANUFACTURING INC.

Product: ______

Reporting Centre: Plant A

Reporting Period: Base Period

Prepared by ______ Date ______

Data Sub-Periods	Energy Quantities in Purchased Units [see 2.5.2]							Output (units) [see 2.5.1] (8)
	Fuel Oil Type: #6 (litres) (1)	Natural Gas (m3) (2)	Electricity (kWh) (3)	(4)	(5)	(6)	(7)	
Jan	24,000		50,000					1,250
Feb	20,000		65,000					1,625
Mar	18,000		65,000					1,625
Apr	17,000		65,000					1,625
May	8,000		80,000					2,000
Jun	2,000		100,000					2,500
Jul	2,000		80,000					2,000
Aug	1,000		75,000					1,875
Sep	10,000		60,000					1,500
Oct	18,000		60,000					1,500
Nov	20,000		50,000					1,250
Dec	20,000		50,000					1,250
End of Period Adjustment								
Totals	160,000		800,000					20,000 (9)

REPORTING CENTRE
TOTAL ENERGY CONSUMPTION
Form 2

[see 2.5.2]

Organization: ABC MANUFACTURING INC.

Reporting Centre: Plant A

Product:

Reporting Period: Base Period

Total Production Output: 20,000 tonnes F-1(9)

Prepared by:

Date:

(1) Energy Type	(2) Quantity Used* (physical units)	(3) Energy Conversion Factor (MegaJoules [MJ]/unit)	(4) = (2) x (3) Energy Consumption (MJ)
Heavy Fuel Oil (#6)	160,000 litres	40.5 MJ/litre	6,480,000
Electricity	800,000 kWh	3.6 MJ/kWh	2,880,000
			TOTAL 9,360,000 (5)

*total from columns 1-7 on Form F-1

REPORTING CENTRE GROSS ENERGY PERFORMANCE
(CHANGE IN ENERGY PRODUCTIVITY)
Form 3
[see 2.5.4]

Organization ABC MANUFACTURING INC.

Reporting Centre Plant A

Reporting Period 1988

Base Year 1986

Prepared by ______________ Date ______________

$$\text{Production Index} = \frac{Q_c}{Q_b} = \frac{\text{F - 1(9) Current Year}}{\text{F - 1(9) Base Year}} = \frac{(\ 28{,}000\ )}{(\ 20{,}000\ )} = 1.4 \quad (1)$$

$$E_{be} = E_b \times \text{Production Index} = \text{F - 2(5)} \times (1)$$

$$= (\ 9{,}360{,}000\ ) \times (\ 1.4\ ) = 13{,}104{,}000 \text{ MJ} \quad (2)$$

EP_g *(Change in Energy Productivity)*

$$= \frac{E_{be} - E_c}{E_{be}} \times 100$$

$$= \frac{(2) - [\text{F - 2(5)}]}{(2)} \times 100 = \frac{(\ 13{,}104{,}000\ ) - (\ 12{,}270{,}000\ )}{(\ 13{,}104{,}000\ )} \times 100$$

$$= 6.4\ \%$$

NOTE: If the result is (+) performance has improved; if the result is (-) performance has deteriorated

COMBINED GROSS ENERGY PERFORMANCE OF REPORTING CENTRES

Form 4

[see 2.5.4]

Organization: ABC MANUFACTURING INC.

Reporting Period: 1988

Name of Combined Reporting Centres: ______

Prepared by: ______ Date: ______

Reporting Centre (1)	Current Year Total Energy Use (MJ) [from F - 2(5)] (2)	Base Year Equivalent Energy (MJ) [from F - 3(8)] (3)
Plant A	12,270,000	13,104,000
Plant B	7,221,600	7,848,000
Plant C	15,940,800	16,770,000
TOTALS	35,432,400 (4)	37,722,000 (5)

$$\text{Combined } EP_g = \frac{E_{be} - E_c}{E_{be}} \times 100$$

$$= \frac{(5) - (4)}{(5)} \times 100 = \frac{(37{,}722{,}000) - (35{,}432{,}400)}{(37{,}722{,}000)} \times 100$$

= 6.1 % (6)

(+) = Improvement (-) = Deterioration

REPORTING CENTRE ENERGY ADJUSTMENTS AND NET ENERGY PERFORMANCE

Form 5

[see 3.3]

Organization: ABC MANUFACTURING INC.

Reporting Period: 1988

Reporting Centre: Plant A

Base Year: 1986

Prepared by ______ Date ______

TYPE OF ADJUSTMENT	FORMULA AND CALCULATIONS	ADJUSTMENTS (MJ)
1. Raw Material Quality Change (see 3.3.1)	$= Qi_c \left[\frac{VE_c}{Qi_c} - \frac{VE_{c-1}}{Qi_{c-1}} \right] = (720) \left[\frac{(11,043,000)}{(720)} - \frac{(8,424,000)}{(680)} \right]$ =	2,123,471
2. Interfuel Substitution (see 3.3.2)	$= ei_c - \left[\frac{ei_c \times U_i}{U_j} \right] = (8,518,800) - \left[\frac{(8,518,800) \times (85)}{(82)} \right]$ =	(311,663)
3. Change in Rate of Output (see 3.3.3)	$= Q_c \, [E_{cr} - E_{br}] = (28,000) \, [(394) - (421)]$ =	(756,000)
4. Climate (see 3.3.4)	$= HE_b \left[\frac{D_c - D_b}{D_b} \right] = (\quad) \left[\frac{(\quad) - (\quad)}{(\quad)} \right]$ =	
5. Change in Safety/Environmental Regulations (see 3.3.5)	REQUIRES ANALYSIS OF SPECIFIC CIRCUMSTANCES	
6. Make/Buy Decisions (see 3.3.6)	REQUIRES ANALYSIS OF SPECIFIC CIRCUMSTANCES	
7. Other (see 3.3.7)		
	TOTAL ADJUSTMENT TO BASE YEAR EQUIVALENT ENERGY	1,055,808 MJ(1)

Adjusted Base Year Equivalent Energy (E'_{be}) $= E_{be}$ + Adjustments = (F - 3(2)) + (1)

= (13,104,000) + (1,055,808) = 14,159,808 MJ(2)

Reporting Centre Net Energy Performance (EP_n) $= \frac{E'_{be} - E_c}{E'_{be}} = \frac{(2) - (F - 2(5))}{(2)}$

$= \frac{(14,159,808) - (12,270,000)}{(14,159,808)} \times 100 =$ 13.3 %

CUMULATIVE DATA ON ENERGY CONSUMPTION

Form 6

[see 3.4]

Organization ABC MANUFACTURING INC. Reporting Period 1988

Prepared by ______________ Date ______________

(1) Reporting Centre	(2) Current Year Energy Consumption [from F-2(5)] (MJ)	(3) Base Year Equivalent Energy [from F-3(2)] (MJ)	(4) Base Year Energy Adjustments [from F-5(1)] (MJ)	(5) = 3 + 4 Adjusted Base Year Equivalent Energy (MJ)
Plant A	12,270,000	13,104,000	1,055,808	14,159,808
Plant B	7,221,600	7,848,000	-	7,848,000
Plant C	15,940,800	16,770,000	-	16,770,000
TOTALS	35,432,400 (6)	37,722,000 (7)	1,055,808 (8)	38,777,808 (9)

COMBINED ANNUAL PERFORMANCE REPORT:
PERCENT IMPROVEMENT IN ENERGY EFFICIENCY

Form 7

[see 3.5]

Organization ABC MANUFACTURING INC.

Reporting Year 1988

Base Year 1986

A. Current Year Total Energy Consumption — 35,432,400 mega joules — F - 6(6) or F - 4(4)

B. Base Year Equivalent Energy Consumption — 37,722,000 mega joules — F - 4(5) or F - 6(7)

C. Combined Gross Energy Performance (%)

$$\frac{\text{Base Year Equivalent Energy} - \text{Current Year Energy}}{\text{Base Year Equivalent Energy}} \times 100$$

$$= \frac{B - A}{B} \times 100 = \underline{\ 6.1\ }\ \%$$ F - 4(6)

D. Adjustments* — 1,055,808, mega joules — F - 6(8)

E. Adjusted Base Year Equivalent Energy Consumption:

Base Year Equivalent Energy + Adjustment

B + D = 38,777,808 mega joules — f - 6(9)

F. Combined Net Energy Performance (%)

$$\frac{\text{Adjusted Base Year Equivalent Energy} - \text{Current Year Total Energy Consumption}}{\text{Adjusted Base Year Equivalent Energy}} \times 100$$

$$= \frac{E - A}{E} \times 100 = \underline{\ 8.6\ }\ \%$$

* Adjustments (type and quantity)

- raw material quality change	2,123,471
- interfuel substitution	(311,663)
- change in rate of output	(756,000)

CALCULATING COST SAVINGS
[based on unadjusted changes in energy productivity]
Form 8A
[see 4]

Organization ABC MANUFACTURING INC.

Reporting Centre Same

Reporting Period ____________

Prepared by ____________ Date ____________

	(1) Imputed Energy Consumption (MJ)	(2) Actual Energy Consumption (MJ)	(3) = 1 - 2 Energy Savings (MJ)	(4) Average Cost of Energy ($/MJ)	(5) = 3 x 4 Cost Savings ($)	(6) Cumulative Cost Savings ($)
Base Year (BY)	27,492,000	27,492,000	0	-	-	-
BY + 1	32,100,000	31,000,000	1,100,000	0.0062	6,820	6,820
BY + 2	37,722,000	35,432,400	2,289,000	0.0068	15,565	22,385
BY + 3						

COST SAVINGS CALCULATION
[based on adjusted changes in energy productivity]
Form 8B
[See 4]

Organization ABC MANUFACTURING INC.

Reporting Centre SAME

Reporting Period

Prepared by ________ Date ________

	(1) Imputed Energy Consumption (MJ)	(2) Actual Energy Consumption (MJ)	(3) = 1 - 2 Energy Savings (MJ)	(4) Average Cost of Energy ($/MJ)	(5) = 3 x 4 Cost Savings ($)	(6) Cumulative Cost Savings ($)
Base Year (BY)	27,492,000	27,492,000	-	-	-	-
BY + 1	32,300,000	31,000,000	1,300,000	0.0062	8,060	8,060
BY + 2	38,777,808	35,432,400	3,345,408	0.0068	22,749	30,809
BY + 3						

TABLE 3

CASE STUDY EXAMPLE: CANADA OFFICE PLAZA

	Canada Office Plaza
Base Period	
1. Production (m^2)	20 000
2. Electricity Use (kW.h)	3 000 000
3. Natural Gas (m^3)	350 000
4. Heavy Fuel Oil (litres)	—
5. Total Energy Consumption (MJ)[1]	23 820 000
Current Period	
6. Production (m^2)	20 000
7. Electricity	2 820 000
8. Natural Gas	329 000
9. Heavy Fuel Oil	—
10. Total Energy Consumption (MJ)[1]	22 390 800
11. Production Index (= 6/1)	1.0
12. Base Year Equivalent (Imputed) Current Year Energy Consumption (at Base Year Energy Intensity) (= 5 x 11)	23 820 000
13. Gross Energy Performance (Change in Energy Productivity) $\left(= \frac{12 - 10}{12} \times 100\right)$	+ 6.0%

[1]Total energy consumption in MJ is calculated as electricity use (kW.h times 3.6 MJ/kW.h, plus natural gas use (m^3) times 37.2 MJ/m^3, plus heavy fuel oil use (litres) times 40.5 MJ/litre.

ENERGY CONSUMPTION AND PRODUCTION RECORD
Form 1

Organization: CANADA OFFICE PLAZA

Product: ______

Reporting Centre: Same

Reporting Period: Base Year

Prepared by: ______ Date: ______

Data Sub-Periods	Energy Quantities in Purchased Units [see 2.5.2]							Output (units) [see 2.5.1] (8)
	Fuel Oil Type: ______ (litres) (1)	Natural Gas (m^3) (2)	Electricity (kWh) (3)	(4)	(5)	(6)	(7)	
Jan		50,000	275,000					20,000
Feb		45,000	275,000					20,000
Mar		45,000	275,000					20,000
Apr		40,000	250,000					20,000
May		25,000	225,000					20,000
Jun		10,000	225,000					20,000
Jul		5,000	225,000					20,000
Aug		15,000	225,000					20,000
Sep		15,000	225,000					20,000
Oct		20,000	250,000					20,000
Nov		30,000	275,000					20,000
Dec		50,000	275,000					20,000
End of Period Adjustment		N/A	N/A					
Totals		350,000	3,000,000					20,000 (9)

REPORTING CENTRE
TOTAL ENERGY CONSUMPTION
Form 2

[see 2.5.2]

Organization CANADA OFFICE PLAZA

Reporting Centre SAME

Product

Reporting Period BASE YEAR

Total Production Output ______ F-1(9)

Prepared by ______ Date ______

(1) Energy Type	(2) Quantity Used* (physical units)	(3) Energy Conversion Factor (MegaJoules [MJ]/unit)	(4) = (2) x (3) Energy Consumption (MJ)
Electricity	3,000,000 kWh	3.6	10,800,000
Natural Gas	350,000 m^3	37.2	13,020,000
			TOTAL 23,820,000 (5)

*total from columns 1-7 on Form F-1

REPORTING CENTRE GROSS ENERGY PERFORMANCE (CHANGE IN ENERGY PRODUCTIVITY)

Form 3

[see 2.5.4]

Organization CANADA OFFICE PLAZA

Reporting Centre ____

Reporting Period 1988

Base Year 1986

Prepared by ____ Date ____

$$\text{Production Index} = \frac{Q_c}{Q_b} = \frac{\text{F - 1(9) Current Year}}{\text{F - 1(9) Base Year}} = \frac{(\ 20{,}000\ )}{(\ 20{,}000\ )} = \underline{\ 1.0\ } \quad (1)$$

$$E_{be} = E_b \times \text{Production Index} = \text{F - 2(5)} \times (1)$$

$$= (\ 23{,}820{,}000\ ) \times (\ 1\ ) = \underline{\ 23{,}820{,}000\ } \text{ MJ } (2)$$

EP_g *(Change in Energy Productivity)*

$$= \frac{E_{be} - E_c}{E_{be}} \times 100$$

$$= \frac{(2) - [\text{F - 2(5)}]}{(2)} \times 100 = \frac{(\ 23{,}820{,}000\ ) - (\ 22{,}390{,}800\ )}{(\ 23{,}820{,}000\ )} \times 100$$

$$= \underline{\ 6.0\ } \ \%$$

NOTE: If the result is (+) performance has improved; if the result is (-) performance has deteriorated

COMBINED GROSS ENERGY PERFORMANCE OF REPORTING CENTRES
Form 4
[see 2.5.4]

Organization: CANADA OFFICE PLAZA

Reporting Period: 1988

Name of Combined Reporting Centres ______

Prepared by ______ Date ______

Reporting Centre (1)	Current Year Total Energy Use (MJ) [from F - 2(5)] (2)	Base Year Equivalent Energy (MJ) [from F - 3(8)] (3)
Canada Office Plaza	22,390,800	23,820,000
TOTALS	22,390,800 (4)	23,820,000 (5)

$$\text{Combined } EP_g = \frac{E_{be} - E_c}{E_{be}} \times 100$$

$$= \frac{(5) - (4)}{(5)} \times 100 = \frac{(23{,}820{,}000) - (22{,}390{,}800)}{(23{,}820{,}000)} \times 100$$

= 6.0 % (6)

(+) = Improvement (-) = Deterioration

REPORTING CENTRE ENERGY ADJUSTMENTS AND NET ENERGY PERFORMANCE

Form 5

[see 3.3]

Organization: CANADA OFFICE PLAZA

Reporting Centre: ____________

Reporting Period: SAME

Base Year: 1988

Prepared by: 1986 Date: ____________

	TYPE OF ADJUSTMENT	FORMULA AND CALCULATIONS	ADJUSTMENTS (MJ)
1	Raw Material Quality Change (see 3.3.1)	$= Qi_c \left[\frac{VE_c}{Qi_c} - \frac{VE_{c-1}}{Qi_{c-1}} \right] = (\quad) \left[\frac{(\quad)}{(\quad)} - \frac{(\quad)}{(\quad)} \right]$ =	
2	Interfuel Substitution (see 3.3.2)	$= ei_c - \left[\frac{ei_c \times U_i}{U_j} \right] = (\quad) - \left[\frac{(\quad) \times (\quad)}{(\quad)} \right]$ =	
3	Change in Rate of Output (see 3.3.3)	$= Q_c\, [E_{cr} - E_{br}] = (\quad)\, [(\quad) - (\quad)]$ =	
4	Climate (see 3.3.4)	$= HE_b \left[\frac{D_c - D_b}{D_b} \right] = (13{,}020{,}000) \left[\frac{(4{,}146) - (4{,}635)}{(4{,}635)} \right]$ =	(1,373,631)
5	Change in Safety/Environmental Regulations (see 3.3.5)	REQUIRES ANALYSIS OF SPECIFIC CIRCUMSTANCES	
6	Make/Buy Decisions (see 3.3.6)	REQUIRES ANALYSIS OF SPECIFIC CIRCUMSTANCES	
7	Other (see 3.3.7)		

TOTAL ADJUSTMENT TO BASE YEAR EQUIVALENT ENERGY (1,373,631) MJ(1)

Adjusted Base Year Equivalent Energy (E'_{be}) $= E_{be} + \text{Adjustments} = (F - 3(2)) + (1)$

$= (23{,}820{,}000) + (-1{,}373{,}631) =$ 22,446,369 MJ(2)

Reporting Centre Net Energy Performance (EP_n) $= \frac{E'_{be} - E_c}{E'_{be}} = \frac{(2) - (F - 2(5))}{(2)}$

$= \frac{(22{,}446{,}369) - (22{,}390{,}800)}{(22{,}446{,}369)} \times 100 =$ 0.25 %

CUMULATIVE DATA ON ENERGY CONSUMPTION

Form 6

[see 3.4]

Organization CANADA OFFICE PLAZA

Reporting Period 1988

Prepared by ______________ Date ______________

(1) Reporting Centre	(2) Current Year Energy Consumption [from F-2(5)] (MJ)	(3) Base Year Equivalent Energy [from F-3(2)] (MJ)	(4) Base Year Energy Adjustments [from F-5(1)] (MJ)	(5) = 3 + 4 Adjusted Base Year Equivalent Energy (MJ)
Same	22,390,800	23,820,000	(1,373,631)	22,446,369
TOTALS	22,390,800 (6)	23,820,000 (7)	(1,373,631) (8)	22,446,369 (9)

COMBINED ANNUAL PERFORMANCE REPORT: PERCENT IMPROVEMENT IN ENERGY EFFICIENCY

Form 7

[see 3.5]

Organization: CANADA OFFICE PLAZA

Reporting Year: 1988

Base Year: 1986

A. Current Year Total Energy Consumption — 22,390,800 mega joules — F - 6(6) or F - 6(6)

B. Base Year Equivalent Energy Consumption — 23,820,000 mega joules — F - 4(5) or F - 6(7)

C. Combined Gross Energy Performance (%)

$$\frac{\text{Base Year Equivalent Energy} - \text{Current Year Energy}}{\text{Base Year Equivalent Energy}} \times 100$$

$$= \frac{B - A}{B} \times 100 = 6.0\ \%$$ F - 4(6)

D. Adjustments* — (1,373,631) mega joules — F - 6(8)

E. Adjusted Base Year Equivalent Energy Consumption:

Base Year Equivalent Energy + Adjustment

$$B + D = 22{,}446{,}369 \text{ mega joules}$$ f - 6(9)

F. Combined Net Energy Performance (%)

$$\frac{\text{Adjusted Base Year Equivalent Energy} - \text{Current Year Total Energy Consumption}}{\text{Adjusted Base Year Equivalent Energy}} \times 100$$

$$= \frac{E - A}{E} \times 100 = 0.25\ \%$$

* Adjustments (type and quantity)

- climate (degree day change)	(1,373,631)

CALCULATING COST SAVINGS
[based on unadjusted changes in energy productivity]
Form 8A
[see 4]

Organization CANADA OFFICE PLAZA

Reporting Centre SAME

Reporting Period

Prepared by ______ Date ______

	(1) Imputed Energy Consumption (MJ)	(2) Actual Energy Consumption (MJ)	(3) = 1 - 2 Energy Savings (MJ)	(4) Average Cost of Energy ($/MJ)	(5) = 3 x 4 Cost Savings ($)	(6) Cumulative Cost Savings ($)
Base Year (BY)	23,820,000	23,820,000	-	-	-	-
BY + 1	23,820,000	23,200,000	620,000	0.0076	4,712	4,712
BY + 2	23,820,000	22,390,800	1,429,000	0.0084	12,004	16,716
BY + 3						

COST SAVINGS CALCULATION
[based on adjusted changes in energy productivity]
Form 8B
[See 4]

Organization CANADA OFFICE PLAZA

Reporting Centre SAME

Reporting Period

Prepared by Date

	(1) Imputed Energy Consumption (MJ)	(2) Actual Energy Consumption (MJ)	(3) = 1 - 2 Energy Savings (MJ)	(4) Average Cost of Energy ($/MJ)	(5) = 3 x 4 Cost Savings ($)	(6) Cumulative Cost Savings ($)
Base Year (BY)	23,820,000	23,820,000	-	-	-	-
BY + 1	23,200,000	23,200,000	-	0.0076	-	-
BY + 2	22,446,369	22,390,800	55,569	0.0084	467	467
BY + 3						

APPENDICES

GLOSSARY OF TERMS

Adjusted Base Period Equivalent Energy is the Base Period Equivalent Energy (see below) adjusted to take into account those factors affecting energy productivity that are outside the control of energy managers.

Base Period is the reference period in the past to which a Current Period is compared.

Base Period Energy is the total amount of energy used in the base period.

Base Period Equivalent Energy (Imputed Energy) is the total amount of energy that would be required, at the original base year energy intensity, to produce the current year production output.

Cooling Degree Days are units of measure representing one degree of difference above a given point (e.g. 22°C) in the mean daily outdoor temperature. They're used for measuring cooling energy requirements.

Current Period is the period currently being accounted for.

Current Period Energy is the total amount of energy used in the current reporting period.

Energy is the capacity for doing work. Energy may take a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical and chemical energy. It is measured in energy units such as megajoules (MJ), or energy equivalent units such as barrels of crude oil equivalent (BOE).

Energy Productivity is the amount of energy required to produce a product or group of products, or to operate a building, expressed in energy used per unit of production output. The concept may also be denoted by the terms 'energy intensity', 'energy-output ratio', 'energy coefficient' or 'energy efficiency'.

Energy Utilization Efficiency is the efficiency of end-use equipment in converting input energy into useful output energy.

Fixed Energy is the energy required to operate the plant or building (including items such as lighting, heating, air conditioning, etc) which is essentially independent of the level or rate of output.

Gross Energy Performance (Unadjusted Energy Productivity Change) is the unadjusted measure of change in the energy per unit of production in the current period versus the base period. It is computed as the per cent difference between base period equivalent energy consumption and current period energy consumption.

Heating Degree Days are units of measure representing one degree of difference below a given point (e.g. 22°C) in the mean daily outdoor temperature. They're used for measuring heating energy requirements.

Joule is a common unit of energy. (Appendix C contains definitions of metric prefixes used to denote multiples of joules).

Net Energy Performance (Adjusted Energy Productivity Change) is energy productivity adjusted for factors outside the control of the energy manager such as weather and other factors covered in this manual. It is computed as the per cent difference between adjusted base period equivalent energy consumption and current period energy consumption.

Output is the quantity of output or level of activity in a given period of time.

Process Rate of Output is the optimum or design quantity of output a process can produce under normal operating conditions per unit of time.

Production Index is the production output of the current year divided by the production output of the base year.

Production Unit is a measure of the quantity of output or the level of activity that closely relates to energy demand.

Reporting Centres are the areas or energy consuming units for which production and energy consumption are measured and reported. They can be a single process, combination of processes, department, plant or building, organization, industrial or economic sector or the economy as a whole.

Variable Energy is the energy associated with production which varies with production output.

SYMBOLS

D_b	Number of Heating Degree Days in the Base Period
D_c	Number of Heating Degree Days in the Current Period
E_b	Base Period Energy Consumption
E_{be}	Base Period Equivalent Energy
E_{br}	Base Period Energy Consumption associated with Rate of Production in the Base Period
E_c	Current Period Energy Consumption
E_{cr}	Current Period Energy Consumption associated with Rate of Production in the Current Period
ei_c	Amount of energy type i used in Current Period
EP_g	Gross Energy Performance
EP_n	Net Energy Performance
E'_{be}	Adjusted Base Period Equivalent Energy
HE_b	Energy Consumed for Space Heating in the Base Period
Q_b	Base Period Production
Q_c	Current Period Production
Qi_c	Current Period Quantity of Raw Material i Consumed
Qi_{c-1}	Period Immediately Previous to the Current Period Quantity of Raw Material i Consumed
U_i	Utilization Efficiency of energy type i
U_j	Utilization Efficiency of energy type j
VE_c	Current Period Variable Energy
VE_{c-1}	Period Immediately Previous to the Current Period Variable Energy

ENERGY CONTENTS

The following typical values for conversion factors may be used when actual data are unavailable. The MJ and Btu equivalencies are heats of combustion. Hydrocarbons are shown at the higher heating value, wet basis. Some items listed are typically feedstocks, but are included for completeness and for reference purposes. The conversion factors for coal are approximate, since the heating value of coal from any specific source is characteristic of that source.

Consistent factors must be used when calculating Base Year and Current Year energy usage.

Energy Type	Metric		British	
Coal				
- metallurgical	29,000	MJ/tonne	25.0	MMBtu/ton
- anthracite	30,000	MJ/tonne	25.8	MMBtu/ton
- bituminous	32,100	MJ/tonne	27.6	MMBtu/ton
- sub-bituminous	22,100	MJ/tonne	19.0	MMBtu/ton
- lignite	16,700	MJ/tonne	14.4	MMBtu/ton
Coke				
- metallurgical	30,200	MJ/tonne	26.0	MMBtu/ton
- petroleum (raw)	23,300	MJ/tonne	20.0	MMBtu/ton
- petroleum (calcined)	32,600	MJ/tonne	28.0	MMBtu/ton
Pitch	37,200	MJ/tonne	32.0	MMBtu/ton
Crude Oil	38.5	MJ/litre	5.8	MMBtu/bbl
No. 2 Oil	38.68	MJ/litre	5.88	MMBtu/bbl
			(0.168	MMBtu/IG)
No. 4 Oil	40.1	MJ/litre	6.04	MMBtu/bbl
			(0.173	MMBtu/IG)
No. 6 Oil (Residual Bunker C)				
- 2.5% sulphur	42.3	MJ/litre	6.38	MMBtu/bbl
			(0.182	MMBtu/IG)
- 1.0% sulphur	40.5	MJ/litre	6.11	MMBtu/bbl
			(0.174	MMBtu/IG)
- 0.5% sulphur	40.2	MJ/litre	6.05	MMBtu/bbl
			(0.173	MMBtu/IG)
Kerosene	37.68	MJ/litre	0.167	MMBtu/IG
Diesel Fuel	38.68	MJ/litre	0.172	MMBtu/IG
Gasoline	36.2	MJ/litre	0.156	MMBtu/IG
Natural Gas	37.2	MJ/m3	1.0	MMBtu/MCF
Propane	50.3	MJ/kg	0.02165	MMBtu/lb
	26.6	MJ/litre	0.1145	MMBtu/IG
Electricity	3.6	MJ/kWh	0.003413	MMBtu/kWh
(Thermal Power)	10.55	MJ/kWh	0.01	MMBtu/kWh

CONVERSION FACTORS

1 Short ton (2 000 lbs)	= 0.9072	tonnes (Metric tons)
1 Pound (lb)	= 0.454	kilograms (kg)
1 Imperial Gallon (Imp. gal.)	= 4.547	litres
1 U.S. Gallon (U.S. gal.)	= 3.785	litres
1 Barrel (35 Imp. gal. or 42 U.S. gal.)	= 159.1	litres
	= 0.1591	cubic metres (m^3)
1 British Thermal Unit (Btu)	= 1055	joules (J)
	= 0.001055	megajoules (MJ)
1 Cubic Foot (ft^3)	= 0.028317	m^3
1 Kilowatt-hour (kW.h)	= 3 600 000	J
1 Tonne	= 1.102	short tons
1 kg	= 2.203	lb
1 litre	= 0.220	Imp. gal.
1 litre	= 0.264	U.S. gal.
1 litre	= 0.006	barrels
1 m^3	= 6.285	barrels
1 m^3	= 35.31	ft^3
1 J	= 0.000948	Btu
1 J	= 0.000000278	kW.h
1 MJ	= 947.9	Btu
1 kilowatt (kW)	= 1.333	horsepower (hp)
1 Btu	= 0.000292	kW.h
1 hp	= 0.75	kW
1 kW.h	= 3413	Btu

METRIC PREFIXES

Multiplying Factor	*Prefix*	*Symbol*
1 000 000 000 000 000 000 $= 10^{18}$	exa	E
1 000 000 000 000 000 $= 10^{15}$	peta	P
1 000 000 000 000 $= 10^{12}$	tera	T
1 000 000 000 $= 10^{9}$	giga	G
1 000 000 $= 10^{6}$	mega	M
1 000 $= 10^{3}$	kilo	k

ENERGY CONSUMPTION AND PRODUCTION RECORD
Form 1

Organization ____________________ Reporting Centre ____________________

Product ____________________ Reporting Period ____________________

Prepared by ____________________ Date ____________

Data Sub-Periods	Energy Quantities in Purchased Units [see 2.5.2]							Output (units) [see 2.5.1] (8)
	Fuel Oil Type: ______ (litres) (1)	Natural Gas (m^3) (2)	Electricity (kWh) (3)	(4)	(5)	(6)	(7)	
Jan								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
End of Period Adjustment								
Totals								(9)

REPORTING CENTRE
TOTAL ENERGY CONSUMPTION
Form 2
[see 2.5.2]

Organization ______________________ Reporting Centre ______________________

Product ______________________ Reporting Period ______________________

Total Production Output ______________________ F-1(9) Prepared by ______________________ Date ____________

(1) Energy Type	(2) Quantity Used* (physical units)	(3) Energy Conversion Factor (MegaJoules [MJ]/unit)	(4) = (2) x (3) Energy Consumption (MJ)
			TOTAL (5)

*total from columns 1-7 on Form F-1

REPORTING CENTRE GROSS ENERGY PERFORMANCE
(CHANGE IN ENERGY PRODUCTIVITY)
Form 3
[see 2.5.4]

Organization ______________________

Reporting Centre ______________________

Reporting Period ______________________

Base Year ______________________

Prepared by ______________________ Date ____________

$$\text{Production Index} = \frac{Q_c}{Q_b} = \frac{\text{F - 1(9) Current Year}}{\text{F - 1(9) Base Year}} = \frac{(\qquad\qquad)}{(\qquad\qquad)} = \underline{\qquad\qquad} \quad (1)$$

$$E_{be} = E_b \times \text{Production Index} = \text{F - 2(5)} \times (1)$$

$$= (\qquad\qquad) \times (\qquad\qquad) = \underline{\qquad\qquad} \text{ MJ } (2)$$

EP_g *(Change in Energy Productivity)*

$$= \frac{E_{be} - E_c}{E_{be}} \times 100$$

$$= \frac{(2) - [\text{F - 2(5)}]}{(2)} \times 100 = \frac{(\qquad\qquad) - (\qquad\qquad)}{(\qquad\qquad)} \times 100$$

$$= \underline{\qquad\qquad} \%$$

NOTE: If the result is (+) performance has improved; if the result is (-) performance has deteriorated

COMBINED GROSS ENERGY PERFORMANCE OF REPORTING CENTRES

Form 4

[see 2.5.4]

Organization ______________________ Reporting Period ______________________

Name of Combined Reporting Centres ______________________ Prepared by ______________________ Date ____________

Reporting Centre (1)	Current Year Total Energy Use (MJ) [from F - 2(5)] (2)	Base Year Equivalent Energy (MJ) [from F - 3(8)] (3)
TOTALS	(4)	(5)

$$\text{Combined } EP_g = \frac{E_{be} - E_c}{E_{be}} \times 100$$

$$= \frac{(5) - (4)}{(5)} \times 100 = \frac{(\qquad) - (\qquad)}{(\qquad)} \times 100$$

$= \_\_\_\_\_\_\_\_ \%$ (6)

(+) = Improvement (-) = Deterioration

REPORTING CENT[illegible] ENERGY ADJUSTMENTS AND NET ENERGY PERFORMANCE

Form 5

[see 3.3]

Organization ______________________ Reporting Period ______________________

Reporting Centre ______________________ Base Year ______________________

Prepared by ______________________ Date ______________

TYPE OF ADJUSTMENT	FORMULA AND CALCULATIONS	ADJUSTMENTS (MJ)
1. Raw Material Quality Change (see 3.3.1)	$= Qi_c \left[\frac{VE_c}{Qi_c} - \frac{VE_{c-1}}{Qi_{c-1}} \right]$ = ( ) [( ) / ( ) - ( ) / ( )]	= ______
2. Interfuel Substitution (see 3.3.2)	$= ei_c - \left[\frac{ei_c \times U_i}{U_j} \right]$ = ( ) - [( ) x ( ) / ( )]	= ______
3. Change in Rate of Output (see 3.3.3)	$= Q_c \left[E_{cr} - E_{br} \right]$ = ( ) [( ) - ( )]	= ______
4. Climate (see 3.3.4)	$= HE_b \left[\frac{D_c - D_b}{D_b} \right]$ = ( ) [( ) - ( ) / ( )]	= ______
5. Change in Safety/Environmental Regulations (see 3.3.5)	REQUIRES ANALYSIS OF SPECIFIC CIRCUMSTANCES	______
6. Make/Buy Decisions (see 3.3.6)	REQUIRES ANALYSIS OF SPECIFIC CIRCUMSTANCES	______
7. Other (see 3.3.7)		______
	TOTAL ADJUSTMENT TO BASE YEAR EQUIVALENT ENERGY	______ MJ(1)

Adjusted Base Year Equivalent Energy (E'_{be}) $= E_{be}$ + Adjustments = (F - 3(2)) + (1)

= (   ) + (   ) = ______________ MJ(2)

Reporting Centre Net Energy Performance (EP_n) $= \frac{E'_{be} - E_c}{E'_{be}} = \frac{(2) - (F - 2(5))}{(2)}$

= [(   ) - (   )] / (   ) x 100 = ______________ %

CUMULATIVE DATA ON ENERGY CONSUMPTION

Form 6

[see 3.4]

Organization ______________________ Reporting Period ______________________

Prepared by ______________________ Date ______________

(1) Reporting Centre	(2) Current Year Energy Consumption [from F-2(5)] (MJ)	(3) Base Year Equivalent Energy [from F-3(2)] (MJ)	(4) Base Year Energy Adjustments [from F-5(1)] (MJ)	(5) = 3 + 4 Adjusted Base Year Equivalent Energy (MJ)
TOTALS	(6)	(7)	(8)	(9)

COMBINED ANNUAL PERFORMANCE REPORT: PERCENT IMPROVEMENT IN ENERGY EFFICIENCY

Form 7

[see 3.5]

Organization ____________________ Reporting Year ____________________

Base Year ____________________

A. Current Year Total Energy Consumption ____________ joules F - 6(6) or F - 4(4)

B. Base Year Equivalent Energy Consumption ____________ joules F - 4(5) or F - 6(7)

C. Combined Gross Energy Performance (%)

$$\frac{\text{Base Year Equivalent Energy} - \text{Current Year Energy}}{\text{Base Year Equivalent Energy}} \times 100$$

$$= \frac{B - A}{B} \times 100 = \_\_\_\_\_\_\_\_ \%$$ F - 4(6)

D. Adjustments* ____________ joules F - 6(8)

E. Adjusted Base Year Equivalent Energy Consumption:

Base Year Equivalent Energy + Adjustment

B + D = ____________ joules f - 6(9)

F. Combined Net Energy Performance (%)

$$\frac{\text{Adjusted Base Year Equivalent Energy} - \text{Current Year Total Energy Consumption}}{\text{Adjusted Base Year Equivalent Energy}} \times 100$$

$$= \frac{E - A}{E} \times 100 = \_\_\_\_\_\_\_\_ \%$$

* Adjustments (type and quantity)

____

____

____

____

____

____

CALCULATING COST SAVINGS
[based on unadjusted changes in energy productivity]
Form 8A
[see 4]

Organization ______________________

Reporting Centre ______________________

Reporting Period ______________________

Prepared by ______________________ Date ____________

	(1) Imputed Energy Consumption (MJ)	(2) Actual Energy Consumption (MJ)	(3) = 1 - 2 Energy Savings (MJ)	(4) Average Cost of Energy ($/MJ)	(5) = 3 x 4 Cost Savings ($)	(6) Cumulative Cost Savings ($)
Base Year (BY)						
BY + 1						
BY + 2						
BY + 3						

COST SAVINGS CALCULATION
[based on adjusted changes in energy productivity]
Form 8B
[See 4]

Organization ______________________

Reporting Centre ______________________

Reporting Period ______________________

Prepared by ______________________ Date ____________

	(1) Imputed Energy Consumption (MJ)	(2) Actual Energy Consumption (MJ)	(3) = 1 - 2 Energy Savings (MJ)	(4) Average Cost of Energy ($/MJ)	(5) = 3 x 4 Cost Savings ($)	(6) Cumulative Cost Savings ($)
Base Year (BY)						
BY + 1						
BY + 2						
BY + 3						