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METHODOLOGIES FOR COMPREHENSIVE COMMUNITY ENERGY MANAGEMENT PLANNING

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I. Comprehensive Community Energy Management (CCEM) Program

Prompted by recent fuel shortages and fluctuations in the price of energy, decision makers at all levels of government and in the private sector have come to appreciate the need to minimize the dependence of their operations on nonrenewable energy sources. The potential applications and benefits of energy planning and management have become increasingly apparent to rural towns, municipalities, counties, and regional bodies. However, the efforts of those that have ventured into this field have been constrained by inadequate reserves of trained technical personnel, a lack of adequately demonstrated methodologies and tools, and limited financial resources. In order to address these barriers to community energy conservation efforts, the U.S. Department of Energy (DOE) has established the Comprehensive Community Energy Management (CCEM) program. The role of CCEM is to provide direction and technical support for energy conservation efforts at the local level.

Experience with successful housing, transportation, and environmental programs has indicated that in order to be truly effective, energy programs must be developed, administered, and evaluated within a comprehensive planning and execution framework. Accordingly, specific CCEM program objectives are to:

- Develop, test, and evaluate:
  - detailed approaches for establishing appropriate municipal frameworks and management organizations to conduct effective energy planning and management.
  - specific methodological tools for development of local long-term energy management plans based upon preparation of community energy audits, formulation of energy objectives, and identification and assessment of conservation alternatives.
- Prepare information materials describing comprehensive community energy management methodologies and application experiences in formats designed for dissemination to specific target audiences.
- Promote and facilitate the actual implementation of community energy management plans through incentives, and technical and financial assistance to localities.

In its role, the CCEM activity serves as an evaluating and synthesizing mechanism for diverse community energy conservation research and demonstration efforts conducted within DOE, by other federal agencies, by academic institutions, and at state and local government levels. Strategies and options resulting from these efforts which are realistic and potentially effective approaches to community conservation of nonrenewable energy resources are incorporated into CCEM case study and demonstration activities for testing.

Communities vary in terms of size, economic base, climatic region, level of development, governmental structure, and relative experience with energy related programs. Recognition of this fact is implicit in the program plan strategy for CCEM. The program to date has included project efforts to develop combinations and variations of community energy planning and management tools applicable to communities of diverse characteristics. This paper describes the salient features of some of the tools and relates them to the testing program soon to begin in several pilot study communities. For the sake of brevity, the other half of the pilot study testing -- namely, appropriate municipal frameworks and management organizations to conduct energy planning and management -- will not be treated to any significant extent here.

II. CCEM Methodologies

Several methodologies were developed to meet the immediate objective of energy planning in a specified locality. The approaches taken have been generalized, however, for possible application in similar circumstances elsewhere. Two methodologies discussed here that arose within such an actual planning context are taken from DOE-sponsored projects in Clarksburg, West Virginia[1] and the proposed new capital city for Alaska.[2]

Energy management in smaller communities and/or communities with limited funding and manpower resources has received special attention. One project[3] of this type developed in general methodology that emphasizes efficient ways for small communities to reach agreement on local energy problems and potential solutions; by this guidance, the community is led to understand where it should concentrate its efforts in subsequent management activities. The other project[4] discussed here concerns rapid growth of either a new or an existing community that could easily outstrip the management resources available locally. In addition to merely coping with the impacts, the methodology strives to enable the community to seize the opportunity for energy conservation through integrating the design of its energy systems and its development pattern.

The fifth and last methodology included in this discussion is the result of a substantial project whose express purpose was the creation of generally applicable tools for comprehensive community energy planning. Analytic techniques for two distinctly different levels of application -- constituting separate "planner's" and "energy analyst's" methodologies -- have been developed during the project. Because the approach of the planner's level methodology[5] is more comparable to the four introduced in the preceding paragraphs, it alone is described in the following review of methodologies.

For convenience, the five methodologies will be referred to as Clarksburg, Alaska, Sizemore, Ekistics, and Hittman, in the order introduced.

A. Intended Applications

Although any of the methodologies could be adapted for a variety of applications, they were constructed for more or less well defined purposes, and only a very limited number of real or hypothetical example applications are available in the reports cited. Their use beyond the original studies will be easiest in cases that closely approximate these "intended applications." The applications of the methodologies are characterized in Table 1 by several properties of the community planned for and by the extent of the energy management subjects addressed. Entries in this table should be interpreted as those central the development of a methodology and most fully described in the report of it.

Even with so few dimensions, distinct realms of application begin to emerge. With regard to the community descriptors, none of the methodologies has been developed explicitly for application in large cities or regions. Two (Clarksburg and Sizemore) of the three methodologies addressed to existing communities treat only current conditions; this restriction could weaken recommendations for large scale and/or long-term energy conservation options. The methodologies that are being applied to new communities (Alaska and Ekistics) naturally are concerned only with projected conditions, which are themselves partially a function of the planning process. The projected conditions dealt with initially by the Hittman methodology are those expected to occur without any actions specifically taken for energy management.

Table 1. Applications of the CCEM Methodologies
(Symbols used: X, a central feature; -, dealt with in less detail; and blank, not covered)

	Application	Clarksburg	Alaska	Sizemore	Ekistics	Hittman
Community Properties	Existing Community	X		X		X
	New Community		X		X	-
	Small City	X	X	X	X	X
	Medium City	X	X			X
	Large City					
	Region					
	Current Conditions	X		X		X
	Projected Conditions		X		X	X
Energy Management Considerations	Demand Analysis	-	X	X	X	X
	Supply Analysis	X	X		X	-
	Analytic Methods	X	X	-	X	X
	Organization Methods		X	X		-

More will be said later about energy management considerations, but for initial distinctions, relative emphases between energy supply and demand and between a concern for analytic planning and formulation of the organizations to support and carry out the planning effort are indicated in Table 1. Demand analysis is related to energy conservation possible by the manner of using existing structures and equipment; the retrofit of existing structures; and the design, materials, location, and placement of new structures. Supply analysis deals with improved efficiency in the generation and delivery of energy to its point of end use and with the substitution of unused, renewable, or abundant energy sources for those in scarce supply. In the Clarksburg study, the attention given to integrated community energy systems stands out as a potential area for strong community action, whereas demand is treated more generally and left largely to individual property owners for implementation. Demand and supply are equally within the control of the planners of the new communities (Alaska and Ekistics). Sizemore and Hittman are primarily concerned with the use of energy forms supplied to particular end-use sectors.

This paper, as mentioned previously is primarily concerned with methods for planning analysis, but it is worth noting that the Alaska and Sizemore reports give considerable attention to the organization of the planning effort, involving all sectors of the community.

B. Process

A methodology useful for comprehensive community energy mangement planning consists of a process and the separate analytic and decision-making packages within it. Figures 1 through 5 are diagrams of the processes followed in the five methodologies. (Figures 3 and 4 summarize the detailed flow charts contained in Refs. 3 and 4, respectively.) The general planning model of data collection, problem identification, generation of potential solutions, evaluation of their impacts, and the selection of acceptable solutions and implementation devices is evident in all the processes. This is mostly clearly exemplified by the linear progression of steps in the Sizemore and Hittman methodologies. In actual application, both of these admit the possibility of iterating the analysis of energy conservation options and implementation strategies. The Clarksburg methodology, too, is relatively straight-forward, with the emphasis on energy resources and integrated energy systems being apparent in Fig. 1.

In the Ekistics methodology (Fig. 4) balance between energy system planning and development planning is emphasized. As a methodology for design of the community "from the ground up," there is no fixed energy baseline, but rather an evolution of supply and demand forming constraints for each other, leading toward an optimum development program. In existing communities, of course, less freedom exists to simultaneously adjust both sides of the design equation. The Alaska methodology applies to new community applications, also; it, however, is primarily intended to compare broad-gauged attributes during the preliminary or conceptual planning stage of the community, ending with guidelines to be applied during more detailed planning and design stages. Within the methodology (Fig. 2) the two parallel tasks, "analyze conservation technologies" and "define community functions and configurations," represent the survey of both supply and demand options. There is not an explicit integration of the two, and in contrast to the Ekistics methodology an optimum solution is not proposed.

PHASE I - BASE DATA

Task I. Description of object of study.
Task 2. Energy consumption by types of fuels and categories of users.
Task 3. Energy consumption by end-uses.
Task 4. Energy flow diagram of the City.

PHASE II - RESOURCES

Task I. Identification of energy resources.
Task 2. Characterization and quantification of energy resources.

PHASE III - IDENTIFICATION AND QUANTIFICATION OF CONSERVATION POSSIBILITIES AND OPPORTUNITIES FOR INTEGRATION OF ENERGY RESOURCES IN CITY'S ENERGY FLOW DIAGRAM

Task 1. Identify and quantify opportunities for conservation by categories of users and end-uses.
Task 2. Evaluate city energy requirements by categories of users and end-uses after implementation of conservation measures.
Task 3. Develop potential scenarios for integration of energy resources in city energy flow diagram.
Task 4. Pre-selection of attractive integrated energy system scenarios.

PHASE IV - EVALUATION OF PHYSICAL OPPORTUNITIES FOR INTEGRATED ENERGY SYSTEMS

Task 1. Evaluation of the scenarios for integrated energy systems selected in Task 4 of Phase III.
Task 2. Selection of integrated energy systems and relative ranking of the systems.

PHASE V - IMPLEMENTATION PLAN - RECOMMENDATIONS

Task 1. Institutional, financial, social, and technical problems associated with the implementation of integrated energy systems selected in Task 2 of Phase IV.
Task 2. Implementation plan for selected systems.
Task 3. Recommendations - Near-term and long-term.

Fig. 1. Schematic Representation of Methodology for City Integrated Energy System Applied in the Clarksburg Study

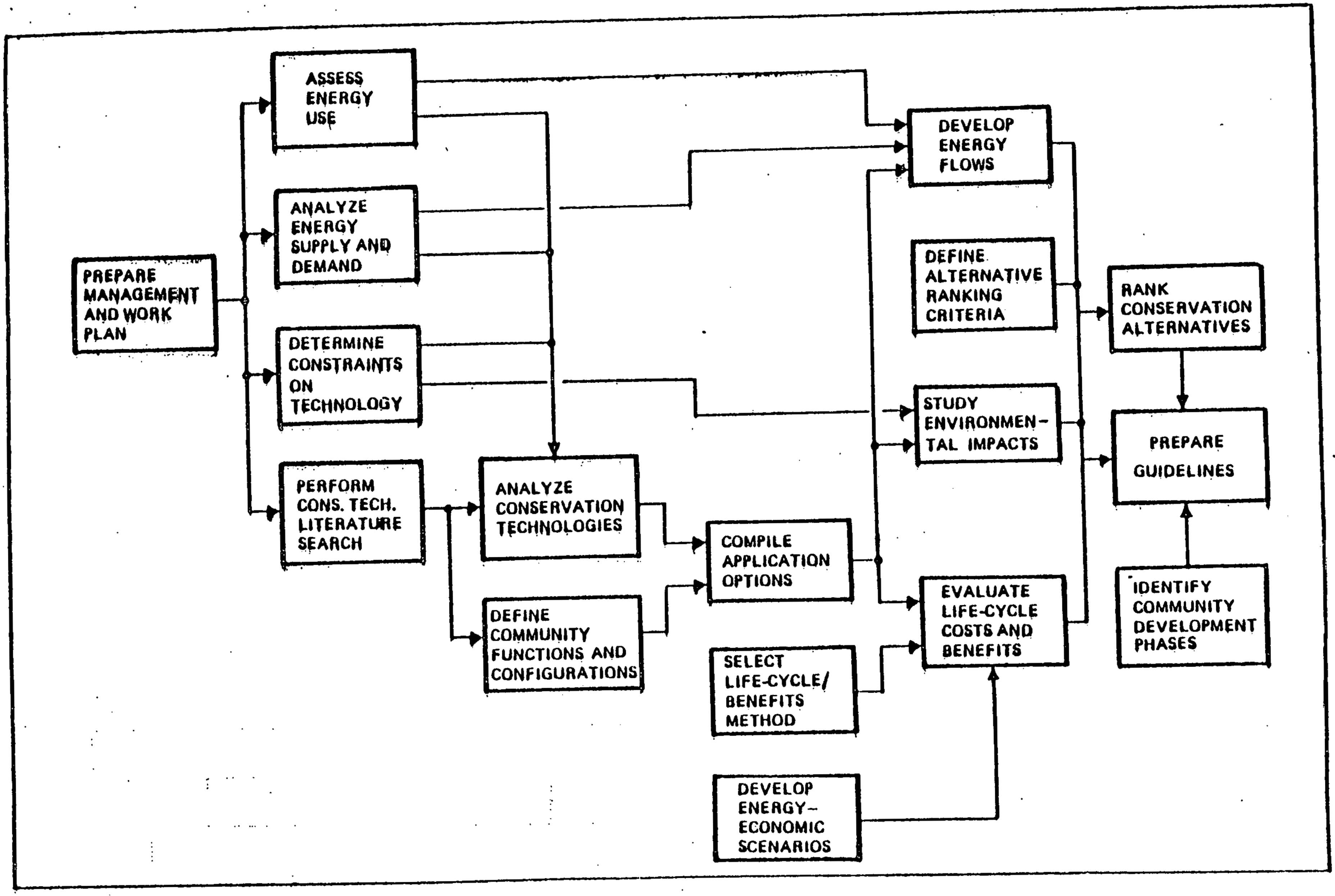

Fig. 2. Alaska Study Task Relationships

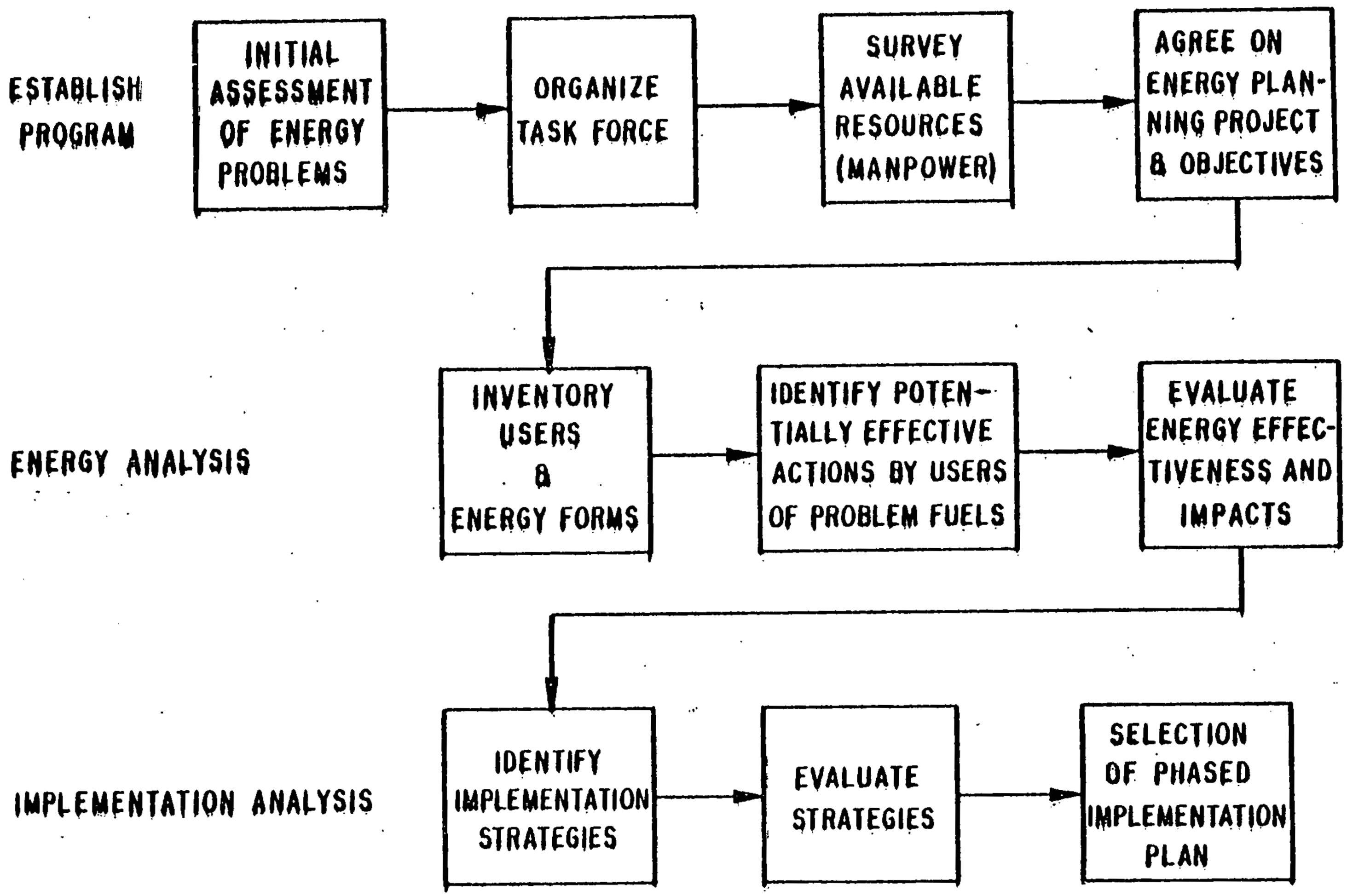

Fig. 3. Principal Steps in the Sizemore Methodology

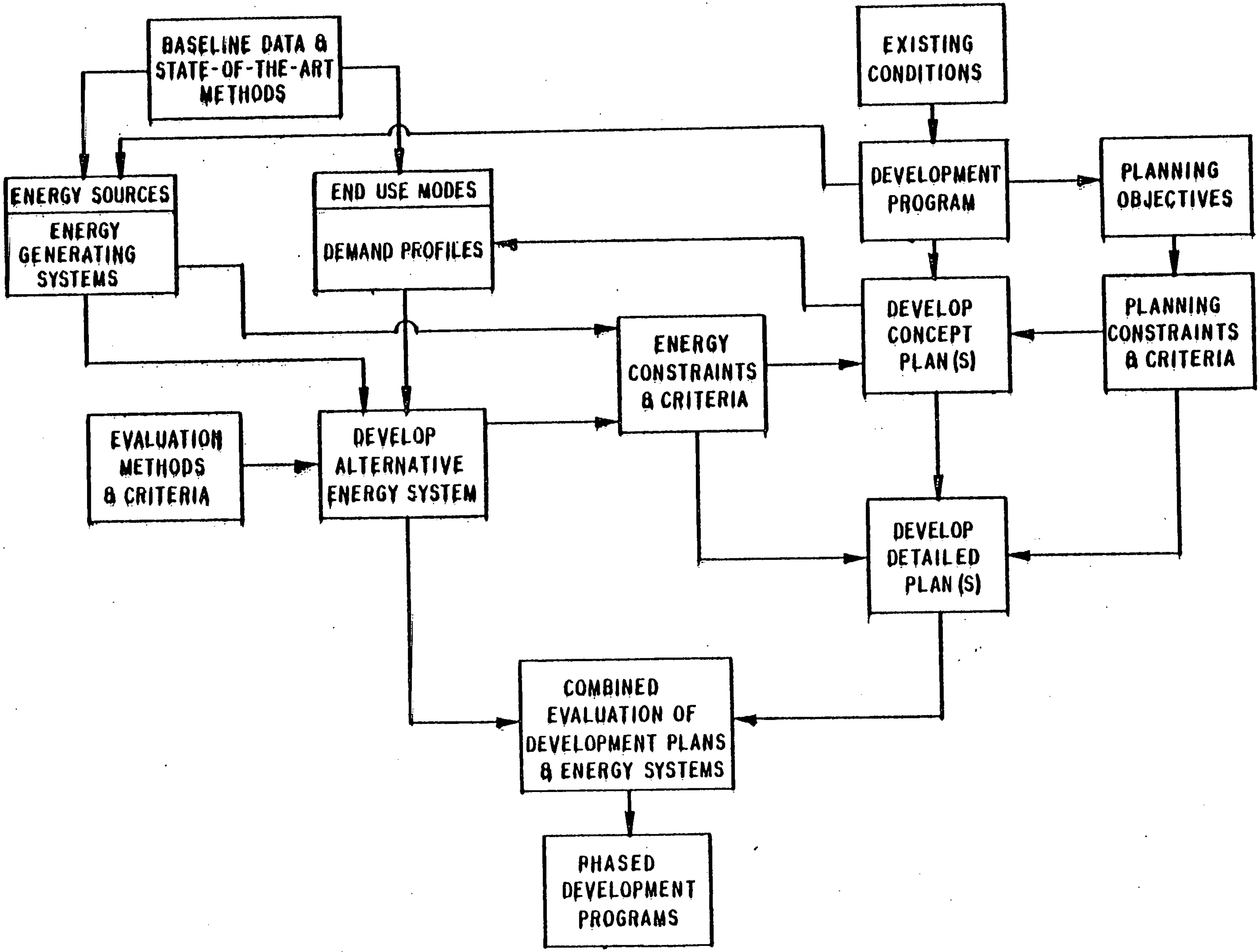

Fig. 4. Condensed Representation of the Ekistics Design Methodology

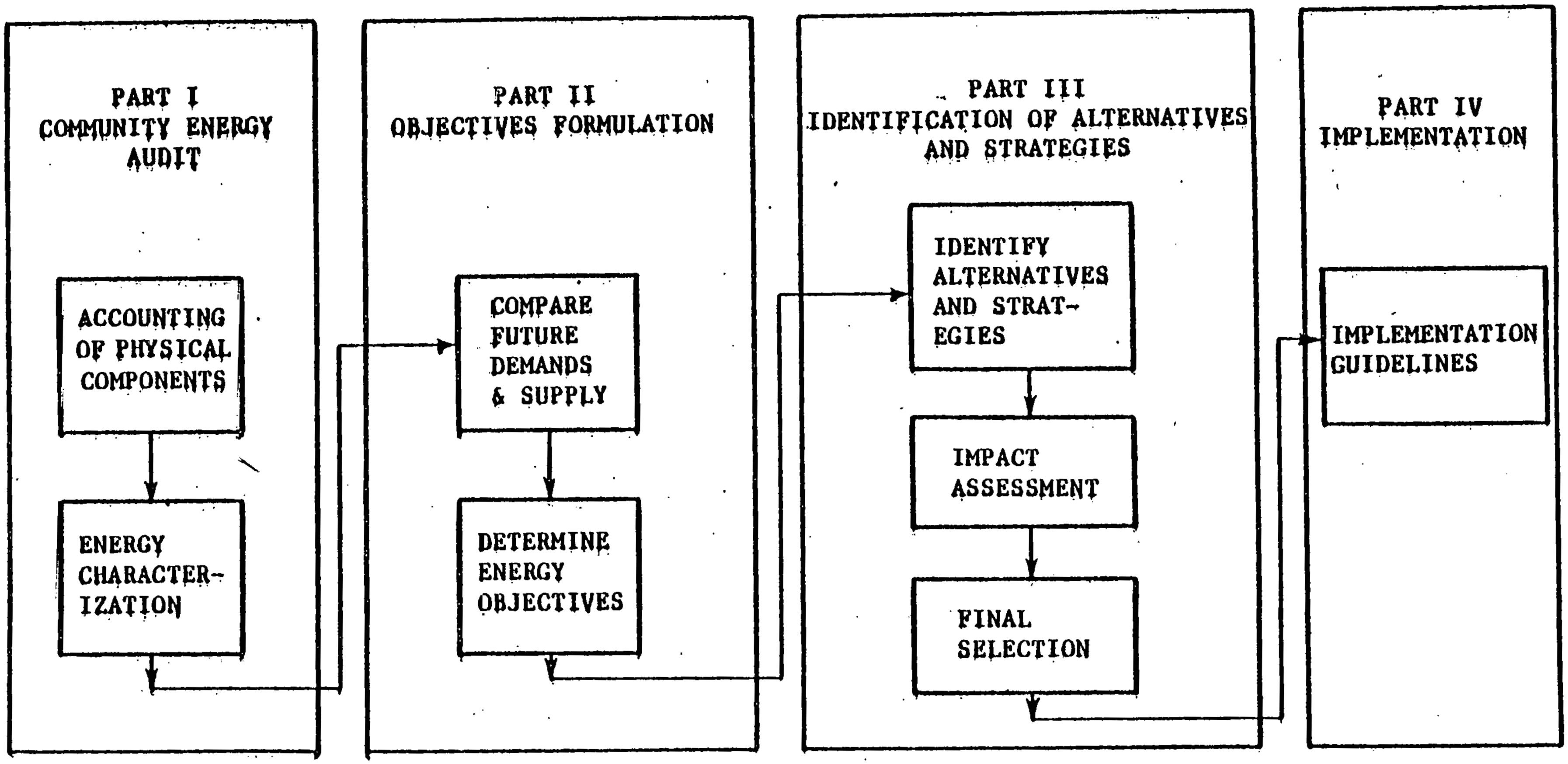

Fig. 5. Comprehensive Community Energy Planning Methodology Developed by Hittman

C. Analytic Components

Looking more closely still at these methodologies, one can compare the techniques which they use to carry out particular tasks. The two analytic areas that will be described are the energy analysis and the generation and evaluation of energy conservation options and implementation strategies.

1. Energy Analysis

The energy analysis distinguishes a CCEM from various other planning and management efforts to which most of the preceding discussion could be equally well applied. It is needed to understand the current energy situation and that which will prevail if no direct energy conservation actions are taken. It is subsequently applied in the evaluation of the energy effectiveness of potential options.

At the outset, an energy analysis requires choices concerning a few basic dimensions. The *sectors* of energy end use must be determined. Will the sectors follow the basic land use categories, such as residential, commercial, industrial, and institutional, and if so how finely subdivided within a land-use category must one go? Or can a new set of energy-sensitive descriptors be devised that will more efficiently yield all necessary energy information? It is also necessary to choose the *units of area* over which energy information will be summed. Is a community energy consumption total (for each sector considered) sufficient? In contrast, is it necessary to record information for every physically distinct energy user? What might be the basis for choosing an intermediate sized analysis area? The averaging *time base* for recording energy use is a third dimension to consider. Is the analysis based on annual energy consumption? Will it instead require demand profiles constructed from hourly records of energy use under a variety of climatological and operating conditions?

Once the dimensions of the analysis are decided, a program of data collection is needed. Several of the possibilities and their drawbacks are outlined in the Clarksburg report:

> Several approaches to this problem are possible: direct monitoring of actual consumption data for selected, typical consumers; inquiries - forms to be filled; census type - by selected energy users; analysis of sales data from utilities; computer modeling of typical consumers - housing units, business, etc. Direct monitoring is probably the most reliable method, but to be significant must extend over long periods of time and requires a large investment in equipment and personnel.

> Inquiries with users are of doubtful value because of the large uncertainty in the data supplied. How many homeowners know what their energy consumption is, or even what the basic cost of energy is? Sales data by utilities may or may not be directly accessible, may be in a form difficult to interpret, and, if accessible, may be cumbersome and require extensive interpretation. Modeling is open to criticism concerning the selection of typical users and usually does not take into account personnel or family habits or behavior.

Finally, there is the question of the relative importance given to energy demand and energy supply data and the manner in which these are reconciled. An energy flow diagram for the community can be constructed solely from information about the energy supplied. Greatest flexibility in the analysis, however, requires information about end-use demands independent of the current manner of meeting them and about available energy supplies that are presently under-utilized.

The energy analysis procedures in the five methodologies can be described in terms of the general characteristics just outlined. This description is facilitated by grouping the methodologies into those applied to existing communities and current conditions (Clarksburg and Sizemore), new communities and projected conditions (Alaska and Ekistics), and the Hittman methodology which is applied to both current and projected conditions.

The Clarksburg and Sizemore methodologies have energy end-use sectors that are traditional land use categories: residential, commercial, industrial, and transportation sectors in the Clarksburg methodology and residential, industrial, public facilities, commercial, and government and infrastructure sectors in Sizemore. Analysis areas receive the following treatment in the Clarksburg methodology:

> Energy Districts are defined as geographic areas of the city having similar characteristics, such as type of housing, socio-economic background, type of energy used, etc. For instance, a new development having all electric homes only could be an Energy District, so could a business section or an industrial park. Whenever possible the boundaries of these districts will follow easily recognizable landmarks such as railroad tracks, a river, etc., and will take into account the metering routes followed by the utilities to simplify the analysis of the raw data. The purpose of this subdivision of the city into Energy Districts is to define entities which are easier to handle and which fit logically into scenarios for the integration of local resources in the city's energy flow diagram.

The time dimension in the Clarksburg methodology is basically an annual one, although monthly residential natural gas consumption is analyzed as a means to determine the percentage requirement for space heating by separating seasonally varying and base consumptions. Example applications of the Sizemore methodology are incomplete, leaving the area and time dimensions unclear.

Energy consumption records form the primary data source utilized in the Clarksburg methodology to construct energy flow diagrams for the community. These data are acquired from the energy suppliers. No separate measures or estimates of energy demand are made. The Sizemore methodology presents detailed questionnaires to acquire energy consumption directly from industrial and commercial users. The questionnaire for residential consumers solicits information about the dwelling and the way heating/cooling equipment and appliances are used. This residential information is then used in an energy analysis based on Manual J, "a load calculation booklet for residential winter and summer air conditioning, published by the National Environmental Systems Contractors Association."

For new communities, also, relatively traditional basic sectors are chosen: the Alaska methodology considers residential, commercial, industrial, institutional, community, and intracity transportation sectors; for the Ekistics methodology the sectors are residential, central facilities, agriculture, manufacturing, recreation, utilities, and transportation networks. The entire city is the unit of area for the Alaska study, but a set of five development configurations, with varying patterns of development and different mixes and densities of structures, is hypothesized for comparisons. In the Ekistics study, the scale of analysis becomes finer as the planning and design process progresses toward final designs. The question of community form is treated in terms of the concepts of structure and texture.

> There are two significant aspects of community form: *structure* and *texture*. The first refers to its overall articulation into an organized whole. The second indicates the distinctive features of its fabric, the size and distribution of its constituent particles.
>
> There are two main elements which can reveal structure: *the locational organization of functions* and *the pattern of transporation lines*. The first refers to the distribution of locally based activities and the second to their connection and accessibility.
>
> On the other hand, the most prominent characteristics of texture are *density* and *grain*. Density is the ratio of population to the site area, indicating the degree to which space is occupied by people and, consequently, by buildings and other installations. Grain refers to the way building units are distributed and arranged.

The Alaska study deals only with annual energy consumption. Because energy system design is an objective of the Ekistics methodology, it utilizes daily energy demand profiles for the various end uses considered.

Simulations, standards, rules of thumb, and experience with similar applications must serve as the basis for energy "data" in the planning and design of new communities. In the Alaska study, typical unit energy consumption values in similar Alaskan communities were used to formulate baseline energy conditions. A detailed survey of the energy conservation possible from various technology options, both for end-use reduction and increased supply efficiency, was then utilized to determine the community energy totals for differing community configurations and energy supply alternatives. A computer program, ESTILOD, has been developed for the Ekistics methodology to generate energy demand profiles (i.e., daily load curves for different periods of the year, for a specified type of load or a sector of consumption -- e.g., residential -- as well as the total electric loads and demand profiles). The energy demand profiles are based on the assumption of "energy conscious" buildings, meaning that account is taken "of such building design variables as orientation, amount of fenestration, shading, compactness, etc. which affect the heating and cooling requirements of a building; also ... preliminary estimations ...[of] the extent to which it is economical for roof and wall insulation, or for double glazing to be used on buildings." The total system design process in the Ekistics methodology then involves analysis of the performance characteristics of each proposed supply system and a check of the balance between supply and demand.

The energy analysis in the final methodology (Hittman) is also based on land use categories; the fundamental sectors are residential, commercial/civic/institutional, municipal, industry, and transportation. These sectors are then finely divided into a number of individual types, such as single family detached, single family attached, multifamily low use, etc., for the residential sector. A single energy total is recorded for each of these subsectors which, in the comprehensive case, would be all such units within the entire study area, i.e., only one analysis area is considered. Only annual energy consumption is considered.

A large part of the Hittman energy analysis is devoted to determining the energy consumption of the community from a detailed physical inventory of the community. Lists of total structures and end-use modes and fuels used within them are converted to energy consumption through the application of standard unit consumption values ("energy intensity factors") modified to reflect local climatological conditions. These consumption values are compared to records of energy actually supplied. Balance between supply and consumption is achieved by suitably adjusting the parameters that convert the physical inventory to energy consumption, in a calibration process. The adjusted parameters are then used in subsequent calculations for projected conditions and for the effects of various conservation options.

2. Evaluation of Conservation Options/Strategies

Energy is only one of the evaluations that must be applied in developing a CCEM plan. The economic, environmental, social, and institutional effects of any proposal must be acceptable before it can become part of a plan for community action. The evaluation of these "other" impacts of energy conservation options (or of *any* community action, for that matter) are already a part of planning processes in general and will be familiar to most planners setting out on their first energy management planning endeavor. For this reason there is some tendency to pass over these evaluations somewhat lightly in methodologies for CCEM planning. The definite exceptions to this rule in the methodologies under review here are worthy of brief mention.

First, however, it should be pointed out that generation of conservation options and appropriate implementation strategies for them cannot readily be built into a general CCEM process. Each planning application is unique and the options are so numerous that to predetermine a small set of options for every possible application is clearly unproductive, if even possible. Instead, some intuition concerning the basic soundness of certain kinds of conservation options is required of the CCEM planner. The methodologies *can* help, however, by presenting relatively voluminous, but well ordered, compilations of options and strategies that are possible. Two of the methodologies are particularly noteworthy in this regard: the Alaska study had an extensive review of conservation technologies in its early stages, and the Hittman methodology contains detailed appendices of options for demand reduction, implementation strategies involving varying degrees of governmental power, and guidelines for the evaluation of the impacts of each.

With regard to evaluation of impacts, the methodologies give fullest treatment to economic evaluations. The Alaska and Clarksburg methodologies give rather extensive discussions of the application of life-cycle costing techniques for economic evaluations. The Hittman methodology gives first costs for the conservation options contained in it, but it does not calculate the dollar value of any energy savings.

Other types of evaluations are spotty. Perhaps the most complete treatment is in the supporting reports for the Alaska study. It contains particular sensitivity to the general political acceptability of the various options. (This is dealt with in the Sizemore methodology through the supportive and review organizations that are set up as part of the process.) The lack of commensurability among the various evaluations is handled in the Clarksburg methodology by the production of a so-called Differential Energy Related Matrix (DEREM). This is primarily a presentation device, and the relative importance assigned to the different impacts tabulated in the matrix is left to the CCEM planner to decide.

III. CCEM Pilot Studies

In September of this year, approximately a dozen diverse communities -- cities, counties, and area-wide governments of varying sizes -- will undertake CCEM planning pilot studies funded by the Department of Energy and under the general responsibility of Argonne National Laboratory. The efforts will be structured initially on the process and techniques of the Hittman methodology and are intended to provide a carefully monitored test of its effectiveness and of adaptions that can lead to even better CCEM tools that can be applied by communities generally. As can be seen from this review of only a subset of the methodologies produced for the Community Systems Program, an abundance of approaches to CCEM methodologies is available. It is now time for testing, synthesis, and refinement.

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