GUIDEBOOK ON INTEGRATED COMMUNITY ENERGY SYSTEMS:
INDIRECT ECONOMIC AND ENERGY IMPACTS

ARGONNE NATIONAL LABORATORY

**ENERGY AND ENVIRONMENTAL SYSTEMS
DIVISION**

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CHAPTER 1: INTRODUCTION

Integrated community energy systems (ICES) represent potential means of aiding communities to conserve scarce fuels. Because ICES combine energy services, typically by concurrent generation of electricity and thermal energy, both the amount of energy needed within a community and the fuels used to meet those needs can be altered.

Such energy conservation, however, inevitably has associated impacts, and it is a matter of concern to all those involved how large the impacts are and how they are distributed. Since ICES are community systems, they may affect a variety of participants, who will have different perspectives on the costs and benefits of energy savings. As a consequence, impacts from ICES must be described in terms of the communities they serve.

Impacts resulting from development and operation of an energy system are both direct and indirect. In addition to costs and benefits showing direct economic and energy effects to the owner, there are secondary or indirect effects which are important to the broader community. In particular, employment, fiscal impact on local government, and reliability of fuel source can be significant to both public and private groups within the community; and if the indirect characteristics can be evaluated early in the design stage, there are opportunities to choose how the system can best accommodate divergent views.

This Guidebook is designed to demonstrate how indirect impacts of energy systems can be estimated, so that the various members of the community can understand them and participate in the energy-related decisions.

The community's role in energy planning is related to its energy needs. If the community can be described, for example, as mostly residential with just a sprinkling of commercial and industrial locations; it has one set of opportunities. If it is highly industrial including power generation and chemical processing with few domestic uses, there will be another set of opportunities. The community can choose its role depending upon the technical alternatives available to meet its needs.

The use of an integrated approach to energy conservation can be coordinated with the community's development or redevelopment process. In these cases "community" can be defined as a complex of buildings serving various human activities connected by transportation and communication networks. The community's functions can be residential, commercial, industrial, agricultural, etc., thus requiring its energy system(s) to be responsive to a variety of needs. By its actions on energy alternatives a community can develop or redevelop in such a manner that energy use can be optimized while economic costs and environmental effects are minimized.

This Guidebook on Integrated Community Energy Systems (ICES) is designed to provide members of the community with a means of evaluating energy sources as well as the other aspects of an energy system. It may be used by:

- Representatives of local and regional governments interested in energy participation;
- The private developer considering residential, commercial, and industrial projects;
- Members of public/private authorities in allied services evaluating the role of energy supply;
- Industrialists with high energy requirements considering changes in fuel source;
- Representatives of trade and commerce groups interested in the role energy plays in attracting new industry.

Each of these potential users of ICES has a different viewpoint on the community's functions and its energy needs. This Guidebook responds to as many of their common requirements as is feasible in a single format.

From the largest perspective, integrated community energy systems represent combinations of innovative technologies, energy conserving community designs, and appropriate financial and regulatory mechanisms for implementation. However, for purposes of this Guidebook, ICES will be limited to the technical components of co-generation encompassing alternative fuel sources, technologies, and end uses with the corresponding institutional aspects of participants, purposes, and utility roles. For example, technical components can include a coal-fired power generation unit where the waste heat is captured for local heating needs. In another case, use of an ICES approach can lead to fuel switching including utilization of municipal solid waste for energy recovery. Areas such as downtowns, university or medical complexes, urban renewal projects, government complexes, and new developments offer potential applications. The ICES approach can provide a community with the opportunity to evaluate indirect effects of alternative technical systems for the generation and distribution of energy, as well as to plan the necessary institutional requirements in order to make energy-related decisions consistent with the community's economic and social objectives.

An evaluation of indirect impacts of ICES is formed on four basic parts: the resource components, the central plant component, the distribution and storage component, and the end-use component. Figure 1, "The Integrated System" presents a summary of these parts.

FIGURE 1
INTEGRATED SYSTEM

Taken from "Integrated Community Energy Systems," DOE/CS-0037, Department of Energy, Washington, DC, June 1978.

Resource: The supply of primary fuel(s) or energy which is most appropriate for designated community.

Central Plant: The conversion of primary resource(s) into usable form(s) of energy.

Distribution and Storage: The process for supplying energy to match the community's demand.

End Use: The provision of energy services in appropriate form at a reasonable rate.

The separation of the ICES into its components demonstrates how the characteristics of an ICES can vary from traditional systems which do not attempt to optimize their parts. From these components, alternatives for fuel switching, utilization of waste heat, specific distribution systems, storage, and financing procedures can now be evaluated.

The evaluation of economic and energy impacts from an ICES is a major step in community planning. The primary or direct economic and energy impacts of ICES and alternative energy systems are those associated with equipment selection, operation, and financing and fall directly upon the owner. The indirect economic effects, which result from the direct economic impacts, appear as employment rates, revenues, and costs of municipal services and are felt across the community and even the region. The evaluation of these indirect impacts will assist in analyzing specific energy proposals as well as in comparing alternatives. It will provide information for issues concerning municipal participation and distribution of costs and benefits.

Similarly, the indirect energy impacts are based upon the direct energy effects of the fuel and electricity consumed by the end users. Indirect energy impacts are a measure of availability and reliability of the chosen

resource which complement direct energy characteristics and also have broad implications for the community. The indirect energy evaluation will assist the community in decisions on choice of fuel when resources may be scarce and alternatives may be available. The utilization of solid waste as a fuel source, for example, may be compared with coal or oil.

The following chapters outline and describe procedures for determining the indirect economic and energy impacts which interest a community. By following the procedures, users of the Guidebook have the opportunity of determining their roles in the encouragement of new technologies. Both private and public parties will find information to aid their evaluations. Such issues as municipal participation in system implementation, alternative procedures for cost distribution, and public/private structures for ownership and operation come to light as the chapter on indirect economic impacts unfolds. Questions such as the best initial fuel selection which influence the consumer's ultimate cost are also addressed. The chapters identify those issues that must be considered in the evaluation of energy systems and provide methods by which to examine them.

The next chapter, on indirect economic impacts, proceeds through four interrelated phases:

- One. Conditions Affecting Impact Estimates
- Two. Employment
- Three. Fiscal Impacts
- Four. Evaluation

The methodology develops an iterative sequence in order to permit a change in initial conditions and subsequent reevaluation of the impacts. The issues of public versus private ownership, distribution of costs, and ability to attract

new industry are raised in order to facilitate a thorough evaluation. In this way the chapter is made more useful both to the municipal official who wishes to test various alternatives and to the private developer who attempts to better illustrate his potential project.

The final chapter, on indirect energy impacts, develops a procedure for tracking the series of processes from initial mining or extraction of energy resource through to its actual use. This permits the evaluation of the energy associated with each step of processing, transportation, conversion, and consumption for a fuel or power source. Five steps are utilized in this procedure:

- One. Determination of Energy Consumption
- Two. Description of Supply Processes
- Three. Characterization of Processes
- Four. Summary of Process Series
- Five. Determination of Total Demand Alternatives

With this methodology, the resource requirements of various energy systems can be compared. The comparison is particularly important in estimating the reliability of different fuels for the energy systems in question.

Together the two chapters permit an understanding of the indirect impacts on a community from a proposed energy system. This comprehension can lead to public acceptance and encouragement of an integrated community energy system where its benefit is demonstrated.

CHAPTER II: INDIRECT ECONOMIC EFFECTS

INTRODUCTION

Costs and benefits resulting from construction and operation of an integrated community energy system (ICES) fall into two categories. The first category includes direct effects associated with the selection of equipment, methods of financing, operating requirements, and administration for the system. The second category, and the subject of this chapter, comprises the indirect economic effects of ICES that are realized in the surrounding community and geographic region. Indirect economic impacts are "ripple effects" caused by direct economic characteristics of new development or of redevelopment, and they can be determined by derivation from direct economic conditions needed to support such projects. A complete evaluation of the economic consequences of constructing ICES comprehends the indirect, as well as the direct, calculations of economic impact.

The reasons for concern about indirect economic effects involve the utility of analytical information in making judgments within a community. Since impacts are not limited to a single individual or corporate owner of ICES, but rather the ripple effects take in the municipal community generally, and in some cases the larger regional population, local and regional authorities have interests in supporting or discouraging new technologies such as ICES, especially those that require cooperation among several parties. The integrated system by its nature attracts public attention to three central questions:

- Should the municipality participate in or encourage the introduction and implementation of technological innovations that may affect significant segments of its populace.
- What are the possible distributions of costs and benefits from technology, and are there preferable ways, in which the public sector can

participate, to apportion among those involved.

- How can the ownership and operation of technological systems be structured so that the interests of both the owners and the municipal community are served.

The answers to these questions partly rest on an understanding of the impacts of technology, especially the wider indirect effects that may define community interests. In order that economic analysis be relevant to the concerns of local and regional groups, indirect economic impacts must be determined.

The purpose of this part of the guidebook is to present a summary of how indirect economic impacts can be estimated, in order to permit a useful examination of whether and how an ICES should be implemented with the help of local government. The two principal indirect economic impacts are employment and fiscal impact on the community. Employment estimates are used to indicate how integrated systems might provide work for local residents and what compensating reactions, if any, are likely to be experienced outside the local area. Fiscal impacts include both the tax or other revenue return that might accrue to the city or local authority and the demand for and cost of municipal services to support an ICES facility. Together these two indirect economic effects imply the magnitude of interest a municipal government may take in furthering technology and the manner in which costs and benefits may be spread throughout the municipality.

An energy system, like other utility services, is a means of furthering the objects of development or reconstruction. Since an integrated community energy system is one alternative means of supplying energy services that is to be compared with other options, indirect economic impacts attributable to ICES are likewise drawn from a comparison between ICES and other possible

technologies. The estimates of employment and fiscal impacts that are pertinent to evaluating ICES are those that would occur with an integrated system and that would not otherwise result if another system were chosen. It is therefore the increment or marginal impacts that determine whether ICES is an attractive opportunity for local participation as a method of providing energy services to a community.

There are two increments to be considered in analyzing indirect economic effects of energy system alternatives. The first is the employment and fiscal impacts associated with energy systems themselves. These effects include, for example, the labor necessary to build, operate, and maintain equipment and the taxes paid on energy facilities. There are standard methods for determining such effects and their implications for the local area, and the procedures for estimating impacts are described in this chapter. Because these impacts are readily identifiable with energy systems, comparisons of one alternative versus another is straightforward (though the estimation process can be tedious if great detail is required). Thus methods for evaluating indirect economic consequences from the energy systems themselves can be applied to evaluating incremental employment of ICES against a conventional system of supplying energy.

The second increment associated with ICES is due to the attraction to the community of users that otherwise would not locate in the local area. So, for example, if reliability, cost of power, or some other feature of the integrated system results in residential, commercial, or industrial uses additional to what would be expected without ICES, the employment and fiscal impacts of those new activities are properly attributable to the integrated

alternative and should be calculated. There is no way a priori to ascertain whether increments from attracted users apply to ICES generally. Lacking a general application, each situation must be examined individually; and the determination of whether to estimate indirect effects for this second increment is left to the judgment of the evaluator. If it is decided that ICES is responsible for an additional user, the entire employment and fiscal impacts of the user are to be estimated. Procedures for determining indirect economic impacts for this category are analogous to those for estimating impacts from the energy facilities, although the final accounting is somewhat different. The methods for estimating indirect economic impacts from attracted users, once a decision is made on the utility of such calculations, are also given in the latter part of the chapter.

There are several considerations that affect the magnitude and distribution of indirect economic impacts. They are:

- Origin of impacts. As discussed above, either energy system requirements or users attracted to the community may cause incremental indirect economic impacts that influence the willingness of local government to countenance or encourage integrated community energy systems. The types of employment, as well as the numerical total, will vary according to which source is instrumental in providing jobs. Similarly, revenues to the municipality and services demanded from it are determined by the origin of impacts.
- Ownership. The forms and amounts of employment and city revenue are affected by the ownership pattern. Moreover, the means by which local authorities can act to implement the ICES or to influence distribution of the impacts resulting from it are defined by whether ownership is private, semi-private as in an investor-owned utility, public, or some mix of these. Thus, ownership is not only an issue to be decided following an evaluation of the impacts but a determinant of those impacts as well.
- Analytical boundaries. Although the evaluation of indirect economic impacts is primarily carried out at the local level, there are additional impacts to be examined at a regional scale. One reason for

including the regional boundary in evaluating employment and fiscal impacts is to make certain that effects are not merely shifted from one area to another by accounting for whatever reaction to local impacts occurs outside the municipal level. So, for example, the attraction of industry to one community generally implies that some other location within the region was not selected. The distinction between impacts due to location and those due to absolute growth requires that both local and regional analytical boundaries be used to perform the evaluation of indirect effects.

- Energy system features. There are two features of ICES and other energy systems that can be used to trace indirect economic impacts. First, the steps* in the delivery of electricity and fuels provide mechanisms for examining how employment and fiscal impacts of capital investments and of system service demands vary by system. Second, the equipment in energy systems can be used to identify employment and fiscal effects, as for example the employment associated with the purchase, installation, and maintenance of home heating equipment. By following the supplies of energy and equipment indirect economic impacts can be specified.
- Parties involved. There is a list of potential participants in constructing and operating integrated community energy systems and other alternatives. The distribution of impacts among the participants is one consideration in designing how the implementation of ICES should be managed. Those that may cause or receive indirect economic costs and benefits include consumers, local labor, heating and cooling equipment suppliers, construction contractors, local industry, utilities, local government, and regional authorities. Each entity has individual goals and demands; and it is important to recognize that indirect economic impacts do not affect all parties in the same way. The dissimilarities among parties require that the placement, as well as the magnitude, of indirect effects be heeded in evaluating energy alternatives.
- Phase of development. Economic impacts result from the three phases of development: planning, construction, and operation. The planning phase results in indirect effects as public employees are required to pass on plans for new facilities and to design services to supply the development (e.g. roads, water, sewers). Construction has an associated temporary labor force and short-term fiscal impacts, while operation brings permanent employment, revenue, and monitoring and regulation of some energy utilities. Impacts of each phase differ from those of the others; and separate investigations of the planning, construction, and operation stages are necessary to account for all of them.

*These steps are part of the series of energy production processes discussed further in the chapter on indirect energy impacts.

These several considerations enter into the evaluation of indirect economic consequences and indicate the structure of an analysis that answers the central questions for which indirect effects provide useful answers. The analysis, which must be organized so as to deal with the dimensions just described, includes some parts that are necessarily qualitative and set the context for estimates that follow. Thus the procedures combine recognition of how municipal governments operate with calculation of the effects resulting from direct costs and from local policy choices that modify the impacts. The next section describes how these considerations are addressed methodologically and how the subsequent evaluation procedures are designed to fit together to furnish appropriate analytical results.

METHODOLOGY

Figure 2 illustrates the general methodology for combining qualitative and quantitative features of an analysis of indirect economic impacts. It consists of four phases, beginning with the definition or assumption of conditions that influence derivation of numerical estimates. The second phase is determination of employment impacts associated with the energy systems. The third phase is used to ascertain fiscal impacts from those systems. And the fourth phase is a summary and evaluation both of results and of the conditions that cause them. Based on the evaluation, an iteration may be performed to alter the conditions of the first phase in order to improve or modify results or to test a larger set of alternatives. The sequence can be iterated as necessary for fulfilling the objectives of the analysis.

FIGURE 2
DIAGRAM OF METHOD FOR EXAMINING
INDIRECT ECONOMIC IMPACTS

Phase One is an examination of ownership, taxing policy, revenue structure, regulatory policy, and the public planning process as means to ascertain employment and fiscal impacts. These conditions are the foundation for estimating quantitative effects, though they do not lend themselves to direct numerical equation. Consequently, the investigator must relate the qualitative factors in Phase One to the estimates of subsequent phases.

Employment and fiscal impacts (Phases Two and Three) arise from characteristics of the energy systems themselves and also from secondary effects caused by the primary impacts. Figure 3 illustrates these interactions and their combination to produce measurable totals. Nine steps take the analysis from description of the energy facility through primary and secondary impacts to summary employment and fiscal impacts. The diagram indicates employment impacts from three sources: the energy facility and its associated demands, new uses attracted by the facility, and job growth stimulated by employees' spending and demands for services. The energy facility, attracted uses, and employment lead both to increased revenue and to costs of municipal services and so form the basis for estimating fiscal impacts. The methods of estimation involve first determining the mathematical equivalents of the arrows connecting boxes with one another and then applying them to calculations. Generally, multipliers are used to relate quantities to one another. So, for example, employees' demands for police protection may be estimated from a per capita multiplier. The method for determining indirect impacts is derived from following the "flows" indicated in Figure 3 and estimating multipliers to correspond to them.

For each stage of the development process (planning, construction,

FIGURE 3

DIAGRAM OF INDIRECT ECONOMIC IMPACTS FROM ENERGY FACILITY

and operation) the employment and fiscal impacts must be determined.

It is necessary to carry three separate accounts for the three development stages while using the diagram. These stages are indicated in Step 1, that begins with characteristics of an energy facility. It is the basis for tracing both the employment sequence (Steps 2 through 6) and the fiscal impact sequence (Steps 2, 6, 7, 8 and 9).

Just as Step 1 describes the energy facility and those features of the facility that yield employment and fiscal impacts, so Step 2 examines similar effects from new uses attracted to share in the energy system. Step 2 is needed only for those cases in which additional residential, commercial, or industrial activities that otherwise would not be located there are brought to the community due to the energy system. When such attracted uses occur, their impacts are accounted along with those of the energy facility as results of the choice in energy systems. Then both Steps 1 and 2 form the bases for estimating employment and fiscal effects in subsequent steps in the analysis.

Steps 3, 4, and 5 demonstrate the relations between primary employment, associated with Steps 1 and 2, and secondary employment that is a consequence of increased demand for goods and services. The expenditures of employees that work on the energy facility, and on new facilities attracted to it, give rise to secondary employment, which in turn results in increased demand and thus still more secondary employment, and so on. Secondary employment is, therefore, directly related to primary employment and is normally

estimated as a multiple depending on the type of primary employment (e.g. wage levels, business category) and the locale.

Total employment, Step 6, is simply the sum of primary and secondary employment. Because the planning, construction, and operation stages of development give rise to employment patterns that vary according to duration and magnitude, total employment estimates must be described to correspond to each stage. Also, the locations of impacts (that is, local or regional) influence whether the community is likely to benefit in increased employment from an energy system, and consequently location is a distinguishing factor in listing total employment.

Fiscal impacts follow a series of steps similar to the employment estimates. After the foundation for tracing fiscal impacts is set in Steps 1 and 2, Step 7 is used to evaluate primary effects according to local tax rates and procedures. Secondary fiscal impacts of Step 8 result from the tax revenues and municipal services associated with the employment determined earlier in Step 6. (Fiscal impact estimates therefore follow the employment calculations.) Employment is converted to fiscal impacts using a simple relation between city budget and population. Total fiscal impacts are the sum of results from Steps 7 and 8, and like employment are described by development stage and by location.

The diagram in Figure 3, which outlines Phases 2 and 3 of the analytical method, presents an adequate set of procedures for determining employment and fiscal impacts, though it is incomplete. For example, total fiscal impacts (Step 9) generate additional employment, and so iteration between the employment and fiscal impact portions of the diagram could be continued. The method is intended to provide estimates of major effects rather than to

include all possible impacts. Means for making determinations indicated in the diagram for Phases 2 and 3 yield manageable and suitable results for application in evaluating an energy system for indirect economic results.

Phase 4 of the method for examining indirect economic impacts is evaluation. The evaluation phase concerns comparison of energy system alternatives to ascertain employment and fiscal benefits expected from them. Furthermore, location and duration of impacts can be reviewed along with initial conditions that affect either the magnitude or distribution of benefits. Thus, Phase 4 is used to reflect and adjust assumptions about ownership, taxing policy, revenue structure, regulatory policy, and public planning process as they affect indirect economic impacts. Evaluation is directed to the consequences of Phase 2 and Phase 3 estimates and to the conditions that modify them.

The sections that follow describe how an analysis of employment and fiscal impacts is conducted through the four phases just discussed. Information is presented in such manner that both integrated and conventional systems can be evaluated, so that comparison can be made between ICES and traditional alternatives. The information deals with qualitative conditions in Phase 1, with quantitative estimates in Phases 2 and 3, and with evaluation in Phase 4.

Phase One: Conditions Affecting Impact Estimates

The first requirement in evaluating indirect impacts is to set the context for subsequent calculations. There are several conditions that are variable either through negotiation or design and that accompany the planning, construction, and operation of a new energy facility. They are arrangements that directly involve public authorities in determining the distribution, as well as the magnitude, of indirect economic impacts. The

conditions are first, ownership, and then taxing policy, revenue structure, regulatory policy, and public planning process. In many cases these factors cannot be given quantitative expression themselves, but rather set the framework for other quantitative estimates.

Ownership is a primary indicator of how impacts will be divided; there are many possible ways to devise the planning, building, and operation of an energy facility. This discussion will briefly outline the variation resulting from three modes of ownership; private, semiprivate, and public.

- Private. Private ownership in all three development stages leads to private employment, increased tax revenue, and demands for municipal services. Financing may be difficult and will be obtained at higher interest rates than for public or semiprivate ownership. There are opportunities to negotiate both tax rates and methods of financing with municipal authorities, particularly if there are benefits (e.g. reliability) from encouraging new technology.
- Semiprivate. Semiprivate ownership changes both employment and fiscal impacts relative to private ownership. Of special interest are regulatory relationships and the interconnection of local services with regional supply grids. Semiprivate ownership also offers the possibilities of negotiating financial and tax arrangements with the public sector.
- Public. Public ownership largely redirects the extent and form of fiscal impacts and to a lesser amount changes employment as compared to private or semiprivate ownership. Public ownership implies a separate municipal structure for handling and accounting revenues (e.g. user charges). In addition, municipal powers of financing result in relatively low interest rates, and services may be provided to a public facility on a different basis than to a private or semiprivate one. Employment may occur in the public rather than the private sector, but it is possible to manage the facility on a contract basis. Public ownership thus allows negotiation with private contractors for participation in any or all of the planning, construction, and operation phases, with resultant ramifications for employment and fiscal impacts.

In addition to the three major ownership patterns, joint undertakings are possible. The distribution of risk and responsibility for a new facility both causes and modifies economic impacts that accrue throughout the community

and its surrounding region. Consequently, the size and location of indirect economic impacts can be estimated only after ownership has been established. For analytical purposes, the owner arrangements must be predetermined or assumed, in order to provide a foundation for subsequent steps in the evaluation.

The second precondition to estimating indirect effects is the taxing policy and revenue structure of local and state authorities. The rates, methods of assessment, and classifications affecting energy systems vary significantly among and within regions of the country. As a result, indirect economic impacts on the community can only be determined after local tax and revenue characteristics are established. These characteristics also indicate how taxes might be negotiated to redistribute economic effects between owner and taxing authority either absolutely (e.g. lowering taxes to encourage an innovative energy technology) or temporarily (e.g. postponement), or both. Thus taxing policy and revenue structure are conditions that affect the magnitude and the distribution of indirect economic impacts.

Regulatory policy is a third means by which indirect economics are determined. Regulation of electric and gas utilities is an important characteristic of those energy delivery networks and a determinant of their economic performances. Since integrated community energy systems produce electricity, they may also fall under regulatory review. The indirect impacts of regulation that is associated with conventional energy systems can be estimated from available information, since both the costs of regulation general descriptions of the utilities are available. However, the costs of regulating new systems such as ICES are unknown and can be obtained only as rough approximations. Therefore, it becomes important to judge the regulatory policy of the area in which an ICES is proposed as an indicator

of the magnitude of indirect costs resulting from public regulation.

The last set of characteristics that influence indirect economic impacts is the public planning process at the local level. Significant costs, especially in the review and authorization of systems with which there is no previous experience, can be incurred by local government in staff work, public meetings, and decision-making by appropriate authorities. These costs are attributable primarily to the planning stage of development, though some monitoring of results may carry over to both construction and operation phases. Since the planning process is dependent on the structure and functioning of the government entities involved in it, the impacts may change considerably from one locale to another. Consequently, in each case the public planning process must be evaluated for its potential results on the introduction of energy systems to the community.

The implications of ownership, taxing policy, revenue structure, regulatory policy, and public planning process reappear in the quantitative estimates of employment and fiscal impacts that are described in following sections. Because they are variables that can be worked out to the best advantage of the project, these conditions can be altered in an iterative fashion that permits examination of a wide range of alternatives for planning, building, and operating energy systems such as ICES. The quantitative estimates must be defined in context of the conditions under which they were derived.

Phase Two: Employment

Employment effects are determined from Steps One through Six in the diagram of Figure 3 (see Figure 4 following). That numerical sequence will be used in the descriptions that follow.

FIGURE 4

DIAGRAM OF EMPLOYMENT IMPACTS FROM ENERGY FACILITY

Step One--Identify Characteristics of the Energy Facility that Affect Employment.

a. First note the conditions of ownership, regulatory policy, and public planning process to ascertain what kinds (e.g. public, private) of employment will result.

b. Next list equipment for each energy system alternative and the types of employment associated with its planning, construction and operation. For example, central heating equipment for a building complex may require the equivalent of six manmonths to design and order. A typical list for a complex using an ICES might appear something like this.

<u>Equipment</u>	<u>Planning</u>	<u>Construction</u>	<u>Operation</u>
● Plant Building	● Building Design	● Building	● Boiler and Turbine
● Boiler	● System Design	● Equipment Purchase	● Fuel Handling
● Turbines	● Municipal Services	● Equipment Installation	● Central Unit and Building Maintenance
● Chillers	● Plan Approval	● Municipal Services	● Dispersed Unit Maintenance
● Electrical Distribution		● Inspection	● Administration (e.g. customer billing, payroll, purchasing)
● Dispersed Units			● Monitoring
● Cooling Tower			● Regulation
● Utilities			

c. Then examine the energy supply series associated with the facilities of each alternative. These normally consist of electric and gas utility systems, oil delivery, and coal transportation. There may be unusual fuels, such as wood, or

other sources such as geothermal and solar energy. A listing of employment impacts will follow a tabulation similar to the one below.

<u>Energy Supply</u>	<u>Planning</u>	<u>Construction</u>	<u>Operation</u>
● Gas	● Utility Planning	● Utility Lines, Mains	● Delivery
● Oil	● Municipal Approval of Easements, etc.	● Roads	● Maintenance and Repair
● Coal		● Inspection	● Administration
● Electricity	● Transportation Planning		

d. Finally, determine the location (i.e. local or regional) of each activity. For example, ascertain how much equipment is to be installed using local labor and how much installation will rely on workers from elsewhere in the region.

Step Two--Estimate Uses Attracted by the Energy System and Their Employment Characteristics. If industrial, commercial, or other customers are attracted to the location solely in order to obtain energy from the local system, impacts of those customers can be wholly attributed as indirect effects of the system. Consequently, this step relies on the evaluator's judgment to determine whether new employment is caused by uses other than the system itself. An example of such a situation is the following:

An industrial facility requiring large amounts of low-temperature heat for round-the-clock operations can be supplied at low cost with waste heat from an ICES, removing the need for an additional capital investment for a steam system. This opportunity is decisive in management's choice of location. As a consequence, the ICES is credited with employment effects arising from the industrial plant.

This step should be omitted if users cannot be shown to be attracted to the location because of its energy system. However, subsequent to a positive

finding, the procedures described below should be applied. It should be noted that in general the net regional employment from attracted uses is zero, since employment added to one municipality is likely to be gained at the expense of another in the region. That is, an energy system may redistribute new uses within the regional area but is expected neither to create them nor to draw them from long distances. However, from the local viewpoint such redistribution is beneficial and desirable; the accounting of employment due to attracted uses, though it will demonstrate no net regional gain, nevertheless indicates relative incentives to the local area of adopting various energy alternatives.

a. Determine employment categories generated by new uses attracted to share in the energy system. Employment will correspond with parts of the planning, construction, and operation stages and may be described as indicated below.

<u>Planning</u>	<u>Construction</u>	<u>Operation</u>
● Facility Design	● Building	● Production
● Financial Arrangements	● Equipment	● Supervision
● Materials and Equipment Purchase	● Raw Materials Transport and Handling	● Administration
● Public Planning and Approval	● Product Transport and Handling	● Maintenance and Repair
	● Municipal Facilities	
	● Inspection	

Employment must be classified in terms of both numbers and duration, and so in this step an effort should be made to estimate the length of each development stage.

b. Divide employment categories according to local jobs and those generated elsewhere (e.g. surrounding towns, temporary workforce from nearby metropolitan area).

Step Three--Estimate Primary Employment. This step requires an examination of the items identified in Steps One and Two in order to gauge the magnitude of employment expected for each one. The following information describes how to derive employment estimates for items listed in the tables of Step One b and c.

a. Planning Items

- Building Design--The cost of design is included in the total building cost, usually as an architectural and engineering fee. Employment can be derived from the cost of design by estimating a figure that includes salary, benefit, and overhead expenses for one person and dividing that into the cost of design. Good current estimates are 5.5 percent of total cost for design (1) and \$50,000/employee/yr. (2).
- System Design--The employment associated with design of generation, distribution, and end-use facilities and networks is calculated in the same manner as for building design, by dividing cost of design by cost per employee. Estimates for system design are approximately those of building design.
- Municipal Services--The design of roads and water delivery is especially important. Where such activities are the responsibility of the public sector, employment for these categories is estimated from current use of personnel in city offices for planning roads and water supply, apportioned according to the demands of the energy system. This employment implies a net cost to the municipality. If, on the other hand, the burden of new roads and water lines is borne by private developers, employment for roads and water should be included under system design above.

- Plan Approval--Employment associated with approval of construction plans is dependent on the public planning processes under which the energy facility is designed and built. Employment for this item can be estimated from similar past experience in the same locale. Local planning boards should be contacted to obtain this information.
- Utility Planning*--Utilities, both gas and electric, require planning staffs. They can be related to new energy demands from the following ratios:

Gas Utility Planning Staff/Units of Gas Sold

Electric Utility Planning Staff/Units of Electricity sold

Employment is estimated by multiplying projected gas and electricity consumption by the respective employment ratios. The ratios must be obtained from local utilities. Otherwise, statistical summaries that combine the planning, construction, and operation items in total employment summaries must be used (see under Operation Items).

- Municipal Approval of Easements, etc.--(See Plan Approval, above.)
- Transportation Planning--This takes place for both oil and coal delivery. Transport may include water, rail, or truck delivery. Planning staffs are generally quite small, but estimates can be made by contacting the local companies involved.

b. Construction Items

- Building--Employment is generally proportional to the project cost. For a commercial building the ratio is approximately one employee per \$40,000 of construction cost (3). Total employment (for the duration of construction) is the product of the ratio times building cost.
- Equipment Purchase--Employment can be estimated from the ratio of sales/employees in business sector or sectors supplying equipment for the energy system. This table gives some typical figures for wholesale trade.

*Estimates for utilities are applicable generally to conventional alternatives and in those cases where integrated systems are suppliers or customers of utility networks (e.g. grid-connected ICES, such as a system providing surplus electricity to a utility).

TABLE 1

SALES/EMPLOYEE IN ENERGY EQUIPMENT SECTORS

<u>Sector</u>	<u>Employment-1972</u> <u>(thousands)</u>	<u>Sales-1972</u> <u>(billion dollars)</u>	<u>1972 Sales/</u> <u>Employee</u> <u>(1000 dollars/</u> <u>employee)</u>	<u>Adjusted 1978</u> <u>Sales/Employee</u> <u>(1000 dollars/</u> <u>employee)*</u>
Electrical goods	253	49	190	340
Hardware, plumbing, heating equipment, supplies	175	18	110	210
Machinery, equipment, supplies	725	75	100	200

Source: U. S. Bureau of the Census, 1977 Statistical Abstract, P. 838.

*Adjusted to 1978 dollars to reflect increases in producer prices between the years 1972 and 1978.

It should be noted that sales/employee is an annual number. So, for example, \$340,000 of electrical goods corresponds to one manyear of employment.

- Equipment Installation--According to statistical data, there is approximately one employee per \$50,000 installation of heating equipment (4). This multiplier should be applied to cost of equipment for the project.
- Municipal Services--Construction by the municipality of new water distribution lines may be necessary to service the energy facility. Employment for such construction can generally be approximated by the city engineer, who should be contacted for the appropriate number.
- Inspection--As in the Municipal Services item, employment estimates are most readily obtained from local municipal officials.
- Electrical Utility--Construction is part of the continual activity of electric utilities. Employment for construction may be obtained from the local utility. Otherwise, approximately one out of four electrical utility employees is assigned to construction, or about one employee per annual 14 million kilowatt-hours of sales, according to statistics that are published in industry summaries (5). Thus, construction employment can be estimated by dividing expected annual consumption of electricity by the above factor, or a more precise number may be available from the local utility.

- Gas Utility--Unlike electric utilities, gas utilities employment for construction must either be obtained from the local company or combined with that for other activities in the Operation Item (see below).
- Roads--Special roads may have to be built to serve the energy facility (in order, for example, to haul coal for a coal-fired ICES). To the extent that such roads are for the facility they cause employment. That employment can either be estimated from similar projects in the area, or an average \$60,000 dollars of construction per man year (6) can be divided into the estimated cost to approximate employment effects.

c. Operation Items

- Central Facility--Employment for a central ICES facility is a standard item in the direct operating cost estimates. There is at present no general relation such as kilowatt-hours/year/employee, because of the wide range of technology and equipment options from which an ICES can be designed. Designs for a few demonstration systems indicate the approximate range, however, is 10 to 20 million kilowatt-hours/year/employee (7,8), excluding maintenance of distribution and end-use equipment.
- Administration--This item results for an energy system supplying a variety of customers. The administration costs, like those for other costs, should be included in a direct economic analysis. Employment can be estimated from the costs, using an appropriate factor obtained from the analysis.
- Monitoring and Regulation--Public authorities may monitor the operation of an energy system such as ICES. The employment for monitoring can best be estimated by the authorities that are involved. Regulatory employment occurs within the region due to increased workloads brought by additional electrical or gas service. An estimate of employment in regulation per energy unit can be determined by dividing total personnel in the state utility commission (obtained from the state office) by energy produced by regulated utilities in the state. This ratio can be used as a multiplier to approximate employment due to regulation of the energy system.
- Electric Utility--Employment for electrical operations varies from one utility to another, and so the best numbers are those from the utility serving the project. On a national average, approximately three of every four employees of electric utilities are assigned to operation and maintenance or one employee for each yearly sale of 14 million kilowatt-hour (5). On this basis, demand for electricity is translated to an employment estimate by dividing yearly consumption by the factor 14 million kilowatt-hour/year.

- Gas Utility--For this item, as for the Electric Utility above, local information provides the best estimate. However, on a national average, gas utilities employ one person for each 90 billion Btu (90 million cubic feet) of gas sales (9). Total gas consumption of the energy system divided by 90 billion Btu indicates the gas utility employment generated by the energy system. This estimate includes planning and construction (as well as operation and maintenance), so that if separate numbers were obtained for those activities earlier, they should be subtracted.
- Oil Delivery--Local delivery from bulk suppliers causes increased employment that is best approximated by contacting local suppliers. The national average estimate is 1.8 trillion Btu/employee (10).
- Coal--Employment for coal delivery is somewhat difficult to quantify, but may be approximated according to these ratios:

Rail (long haul) -- 150 billion Btu/employee (11,12)

Truck (short haul) -- 1.4 trillion Btu/employee (13)

Information on the delivery of coal obtained locally may show some variation from the figure for truck haulage and should be used when possible.

The accumulation of employment estimates for the planning, construction, and operation stages completes Step Three. At this point primary employment resulting from the energy facility is ready to be used to calculate additional employment impacts.

Step Four--Employees' Spending and Demands for Services. This step is used to assign the effects of employment to the local or to the regional area. Primary employment impacts from the previous step are distributed according to the analyses of Steps One (part d) and Two. Employment will result in additional local residents if the community offers housing within a price range that can be afforded and provides amenities comparable to surrounding communities. Data on increases due to new development, either in the local area or in similar communities nearby, supply the basis for

estimating how employment will contribute to local population. Remaining employment should be assumed to be regional. From these estimates the following table can be completed.

Employment by Project Stage and Location (Many years)

	<u>Planning</u>	<u>Construction</u>	<u>Operation</u>
Local			
Regional			
Total			

This table, when filled in, supplies the basis for the next calculations.

Step Five--Calculate Secondary Employment. Secondary employment arises from employment identified in Step Three as a consequence of employees' spending. The general means of estimating secondary employment are to use multipliers that account for growth in secondary employment relative to growth in primary employment. For example, a multiplier of 0.5 means that an additional one job results from creating two primary jobs, as the first employees spend wages in the community to pay for goods and services. It is, therefore, a straightforward exercise to calculate secondary employment, once primary employment and the employment multipliers are established.

One method to calculate employment multipliers is derived from local income/sales relationships (14), and consequently depends on the determination of primary income (income generated from primary employment), sales in the area, and (secondary) employment relative to sales. This method provides an estimate of the jobs in local retail sales and service. Although other secondary employment (e.g. from new housing construction) may also result,

sales and service employment includes an adequate approximation of secondary effects. The information for secondary sales and service employment multipliers must be obtained from local sources or estimated from regional or state data. The items are:

- Employment for new project
- Personal income from new project
- Income for area
- Retail sales and service volume
- Employment in sales and service

The calculation for a new project is:

$$\begin{aligned} & (\text{Personal income from project}) \times \frac{(\text{Retail sales and service})}{(\text{Personal income for area})} \times \frac{(\text{Employment in sales and service})}{(\text{Retail sales and service})} \\ & = \text{Secondary employment in sales and service generated by personal income (primary employment) from project.} \end{aligned}$$

Where available, data that directly relate retail sales and service employment to personal income may be used.

Total secondary employment may be modified by a factor known as the capture rate. This factor is applied to account for the proportion of impacts expected in any one locale. So, for instance, if the capture rate for a community is 0.6, that means that 60 percent of the impacts will occur within the community and 40 percent will take place in surrounding areas or elsewhere. The capture rate is analogous to local/regional employment estimates determined above in Step Four and should be derived in the same manner. As a consequence, impacts are described as local or regional according to proportions of the capture rate.

Multipliers vary according to the phase of development. Generally, operation has higher multipliers than construction, and construction multipliers are larger than those for planning. These relations result from the wider demands for goods and services that accompany later stages of developments. Similarly, the duration of secondary impacts varies with primary ones, and so the multipliers are relative to and controlled by characteristics of the primary employment profile. It is necessary to describe secondary employment by the features derived from the primary employment pattern, and results must be reported so as to identify the duration and size of the secondary effects.

The resulting table will appear something like this:

Secondary Employment: Sales and Service (Many years)

	<u>Planning</u>	<u>Construction</u>	<u>Operation</u>
Local			
Regional			
Total			

Step Six: Determine Total Employment. Total employment data are the summaries of Steps Two, Three, and Five. The following table should be completed using information generated earlier.

Total Employment
by
Source, Stage of Development and Location
(Many years)

	<u>Planning</u>	<u>Construction</u>	<u>Operation</u>
Local			
Energy Facility			
Attracted User			
Regional			
Energy Facility			
Attracted User			
Total			

In addition to categories listed in the table, it may be of interest to separate public from private employment, particularly if public employment is associated with municipal costs. Such distinctions can be drawn from the information used to complete earlier steps.

This completes the analysis of employment impacts from an energy system.

Phase Three: Fiscal Impacts

Fiscal impacts to local government are the revenues and the costs of services associated with a new energy system.* They fall into two categories: primary impacts of the facility (for example: taxes paid on equipment,

*These impacts are indirect effects resulting from planning, construction, and operation of a privately owned energy system. If such system is publicly owned, revenue and cost of operation are calculated in a direct economic analysis by traditional methods. Public ownership, for example, implies that government revenues take the form of charges similar to those of private development and that costs include capital, operation, and maintenance, whereas the private ownership discussed here implies revenues are derived from taxes.

costs of extending water service) and secondary impacts from employment due to the energy system (for instance: local taxes paid by ICES employees, the employees' needs for schools, police, etc.). Fiscal impacts are estimated from Steps One, Two, Six, Seven, Eight and Nine of the diagram in Figure 3 (see Figure 5 following). The steps to ascertain fiscal impacts are analogous to those used to estimate employment, and the analysis proceeds in a similar manner.

The two fiscal impacts, revenue and cost of services, are determined from characteristics of the energy facility (Step 1). Since the form and magnitude of impacts are established by the conditions (i.e. ownership, taxing policy, revenue structure, regulatory policy, and public planning process) discussed previously, the description of those impacts depends on conditions under which the facility is planned, built, and operated. Fiscal impacts also result from uses attracted to share the energy system (Step 2) and from employment (Step 6), through taxes and demands for public services. Each of these steps and its fiscal effects (Step 7, Step 8, and Step 9) are dealt with in the next section.

FIGURE 5

DIAGRAM OF FISCAL IMPACTS FROM ENERGY FACILITY

Step One--Identify Characteristics of the Energy Facility that Affect Revenue and Cost of Public Services.

a. Define the ownership and responsibility for each stage of development and the taxing policy, revenue structure, regulatory process, and public planning process in the local area. From these ascertain the kinds of revenue and services associated with the energy facility.

b. Determine the tax rates and methods of computation for the municipality and for other taxing authorities. The only way to obtain pertinent data is to consult the local offices.

Taxing procedures fall into a few general types. Both municipal governments and school districts often levy a separate tax for their own specific purposes. Two basic methods may be utilized to calculate this tax for each taxing district. (Probably the same one will be utilized in any specific geographic area.) Under the first method, the expected assessed valuation is multiplied times the local tax rate, expressed in dollars per hundred or thousand of assessed valuations. (In cases where the tax rate is expressed in mills--one thousandth of a dollar--a conversion to dollars is simple: 78 mills is equal to a tax rate of \$78.00 per thousand or \$7.80 per hundred dollars of assessed valuation.) Second, the market or true value can be multiplied by the equalized tax rate, where the equalized tax rate is a figure developed by higher levels of government to deal with the inequities of assessment. In many instances the municipality and the school district will utilize the first method while county or state governments may utilize the second, as it allows comparison between different practices of assessment in differing communities.

It is essential that the method utilized in the local municipality be followed, even though the assessed value of the property may be less than the market value. The concern here is not to develop equalized tax returns for the sake of comparison between different geographic areas but to determine the actual fiscal return the community will receive. Examples of these different methods are:

Given Assessed Value and Tax Rate:

<u>Assessed Value</u>	<u>Tax Rate</u>	<u>Total Revenues</u>
\$20,000,000 Municipal	1.00/100.00	\$200,000
\$20,000,000 School District	3.00/100.00	\$600,000

Given Market Value and Equalized Tax Rate:

<u>Market Value</u>	<u>Equalized Tax Rate</u>	<u>Revenue</u>
\$25,000,000 Municipal	.80/100.00	\$200,000.00
\$25,000,000 School District	2.40/100.00	\$600,000.00

Given Market Value, Equalization Ratio, and Local Tax Rate:

<u>Market Value</u>	<u>Equalization Ratio</u>	<u>Local Tax Rate</u>	<u>Revenue</u>
\$25,000,000 Municipal	.80	1.00/100.00	\$200,000
\$25,000,000 School District	.80	3.00/100.00	\$600,000

In some cases local governments tax commercial or industrial property on the basis of income. If such a method is indicated, the following example approximates the procedure that will be required.

<u>Annual Rent per Ft.²</u>	<u>Number of Ft.²</u>	<u>Gross Income Multiplier</u>	<u>Equalized Tax Rate</u>	<u>Total Revenue</u>
\$3.00 Municipal	30,000	6.50	.80/100.00	\$ 4,680
\$3.00 School District	30,000	6.50	2.40/100.00	\$14,040

Providing an economic rent can be established, this method may be of particular importance in specific cases where it may be possible to negotiate a lower tax rate.

In addition, certain communities exact another tax of importance, the business property tax. Taxes may be levied on capital equipment including such items as machinery, inventory, and office furniture. The local assessor's office will be able to assist in determining what is to be taxed and what assessment practices to be followed.

c. Determine appropriate value for the taxable items identified in Step One under Employment. For example, the capital cost of an energy facility is likely to be the value that is used to compute taxes. These costs are part of the economic analysis for an energy system and should be obtained from it.

d. Identify public services (e.g. water) required by the facility.

Step Two--Estimate Uses Attracted by the Energy System and their Taxable Assets and Demands for Services. As discussed under Step Two of the Employment section, the question of whether industries or commercial facilities are built in the local area primarily to take advantage of an energy system is left to the discretion of the evaluator. In the case where a use is brought into the community by an energy facility, fiscal impacts from that use are to be estimated. The procedures for the estimation are the same as those described for the facility itself. Consequently, instructions in Step One above apply to the attracted user also, as does the discussion following in Step Seven.

Step Seven--Determine Primary Fiscal Impacts

Revenue

Calculate revenue according to the methods of assessment, revenue structure, ownership, and taxing policy identified earlier. These items

should be considered:

- Central unit and building
- Distribution equipment
- Dispersed units (furnances, air conditioners)
- Electric utility
- Gas utility
- Oil supplier
- Railroad

Revenue should be identified by taxing authority (e.g. local, state), so that fiscal impacts can be assigned consistent with the employment impacts discussed earlier.

Cost of Services

Costs of services can be estimated using any of a large number of techniques. Reviews of current methods can be found in recent publications (15,16), and it is not the purpose to repeat them here. The suggested means of acquiring cost-of-services estimates is to go directly to the departments of municipal (and regional and state, if applicable) government for their judgments on the additional services required by the proposed energy facility and its associated systems. (This method provides an adequate first approximation.) Costs of services should be estimated for the following items:

Planning

- Public planning to accommodate the energy system (e.g. zoning, utility extensions)

- Approvals of permits, applications, and plans
- Public hearings

Construction

- Public utilities
- Roads
- Inspection of facilities

Operation

- Provision and maintenance of utilities
- Road repair
- Monitoring of facilities
- Regulation

These items should be described according to expected costs by year. So, for example, construction may entail one-time expenditures, whereas operation implies continuing costs to the public sector. The present value or a similar measure which allows comparison of discounted cash flows can be used.

Step Eight--Determine Secondary Fiscal Impacts

Secondary fiscal impacts are caused by the employment of Step Six and are addressed by the following procedures:

- a. Estimate employees who will live in the local community. This estimate is made from a comparison of the cost of housing and expected pay scales of employees and is identified in Step Six. Migration to the community is possible for those employees who can afford housing costs (which amount to about 25 percent of earnings). The percentage of those households which will move to the host community cannot and should not be established by the use of any national standard as they remain idiosyncratic in nature. Current migration rates into the community which result from the

construction of industrial facilities should be examined. If none has been built, then migration rates into similarly located communities should be used and, failing this, a migration rate into the community should be established, using school or other local censuses as a basis.

b. Determine total population associated with employment. The average number varies by type of employment and by labor force, and local demographic data should be used wherever possible. Across the nation there are approximately three persons per household (17) and this multiplier may be used in the absence of better information.

c.* Determine per capita revenue to municipal government. Revenue is dependent on tax rates and taxable property. Both these are specific to the locale and should be obtained from local officials.

d.* Determine per capita costs of public services. These data are simply the municipal budget expenditures divided by community population and are readily available from the city office.

*A recent study (15) presents four methods for determining fiscal impacts of residential uses. They are:

Per Capita Multiplier Method - used to ascertain average costs, where service infrastructure bears a close relation to service demand. Typically applicable to mid-size, established suburban areas or second-order cities.

Case Study Method - especially important for areas with significant over-used or under-used service capacities requiring disproportionate amounts of expenditures. Often applied to older or larger cities or smaller rapidly growing cities.

Service Standard Method- concerned with the problem of a population increment in moderately growing suburbs or cities and used to estimate costs of servicing the increment by categories of services.

Comparable City Method - used in situations similar to the Case Study Method, it determines expenditure ratios by population size and growth rate and is sensitive to economies and diseconomies of scale and patterns of growth.

A simple adaptation of the first technique is suggested in c and d. For more detail, the reference should be used.

e. Combine a, b, and c to find revenue expected from employment brought by the energy facility. Employees in local community (households) x People/Household x Revenue/Person = Revenue.

f. Combine a, b, and d to find public costs of services associated with employment of the energy facility. Employees in the local community (households) x People/Household x Costs/Person = Costs.

The totals from e and f are added to those for attracted uses (if applicable) to produce total secondary fiscal impacts resulting from the energy facility.

Step Nine--Estimate Total Fiscal Impacts

Total fiscal impacts are the summaries of Steps Seven and Eight. The data from those Steps are used to complete this table.

TOTAL FISCAL IMPACTS BY SOURCE, STATE OF DEVELOPMENT, AND LOCATION

	<u>Planning</u>		<u>Construction</u>		<u>Operation</u>	
	<u>Revenue</u>	<u>Costs</u>	<u>Revenue</u>	<u>Costs</u>	<u>Revenue</u>	<u>Costs</u>
Local						
Energy Facility						
Attracted User						
Regional						
Energy Facility						
Attracted User						
TOTAL						

Note: Each item should include a time interval. Present values or levelized annual values for costs and revenue can be used for aggregation.

This completes the analysis of fiscal impacts from an energy system.

Phase Four: Evaluation

The issues for which an indirect economic analysis is pertinent form the bases by which to evaluate energy systems. These issues are:

- Should the municipality encourage or participate in integrated community energy systems (ICES) and in other innovative energy technologies.
- What are the expected distributions of costs and benefits.
- How does ownership affect various interests in the community.

The evaluation phase is used to address these questions from the results of employment and fiscal impact analyses. It offers the opportunity to compare alternatives in view of community concerns and to identify changes that might improve the magnitude and distribution of benefits.

The evaluation phase deals with two general measures of indirect economic impacts. The first is the performance of a single energy system. By this measure, additional employment is judged to be either significant or unimportant, and the revenue from the system is compared to cost of services. Also, employment can be related to fiscal impacts, so that, for example, the energy system might be used as a mechanism to translate public expenditures into employment. The employment and fiscal impacts from the energy system can be used to determine the net benefit or the net burden to the community and therefore to decide whether the system will be supported by local interests.

The second measure is the comparison of several energy systems to ascertain which alternative yields the most positive indirect impacts. This measure offers a wider opportunity of selecting a good system for the community than does the single-system measure and is the preferred method

of evaluation. The comparison makes use of judgments similar to those for a single system (e.g. the significance of employment differences between systems); in addition, the basis of choice is similar (net relative benefit or burden). The comparative measure corresponds to a recognition that energy systems are means of meeting demands for services such as heating and lighting and that there may be several options for providing those services.

The evaluation phase also is used to explore potential changes in the conditions affecting the planning, construction, and operation of each energy system. Because employment and fiscal impacts have been tabulated so as to preserve information on the source, location, and development stage, they can be identified with conditions in Phase One that, if altered, might cause significant differences in the results. The evaluation can indicate what kinds of changes in initial conditions may be important, so that they can be tested. Specifications for new conditions are applied to Phase One, and the analyses of Phases Two and Three are then repeated. Thus, the Evaluation Phase accommodates an iterative approach to determining indirect economic impacts. (See Figure 1)

SUMMARY

The analysis of indirect economic impacts is undertaken to supply useful information on which to make judgments about the desirability of new development alternatives. In order for the analysis to be effective, it must include several considerations (origin of impacts, ownership, analytical boundaries, features of the energy system, affected parties,

and stage of development) defining how much and where indirect effects are to be expected. In addition, there are conditions of government such as taxing policy, revenue structure, regulatory policy, and public planning process that set the framework within which analytical distinctions can be made.

The procedures that have been described in this chapter are designed to follow a four-phase method beginning with qualitative factors that determine the utility of analysis (Phase One) and then examining employment (Phase Two) and fiscal impacts (Phase Three). The final phase (Phase Four) is the point at which analytical results enter the decision-making process, either to provide a standard of comparison or to indicate where important improvements might be made.

The utility of the analysis lies in its comprehension of relevant qualitative factors and their coordination with quantitative results. The central questions for which this analysis is meant to provide information, and the responses to these issues, are:

- Should the municipality participate in integrated community energy systems (ICES) and in other innovative energy technologies. The method includes patterns of ownership and participation, tax policy, and regulation and planning, as variables in performing the analysis. These variables allow a thorough investigation of the modes in which a municipality might participate, and the results reflect the measure of incentives to that participation.
- What are the distributions of costs and benefits, and which ones are preferable. The methodology separates impacts according to origin, location, and stage of development. Thus, it provides distribution of impacts for the evaluation of indirect economic benefits and costs.

- How can ownership be structured to serve various interests in the community. This issue is dealt with by the iteration built into the analytical method. Ownership is not only a precondition to performing analysis; it is also indicated by the evaluation, and adjustment can be made accordingly. The method directly addresses how to establish an ownership arrangement that serves community interests.

The evaluation of indirect economic impacts is a process by which pertinent quantitative estimates can be used to determine the worth of local public encouragement of integrated community energy systems. The answers to the questions for which analysis is designed rest partly on an understanding of the impacts of technology, partly on an understanding of the community, and most importantly, on a good synthesis of the two.

CHAPTER III: INDIRECT ENERGY IMPACTS

INTRODUCTION

Just as there are indirect economic effects from a new facility, so there are indirect energy impacts. These latter impacts occur because energy is needed to produce and deliver energy. Because there are energy losses at each stage in the processing of natural resources and delivery of final energy forms, the energy that must be extracted is more than energy that is finally consumed. For example, approximately five gallons of petroleum must be pumped from an oil well to supply four gallons of gasoline to an automobile. The difference between requirements for natural resources and those for final fuel form are the indirect effects that will be described further in the sections that follow.

Energy used in the houses, stores, and factories of consumers is the result of series of processes that transform natural resources into useable fuel and energy forms. An idea of these series can be obtained from Figure 6, which shows typical energy systems for the United States. Through technological operations like those listed in the flow chart, the demands for energy are satisfied from several natural sources. In the event that traditional domestic resources are no longer adequate to supply all the energy demands of consumers, either foreign imports, supplemental domestic supplies, or readjustment of demand must be used to match production with consumption of energy. The tracing of how resources go to satisfy energy demands indicates the resource effects of energy systems and permits an examination of alternative ways to compensate for a lack in the availability of traditional resources.

FIGURE 6

TYPICAL U.S. ENERGY SUPPLY SYSTEMS

The accounting of indirect effects through tracing energy processes identifies which resources are needed to supply energy, and so addresses how substitutes of foreign and domestic supplies or adjustments in demand will impact natural resources. If, for example, domestic oil and gas reserves are insufficient to maintain an adequate supply, then those systems that depend either directly or indirectly on oil and gas are only as reliable as combined foreign and domestic suppliers. Thus determination of indirect energy impacts allows an understanding of resource dependency and an estimate of system reliability.

Indirect energy impacts also contribute to comparisons of system effectiveness. Total energy required to support end uses, the sum of direct and indirect energy effects, is one measure of system effectiveness. By this measure, different energy systems can be compared on the basis of their resource impacts, which can be used to judge the relative worth of one system versus another. Indirect effects comprise a necessary part of a full evaluation of energy options.

In the consideration of an integrated community energy system (ICES) as an alternative to conventional energy supply, the issues of reliability and efficiency are important criteria for establishing worth both to the community and to the nation. If fuels are interruptible or scarce, reliability may become a primary standard, and an ICES that provides better reliability may therefore be evaluated as a means of protecting vital energy functions. In the longer term, improved efficiency translates to reducing the use of natural resources, from which national benefits, in terms of security of supply, international trade, and lower impacts on the

environment, may result. Consequently, an ICES that is more efficient than conventional systems is a method of contributing to the achievement of national goals in conserving natural resources and in continuing economic health. The integrated system can be measured by whether it enhances reliability and efficiency, and indirect energy impacts are part of the analysis that is required to answer such issues.

The purpose of this chapter is to describe procedures by which indirect energy impacts can be determined and used to address choices among energy alternatives. The procedures are based on tracing energy supply from extraction through the processing sequence to final consumption (Figure 6) and estimating energy that is used and lost along the way. Indirect impacts are computed in units of natural energy resources required to supply a demand for fuel and electricity. Relation between resource requirements and final demand takes the form of multipliers, so that the direct use of energy can be quickly converted to resource units, and energy systems can be compared on that basis. Such comparisons are constructed in order to examine the issues of reliability and efficiency in the evaluation of ICES. Procedures described in the following section are means of preparing and presenting information that is useful in selecting energy systems.

ANALYTICAL METHOD

The method for estimating indirect energy impacts of an energy system is divided into five steps. The steps consist of ascertaining direct energy consumption, describing and characterizing the supply processes, summarizing the process series, and determining resource effects that transform direct energy consumption into resource impacts. They apply both to ICES and to the conventional systems against which ICES

is compared. These steps are illustrated in Figure 7, a schematic showing how the process series is formed and used to determine resource effects.

- Step 1 consists of ascertaining direct energy demand by the energy system. Direct energy is normally the fuels and electricity purchased by consumers and may include several energy forms.* For example, direct fuels for an ICES include all fuels purchased by the community to provide energy services. Typically, these are all fuel inputs to the central ICES plant (including electricity from the utility grid if the ICES is grid-connected), as well as any individual fuel purchases for energy services not provided by the ICES. The first step in computing indirect impacts is to obtain the amounts of fuel and electricity required and to convert them into energy units. This sets the foundation for constructing the process series.
- Step 2 is description of the process series for each energy form. For example, fuel oil may be the result of extraction from an oil well in the United States, refining at a coastal refinery, and transportation by tanker and pipeline to final destination. There may be more or fewer steps than those indicated in Figure 7 (as in the example, which has no conversion process), and series may vary according to energy form. This step defines processes, and the links between them, that comprise energy supply for the system.
- Step 3 is used to characterize each process in a series in terms of its energy inputs and outputs. Processes receive energy from earlier parts of the series and from purchases. An oil refinery, for example, receives crude petroleum and also purchased electricity. The lefthand arrows into each box of Step 3 (Figure 7), represent energy to be processed, whereas arrows into the tops of the boxes represent purchases of other fuels and electricity. Energy from the processes passes to the next stage (righthand arrows) and is consumed or lost (bottom arrows), completing an energy balance in each case; that is, energy in equals energy out. Usually, a standard size is employed for all processes.
- Step 4 is the summary of process series into characterizations of complete energy supply series. At this step energy into the series (lefthand and top arrows) is defined in units of natural resources (i.e. Btu of extracted fuels), and energy from the series is standardized according to previously selected process outputs.
- Step 5 connects energy supply with demand determined in Step 1 to obtain the resource requirements for the entire energy system. All energy characteristics of the system are presented as original resources needed to support final consumption. This step yields information to compare alternative energy systems on the basis of their impacts on natural energy sources.

*Under this assumption, energy from such sources as solar radiation or urban waste is treated as renewable and therefore is omitted from the accounting of direct energy requirements.

FIGURE 7.

SCHEMATIC OF METHOD FOR ESTIMATING INDIRECT ENERGY IMPACTS

NOT R denotes energy resources

The five steps just outlined are described in more detail in the sections that follow. They may be applied in conjunction with an analysis of direct effects, such as an economic calculation, for use in those cases where a previous study has not been done, and estimates can be constructed without depending on a second analysis. The following discussion is general in scope, so that the analytical method is applicable to ICES and to other energy systems with which it can be compared.

Step 1: Ascertain Direct Energy Characteristics

Direct energy demands are defined as the requirements for fuels and electricity at the points of end use. For example, a housing complex heated by natural gas might require 100,000 cubic feet of gas per unit per year. The information needed to describe direct effects includes the types, quantities, and heating values of energy forms delivered to the consumers.

Table 2 lists common fuels and their heating values. Oil products vary in heating value and in the operations needed to refine and deliver them. Natural gas may be supplemented or replaced by synthetic gas and by other fuels. The heating value of coal is a measure of its organic matter, which differs by source. The heating value of electricity is a constant 3413 Btu/kwh, but the load profiles determine how demand will be met (i.e. by baseload, intermediate, or peaking power plants). Direct characteristics of Table 2 set the basis for deriving indirect effects by supplementing cost and engineering results.

For many projects kinds and quantities of fuel and electricity are estimated in the economic analyses. Otherwise direct energy demands must be developed from investigation of what buildings and activities will be

TABLE 2

DIRECT FUEL AND ELECTRICITY INFORMATION

<u>Fuel</u>	<u>Heating Value (Btu*)</u>
Oil	
Gasoline	125,000/gal.
Distillate	139,000/gal.
Residual	150,000/gal.
LPG	96,000/gal.
Gas	
Natural	1,032/std. cu. ft.
Synthetic	
Low-Btu	100-200/std. cu. ft.
Intermediate-Btu	300-650/std. cu. ft.
High-Btu	900-1,050/std. cu. ft.
Coal	
Anthracite	26-29 million/ton
Bituminous	24-30 million/ton
Sub-bituminous	17-22 million/ton
Lignite	11-15 million/ton
Electricity	3,412/kwh

*A Btu (British Thermal Unit) equals 0.252 kilocalories

served and from analogies with similar, existing cases.

Generally, the necessary data fall into three categories. First, the demand for heat or other energy services must be ascertained. For instance, the normal requirement for warm room air in a typical building of the northern U.S. is approximately 80 thousand Btu per year per thousand square feet of floor space. (There are additional demands for hot water, air conditioning, refrigeration, lighting, appliances, etc.)

The second category of data is the efficiency with which final demands are met. For example, furnances are between 50 and 80 percent efficient in converting fuel into warm room air; that is, for every 100 Btu of fuel they deliver 50 to 80 Btu of actual heat, depending on furance design and maintenance. The efficiencies of end-use devices vary according to their functions and applications and must be determined for each case.

The third data category is the type of fuel used. Information of this type can usually be established from recent practice for conventional energy systems and from the conceptual design of integrated community energy systems. These three categories, then -- final demand, conversion efficiency, and fuel types -- form the data needed for an estimate of direct energy characteristics.

An ICES may be able to improve conversion efficiency and thus save fuel, and it may also offer an opportunity to change fuel types. Although final energy demand is constant no matter what system, estimation of direct demands for an ICES must be coupled with an understanding of how the system works in order to convert demand into fuel consumption. The integrated system, consequently, requires more thorough analysis than conventional alternatives, and a source such as the companion volume to this guidebook* should be consulted.

*Guidebook on Integrated Community Energy Systems, Argonne National Laboratory.

Direct energy consumption for a development is the sum of demands for units comprising the development. Direct energy should be listed as illustrated in the following table.

<u>Energy Form</u>	<u>Amount</u>	<u>Heating Value</u>	<u>Heating Equivalent</u>
Fuel Oil (specify type)			
Natural Gas			
Coal			
Electricity ¹			

¹Total electric consumption minus that provided internally (e.g. by ICES)

This description identifies direct energy needed to supply the development.

Step 2: Describe Process Series

Process sequences are series of steps through which energy is transformed from natural resource to final delivered fuel form. Depending on the fuel and on the end use system, there may be anywhere from a few to many steps in a complete sequence. In general, there are extraction, process, transportation and conversion phases; and there may be several different operations in each phase for both resources and intermediate products.

The major indirect effects are due to conversion of energy from one form to another. Electrical generating plants, refineries, gas liquids plants, and synthetic fuels facilities are primary points at which energy losses occur. As a result, analysis of the process sequence is

most efficiently applied to determining the conversion facilities involved in providing fuels to the project under investigation. For example, it is important to identify the kinds of generating plants expected to supply electricity and the fuel sources for those plants.

Description of process series for fuels and electricity supplies is accomplished by questioning local suppliers. For example, electric utility staff can list sources of their energy supplies and the mix of fuels used to generate electricity; approximate modes and distances for transportation can usually be obtained, as well. Similarly, gas utilities and oil distributors are able to explain how their fuels are processed and delivered, and other supply series for fuels such as coal can be estimated. Specific information on the extraction and initial processing of energy resources is often unknown (e.g. exactly which well supplies oil or gas), so that average process descriptions may be the best available.

Energy systems are described by their process series, once they have been determined from local utilities, oil distributors, and suppliers of coal or other fuels. Table 3 lists process series for some typical energy supply systems and illustrates the kind of information that is needed for descriptions. (In the event that an actual series corresponds closely to a typical one as shown in the table, the typical sequence should be substituted for it. Numerical data for typical series are provided later.) The table indicates energy intensive stages in the series; and although there may be other items in some series, the extraction, processing, transportation, and conversion stages can be used to include significant operations in almost all cases.

TABLE 3

DESCRIPTIONS OF TYPICAL ENERGY SUPPLY SYSTEMS

<u>System</u>	<u>Resource</u>	<u>Extraction</u>	<u>Processing</u>	<u>Transportation</u>	<u>Conversion</u>
Distillate Oil* (Heating oil and diesel)	Petroleum	Production (current domestic average)	Refining (full-stage refinery)	Pipeline of 600 miles (300 miles as crude, 300 miles as product); truck delivery	None
Residual oil*	Petroleum	Production (current domestic average)	Refining (partial refinery)	Crude pipeline of 300 miles, tug and barge delivery	None
Natural Gas	Gas	Domestic production (current average)	Liquids removal (typical plant)	Gas pipeline	None
Coal	Coal	Underground mining (typical Appalachian mine)	Cleaning (current average)	Rail for 500 miles	None
Oil from Coal	Coal	Underground mining (typical Appalachian mine)	Liquefaction (catalytic hydrogenation)	Rail for 300 miles (coal); tug and barge (oil); truck delivery	Refining (full-stage refinery)

Table 3

Descriptions of Energy Supply Systems (continued)

<u>System</u>	<u>Resource</u>	<u>Extraction</u>	<u>Processing</u>	<u>Transportation</u>	<u>Conversion</u>
Gas from Coal	Coal	Underground mining (typical Appalachian mine)	Gasification (Lurgi process)	Rail for 500 miles (coal); pipeline for distribution (gas)	None
Oil from Shale	Oil Shale	Underground mining	Above ground retorting (gas combustion process)	Pipeline for 500 miles (product)	Refining (full-stage refinery)
Oil-Fired Electricity	Petroleum	-----see Residual Oil above-----			Electrical generation
Gas-Fired Electricity	Gas	-----see Natural Gas above-----			Electrical Generation
Coal-Fired Electricity	Coal	-----see Coal above-----			Electrical generation
Nuclear Electricity	Uranium	Open pit mining	Milling, uranium fluoride produc- tion, enrichment, fuel fabrication	Truck (variable distances)	Electrical generation

*Oil supply systems described in this table are typical domestic examples. Many features of foreign oil supplies, a large contribution to the present energy pattern, vary considerably from these descriptions, particularly in the extraction and transportation stages. Nevertheless, energy characteristics of foreign and domestic supplies have been found to be quite similar, and so the domestic average will be used for all oil supply systems.

Characteristics of the process series indicate reliability and in some cases future cost trends for fuels. For example, petroleum shortages affect the availability both of oil and of oil-generated electricity and are likely to lead to price increases, whereas coal-based systems are less vulnerable to nondomestic interruption and cost escalation. Thus the qualitative aspects of fuel supply are important to estimation of how energy systems will compare in the future. Synthetic fuels and other sequences that rely on abundant domestic resources may deserve consideration on more comprehensive bases than current economic analyses. A determination of the sources and operations required to support fuel delivery yields information necessary to supplement current economic results.

Step 3: Characterize Processes

For each of the processes described in Step 2, an energy balance can be constructed. This balance consists of energy into and from the process and accounts for energy that is received for processing, purchased for operating the process, consumed, lost, and produced. The following figure illustrates the balance and the manner in which processes must be characterized:

FIGURE 8
ENERGY BALANCE

Generally, purchased fuel, a secondary input, is consumed during operation, and some of the raw fuel may be consumed or lost, as well. Product energy is then less than or equal to the raw fuel energy. The efficiency of a process can be approximated by comparing how much energy is produced to how much enters as raw fuel or as fuel and purchased energy. The procedures for such an accounting have been developed more thoroughly elsewhere (18-20); in summary, they consist of converting purchased items into energy equivalents and of careful determination of raw fuel and product characteristics. The raw fuel and product items have proven more significant than secondary energy for all fuel supply systems, so that if fuel supply (as contrasted with, for example, a solar heating system) is being studied, the process can be best described by more attention to losses or consumption of raw fuel than to consumption of purchased items.

Table 4 lists typical energy supply processes for which energy characteristics have been determined. These data apply to current (and for the synthetic fuels, projected) energy supply operations. In each case the process output is 1000 Btu, and therefore primary input of at least 1000 Btu is required. For those processes that consume or lose some of the raw fuel during the operation, primary input is greater than 1000 Btu; and the process efficiency can be computed by dividing 1000 by the primary input. In addition to raw fuel, each process is supported by purchased fuels and electricity that in turn depend on natural energy resources. Also, energy is used to make and move equipment, building materials, and all other parts of an energy system; and such energy has been computed using an input/output technique that accounts for both direct and indirect consumption.* The resource requirements have been determined and listed according to fuel type. Estimates shown in the table have been derived from national data, so that they represent average rather than specific situations.

Oil production, according to Table 4, requires an input of 1053 Btu of oil for every 1000 Btu output of oil. Thus the process efficiency is $1000 \div 1053$, or approximately 95 percent. There are secondary inputs of oil and gas (seven Btu each), coal (five Btu), and nuclear and hydropower (one Btu each). They total**21 Btu, in addition to the 53 Btu of oil lost during production. In summary, the oil production process requires 1074 Btu of resources to yield 1000 Btu of oil. The other processes in Table 4 are similarly characterized. These typical numbers apply to the processes listed in Table 3 and can be used for specific supply systems that correspond to them.

*See Reference 19, p. 203, for a full description of input/output analysis.

**Care must be taken in adding the heat equivalent (Btu) measure of different resources, since the uses of resources vary so that fuels are not wholly interchangeable. However, the Btu sums of different resources are discussed occasionally to illustrate the magnitude of indirect effects; and in those cases where indirect impacts are overwhelmingly attributable to one resource, summary approximations are used.

TABLE 4.

TYPICAL ENERGY CHARACTERISTICS FOR ENERGY SUPPLY PROCESSES
(per 1000 Btu Output)

<u>Process</u>	Primary Input (Btu)	<u>Secondary Inputs (Btu)</u>				
		<u>Oil</u>	<u>Gas</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Hydro</u>
Oil Production	1053	7	7	5	1	1
Distillate Oil Refining	1069	31	31	9	2	2
Residual Oil Refining	1069	16	16	4	1	1
Oil Transport	1010	8	8	4	1	1
Oil-Electric Generation	3048	21	21	20	2	2
Gas Production	1053	7	7	5	1	1
Gas Liquids Removal	1040	1	1	1	-	-
Gas Transport	1059	2	2	2	-	-
Gas-Electric Generation	3048	19	19	18	2	2
Coal Mining	1000	3	3	6	1	1
Coal Cleaning	1137	-	-	1	-	-
Coal Transport	1000	11	2	1	-	-
Coal-Electric Generation	3048	28	28	29	3	3
Nuclear Fuel Production	1266	11	11	25	5	5
Nuclear-Electric Generation	4338	17	17	39	6	6
Electrical Transmission	1099	15	15	13	1	1
Coal Liquefaction	1511	11	11	8	1	1
Coal Gasification	1876	7	7	6	1	1
Oil Shale Operation	1490	62	12	28	4	4

Source: Data taken from Reference 18.

Step 4: Summarize Process Series

This step comprises combination of the process characterizations developed in Step 3. A standard technique is to begin with the last process in the series identified in Step 2 and work backward to determine the initial resource requirements. For example, consider a series made of the two following processes.

They are linked into a series by converting the product of Process A to match the requirements of Process B. In this use Process A must produce 1100 Btu to satisfy Process B. Consequently, its energy balance must be increased all around by multiplying by 1.1 (1100 Btu/1000 Btu). The series then looks like this.

To obtain 1000 Btu of energy product from the series, 1320 Btu of raw fuel resource is needed initially, and an additional 32 Btu (22 Btu plus 10 Btu) of purchased or secondary energy is used. Also, 352 Btu of energy is lost or consumed in Processes A and B. The combined processes can be summarized by these numbers, which form an energy balance for the series.

For the typical series described earlier, the processes of Table 4 have been combined to form energy supply systems shown in Table 5. The combinations were constructed by proportioning the inputs of the Table 4 processes to fit the supply systems described earlier. So, for example, the distillate oil system consists consecutively of production, refining, and transport. According to Table 4, transport requires a primary input of 1010 Btu for each 1000 Btu of output; and therefore the characteristics of refining, that precedes transport, must be adjusted to produce an output of 1010 Btu. This is accomplished by multiplying the refining characteristics by 1.01 (1010 Btu divided by 1000 Btu), and results in a primary input to the refinery of 1080 Btu (1069 Btu times 1.01). Consequently the next earlier process of oil production must yield an output of 1080 Btu, causing the primary input to production, and thus to the system, to be approximately 1140 Btu (1053 Btu times 1.08). The secondary inputs are proportioned accordingly and then summed to produce system characteristics. The result of adjusting primary and secondary inputs is a characterization of the process sequences forming energy supply systems.

According to Table 5, conventional oil, gas, and coal systems all have similar primary inputs (1140-1160 Btu). This means that the process losses during oil, natural gas, and coal processing are of similar magnitude. The synthetic fuels likewise have roughly equivalent losses, as do the oil-,

TABLE 5

TYPICAL ENERGY CHARACTERISTICS FOR ENERGY SUPPLY SYSTEMS

(per 1000 Btu Output)

System	Primary Input (Btu)	Secondary Inputs (Btu)				
		Oil	Gas	Coal	Nuclear	Hydro
Distillate Oil	1140	47	47	18	4	4
Residual Oil	1140	31	31	13	3	3
Gas	1160	26	26	25	2	2
Coal	1140	14	5	9	1	1
Coal/Oil	1630	74	59	34	6	6
Coal/Gas	1990	37	19	22	3	3
Oil Shale/Oil	1500	71	20	32	5	5
Oil/Electric	3810	142	142	81	13	13
Gas/Electric	3880	73	73	62	7	7
Coal/Electric	3810	97	64	71	8	8
Nuclear/Electric	6040	86	86	175	31	31

gas-, and coal-electric systems. Nuclear-generated electricity, due to intensive upgrading necessary to convert uranium ore to nuclear fuel and incomplete fission of the fuel, requires significantly more Btu's of resource per unit of output than do conventional electric power systems.* Thus for each class of energy (i.e. conventional fossil, synthetic fossil, fossil electric, and nuclear electric) the primary input falls within a small range and can be approximated by a single number (e.g. 1150 Btu input for the conventional fossil fuels).

Secondary inputs to the systems vary more than do primary inputs. Among the conventional fuel systems, oil requires a total of 120 Btu in secondary inputs, while gas needs only 81 Btu, and coal requires the least of all, 30 Btu. Similar variations occur for synthetic fuels and for electric systems. As a result, the total resource impacts also vary among some systems in the same class. For example, each 1000 Btu of oil product has, besides the 1000 Btu contained in final output, 260 Btu (140 Btu of primary input and 120 Btu of secondary input) associated with it. On the other hand, 1000 Btu of coal production requires an additional 170 Btu (140 Btu of primary and 30 Btu of secondary) to support the final output.

Multipliers can be developed from these data. The multipliers are simply the ratios of total inputs (primary plus secondary) to outputs. So, for example, if a system has raw fuel requirements of 1200 Btu and purchased energy totalling 50 Btu to produce 1000 Btu of energy, the multiplier is 1.25 (1250 Btu divided by 1000 Btu). For every Btu of energy produced for final consumption, a total of 1.25 Btu of natural energy resources must be extracted. Thus resource requirements can be estimated simply by multiplying final consumption by the appropriate multiplier.

* However, recycling and breeder opportunities provide the nuclear fuel cycle with potential for reducing resource requirements manifold.

The typical systems have the multipliers shown in the following table.

TABLE 6
ENERGY RESOURCE MULTIPLIERS FOR TYPICAL ENERGY SUPPLY SYSTEMS

<u>Supply System</u>	<u>Multiplier</u>
Distillate oil	1.26
Residual oil	1.22
Gas	1.24
Coal	1.17
<hr/>	
Coal/Oil	1.81
Coal/Gas	2.07
Oil Shale/Oil	1.63
<hr/>	
Oil/Electric	4.20
Gas/Electric	4.10
Coal/Electric	4.10
<hr/>	
Nuclear/Electric	6.45

They range from 1.17 to 1.26 for conventional fuel systems and from 1.63 to 2.07 for synthetic fuel systems. The fossil-fueled electric systems all have approximately the same multiplier, 4.10, while current nuclear electric systems have multipliers of approximately 6.45.

Step 5: Determine Resource Requirements for System

A complete system is formed from energy consumption ascertained in Step 1 and from the process series developed in the last three steps. Demand

for energy (both kind and quantity) is coupled with supply characteristics to yield total resource requirements for the system. As an illustration, consider the following case.

Combination of the distillate oil series with consumption is just a matter of proportioning supply to meet demand. In this case, the system summary is:

Resource requirements can be listed separately, or as an approximation the proper multiplier can be used. For the example, 100 billion Btu of demand is multiplied by 1.26 to yield requirements of 126 billion Btu (most, but not all, from petroleum resources*). Thus, the complete system can be put together from information found in earlier steps.

* For the distillate oil series, 94 percent of all requirements are petroleum resources.

Determination of resource requirements allows comparison of one energy alternative with another on the basis of energy that is brought into the community from outside sources. An ICES that burns oil may be judged against a conventional system that uses oil for heating and that relies on electricity from a utility. Resource requirements provide the basis for examining whether one system is likely to provide better reliability or to be more efficient in using fuels than is another one.

For the comparison it is convenient to prepare tables listing energy alternatives and their resource requirements. A tabular form is illustrated below.

ENERGY RESOURCE REQUIREMENTS

FUEL	ANNUAL FUEL CONSUMPTION	ENERGY RESOURCE REQUIRED				
		OIL	GAS	COAL	URANIUM	HYDRO
COAL						
OIL (specify type(s))						
ELECTRICITY (from grid)						
NATURAL GAS						
OTHER						
TOTAL ENERGY RESOURCE REQUIRED						

In addition to a tabular listing, a simple bar chart is recommended as a visual aid. The chart is prepared by plotting the tabular data for each alternative. With the tabular and graphical summaries, reliance on different energy resources and total requirements can be examined for each alternative.

Establishing comparisons of resource requirements among system alternatives completes the analytical procedures.

SUMMARY AND CONCLUSION

The analytical method to estimate energy resources needed to satisfy final demands includes five steps. They begin in Step 1 with definition of the expected kinds and quantities of energy demand (which may be obtained from direct analysis) and then proceed in Step 2 to description of process series forming energy supply. The third step is to derive an energy balance for each process in the series. The balances are combined in Step 4 to determine supply system summaries, and in the final step supply is matched to demand so that the resource requirements for a complete energy system can be obtained.

Resource requirements (the quantities of natural energy resources, normally measured in heat equivalents e.g. Btu, necessary to meet final demand) are a basis for comparing alternative energy systems. They provide measures of the efficiency with which a system uses natural resources and indications of which resources are affected. Consequently, those decisions that rely on an understanding of how much and what kinds of resource impacts

are likely to occur benefit from the results of this analysis. Two criteria for consideration in selecting an energy system are:

- Fuel reliability. Due to its accounting of the energy resources required, the analytical results aid in choosing those systems that are less dependent on scarce or otherwise vulnerable resources.
- Efficiency. True measures of efficiency are those of the resource requirements of complete energy systems (rather than, for example, the operating efficiency of a subsystem). Accordingly, the identification of total resource effects aids in comparing efficiencies of alternative systems.

The results contribute to two of the points by which selection of energy systems are made.

Integrated community energy systems are potential means of achieving energy conservation goals. To further the evaluation of whether integrated community energy systems provide better supply reliability or more efficient use of energy, the analysis described in this chapter contributes to a full accounting of energy characteristics. It permits a comparison of the energy factors influencing selection of ICES or of conventional alternatives.

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