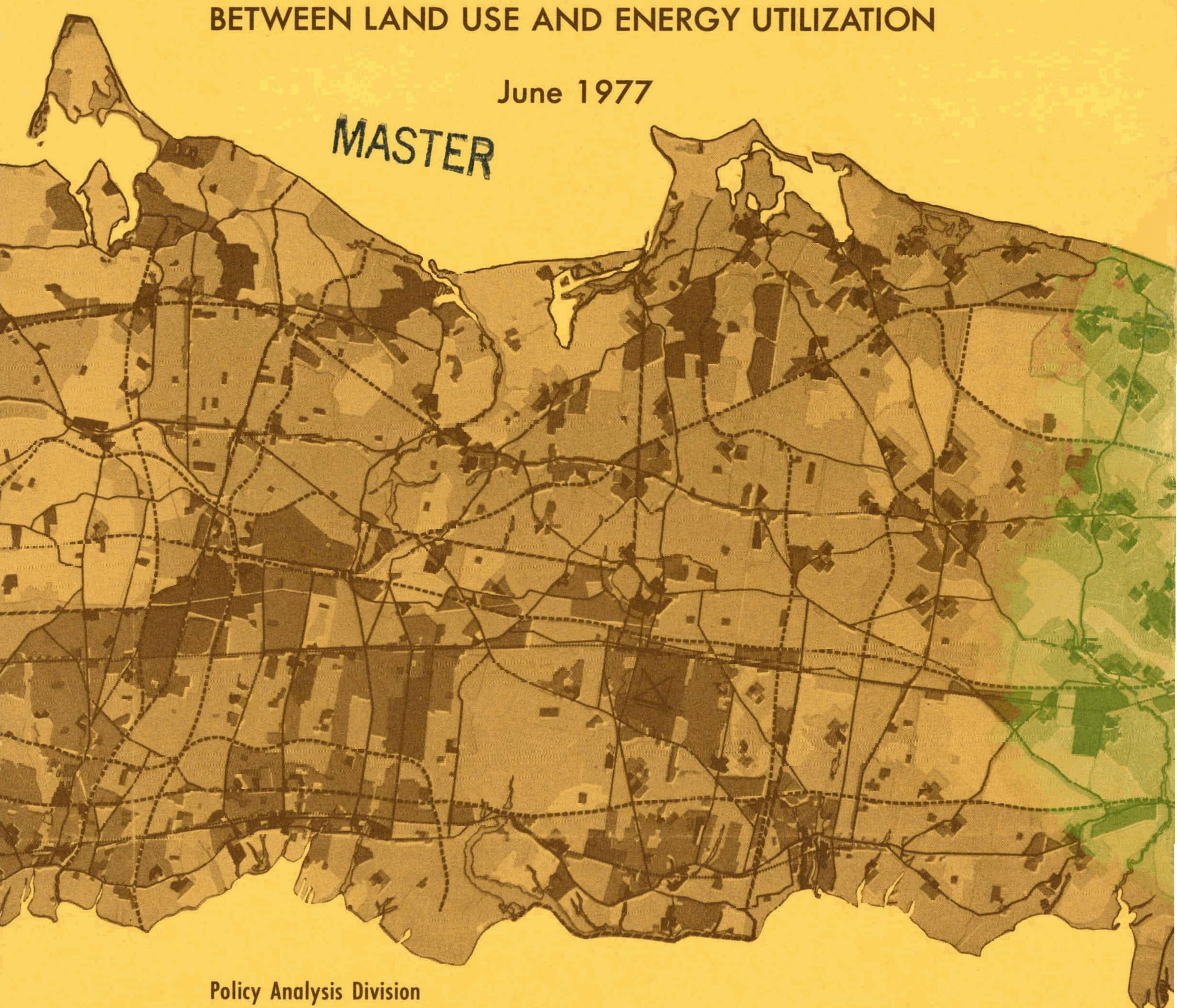
THE PLANNER'S ENERGY WORKBOOK

A MANUAL FOR EXPLORING RELATIONSHIPS BETWEEN LAND USE AND ENERGY UTILIZATION

June 1977



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Abstract

Recently, problems of energy supply and greatly increased energy prices have introduced a major new concern into planning and policy making at all levels of government. In particular, it has been clear that the magnitude and character of a region's energy requirements are intimately related to the spatial configuration and mix of land use activities. To the degree to which they can shape the future configurations of residential, commercial, industrial, and transportation activities, local governments and their planners must give serious consideration to the energy implications of those configurations in the light of future social goals and requirements.

This Planner's Energy Workbook describes a set of procedures that can be used by local planners to carry out their own community and regional energy analyses. The choice of land use activity parameters and their relation to energy use characteristics are associated with the normal planning concepts of land use density, type of residential development, commercial floorspace, industrial sales and employment, and shopping and work trip lengths. At the same time these energy related intensity coefficients are expressed in a form that permits the analysis of short term conservation strategies such as the retrofit of insulation and the introduction of new technologies such as solar energy. An integrating framework is provided to construct total community or area energy consumption profiles and future needs; to examine compatibility between area requirements and the energy supply-distribution system serving the area; and to evaluate the implications for energy use of the physical configuration of urban, suburban and rural areas including such elements as growth policy, density, transportation systems, community service areas, and the design and siting of buildings and communities.

Two cases illustrate the application of the Planner's Energy Workbook. The Long Island area is representative of major suburban regions throughout the U.S. which have undergone major growth and development. A community redevelopment design in Tuscon, Arizona is typical of rapid and major land use development within the environs of an existing city. Using modest and accepted community design considerations, energy savings in area development of up to 40% are estimated, which is indicative of both the range of potential savings and the need to explore opportunities for energy-saving community designs.

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I. INTRODUCTION

A. Energy and Land Use Planning

Over the past several decades land use planning in the United States has been influenced by a shifting set of practical and aesthetic concerns. As new factors of local or national concern have come to the fore, attempts have been made to incorporate them into designs for the development of new areas and as influencing elements in zoning decisions, the planning of road and mass transportation systems and the siting of public service facilities in existing communities. The extent to which land use planning was a necessary social strategy to deal with a new concern affected the acceptability of planning itself.

Recently, problems of energy supply and greatly increased energy prices have introduced a major new concern into planning and policy making at all levels of government. In particular, it has become clear that the magnitude and character of a region's energy requirements are intimately related to the spatial configuration and mix of land use activities.[(1)] To the degree to which they can shape the future configurations of residential, commercial, industrial and transportation activities, local governments and their planners must give serious consideration to the energy implications of those configurations in the light of future social goals and requirements. Viewed from this perspective the new national concern with energy efficiency has endowed the practice of land use planning with a new importance, for only through such planning can the underlying structural causes for our high energy consuming society be changed.

The impact of energy supply and distribution activities can also be strongly affected by land use planning decisions. The requirements for electric generating stations, transmission lines, port facilities, etc., are all a function of the energy requirements of the region. Furthermore, it is important that they be appropriately integrated into overall land use development patterns. For energy producing regions, the regulation of land use becomes a central regional concern and responsibility.

Although the interdependency between land use and energy consumption has been widely recognized at the federal level, comparatively little account of these relationships has been taken at the state and local level. This is due to two factors. The first is the historical lack of involvement of state and local officials in decisions affecting energy supply-demand systems. Utilities and public regulatory agencies have traditionally borne primary responsibility for the siting of power plants, location of transmission lines, and pricing of electricity. Decisions at the federal level have usually been the major factors in determining energy supply, conversion, and end-use technologies, and national prices of essential fuels. The second factor is the lack of information and effective methods for the planner to use to bring energy into his set of goals and criteria. This report is intended as a contribution to overcoming that difficulty.

The incorporation of energy systems considerations into the planning process should be viewed as complementing the traditional goals of the planner-designer. Indeed, a number of studies[2] have shown that land use patterns which are designed to reduce energy consumption can work to satisfy non-energy related planning program objectives including the more effective utilization of open space, the interspersion of residential, commercial, and industrial activities, and the shift of passenger transportation to mass transit modes. Thus, from a number of perspectives, it is important to provide land use planners and designers with a means of addressing energy questions and concerns in their planning and design process and in the decisions and choices they face in evaluating options for community and regional development.

This Planner's Energy Workbook is based on a study funded by the Office of Conservation and Environment of the Federal Energy Administration on Land Use and Energy Utilization and carried out by the Energy Policy Analysis Division at Brookhaven National Laboratory and the Institute for Urban Sciences Research at the State University of New York at Stony Brook. A primary objective of this project, which was started in June of 1974, was to design and validate a computer model which would elucidate the relationships between a variety of land use configurations and the energy supply-demand system. An additional objective of the study was to design a set of procedures that could be used by local planners to carry out their own community and regional energy analyses. The choice of land use activity parameters utilized in the model and the energy workbook reveal this intent. For example, energy use characteristics are associated with the normal planning concepts of land use density, type of residential development, commercial floorspace, industrial sales and employment and shopping and work trip lengths. At the same time, these energy related intensity coefficients are expressed in a form that permits the analysis of short-term conservation strategies such as the retrofit of insulation and the introduction of new energy technologies. Finally, an integrating framework is necessary to construct total community or area energy consumption profiles and future needs; to examine compatibility between area requirements and the energy supply-distribution systems serving the area; and to evaluate the implications for energy use of the physical configuration of urban, suburban, and rural areas including such elements as growth policy, density, transportation systems, community service areas, and the design and siting of buildings and communities.

B. Aim of Planner's Energy Workbook

This workbook has been designed to present a straightforward set of calculational procedures and worksheets which planners and designers can use to carry out their own evaluation of alternative land use planning and design programs. It describes the structure of the methodology for relating energy utilization to land use activity levels and configurations for each major end-use sector. These are expressed in terms related to such factors as local climate, distance from urban core, and utilization of existing technologies. An integrating worksheet format is provided to simplify the use of energy-land use design criteria and to estimate energy consumption profiles for the area in question. Examples are provided to illustrate the trade-offs in terms of alternative uses of land in both urban and suburban settings. The version presented here, though based on a more detailed report issued by the BNL/SUNY Land Use-Energy Utilization Project, does not require the use of computers. A more sophisticated version of the model is available however, which may be used to reduce the problems associated with data storage and manipulation, and to ease the consideration of the complex inter-play between different patterns of land use development and the local energy system.(3)

II. RATIONALE AND USE OF THE METHODOLOGY

The planning framework, or model, on which the procedures in this workbook are based was designed as a means of revealing the interdependencies between the regional and/or community growth development parameters and the local and regional energy supply-demand system. It provides an integrated picture of the manner in which the basic development goals of the geographic area in question such as population, employment and industrial sales, drive energy fuel demands. The model utilizes an energy-variant of the Lowry Land use model[4] to translate developmental targets and design program objectives into a starting set of land use mixes and spatial arrangments. Energy intensity factors are employed to reduce the set of fuel specific and non-fuel specific energy demands. These energy demands, thus generated, are coupled to a model of the area energy system of supply and distribution which is constrained by the available energy technologies, fuel prices, national supplies, and environmental impacts. The methodology described in this workbook represents an attempt to simplify the essential features of this model. The procedures for collecting, evaluating, and analyzing local data as described below, including a listing of sources of pertinent local data, are similar to that used in the application of the more complex version of the model.

In constructing the basic land use-energy utilization model and presenting the results in an energy workbook, our approach emphasizes that energy production and use constitutes only one of numerous contributing factors in determining the final form of land use development. The purpose of land use energy analysis is not to determine energy "optimal" land use configurations, but to assess the impact of a variety of designs and plans on the energy system and vice-versa. In certain cases, where the supply of energy to the locale is either uncertain or is associated with unwanted risks or environmental degradation, our procedures allow the trade-off between alternative land use arrangements and supply options to be compared. In other cases where the conservation of energy is considered to be a primary objective, the procedure enumerated here can be used to establish the overall energy budget of the region in question. In still other cases, energy itself may not be the prime issue, but what is required is simply an assessment of the energy-environmental implications of land use. Again, our procedures can be used to compare alternative energy system impacts. In all these cases however, it is implicitly assumed that area-specific economic, political, aesthetic, and social elements remain the fundamental driving forces for land use development. It is then the intent of the energy analysis to provide a basis for judging the compatibility of the final land use form with the energy system.

There are certain limitations in our approach which are important to note. It is not designed to be used to deal with communities smaller than perhaps several thousand population, particularly when these communities lie within a larger metropolitan area. In such cases, the flow of energy in and out of the region vis-a-vis the movement of goods, services, and people prevents any detailed energy analysis of land use alternatives without a consideration of the larger surrounding area. The methodology is also of limited use in considering short-term, highly detailed questions such as the energy impacts of new apartment complexes or industrial parks. These types of analyses are highly dependent on the specific type of construction or industrial processes employed. The methods, however, show the overall impact of such development on regional fuel supplies and distribution and their compatibility with other energy expenditures in the community. Other limitations in the procedures are derived from the wide variety of community types for which its application is intended. Because the notion of land use activity or energy intensity factors implies the characterization of an aggregated collection of individual activities, they represent statistical averages. As such, they must be verified locally, particularly in cases where the local land use activity profile departs significantly from the norm. We describe procedures for this validation.

A. The Framework for Analysis: General Description

At the core of the methodology is the framework shown in Figure 1 which displays the land use-energy system linkages. A set of land use activities which consist of a definition of their level, mix, and spatial

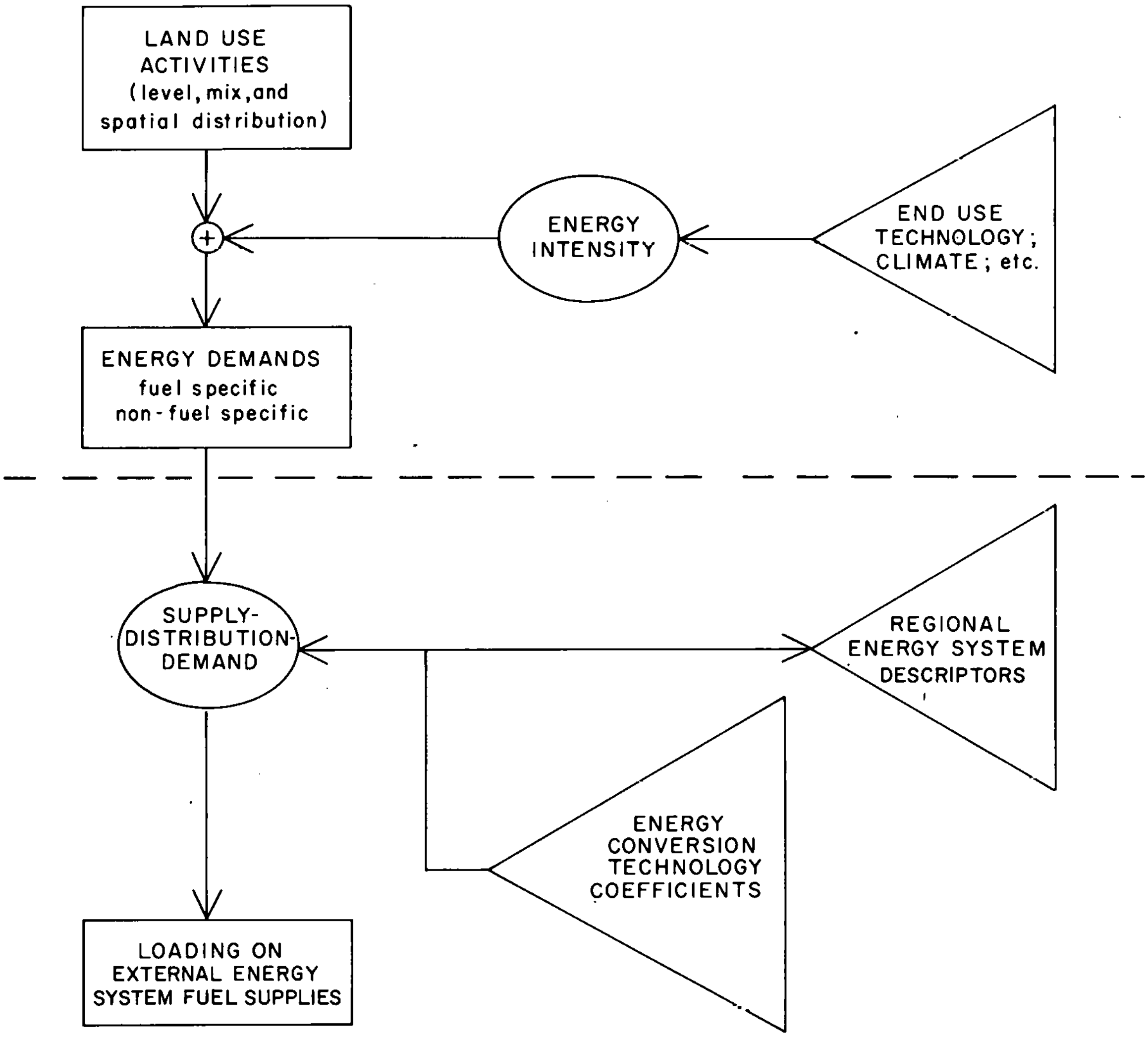

Figure 1. Land use-energy analysis framework.

distribution for the area under consideration serves as the starting point for the analysis. This may be obtained from a design or plan being considered, an extrapolation of current trends, or the use of a set of preferred outcomes.

Using energy intensity factors which are based on area-wide average values and the assumed presence of specific end use energy technologies e.g. space heating, industrial processes, transportation vehicles, the set of projected land use activities are converted into a set of energy demands, some of which are converted to certain fuels. The detailed calculation of this conversion of land use activities to energy demand, forms the essence of this workbook and its procedures are described in detail in Chapter III.

The description of the community or regional energy system which is coupled (loosely at times) to energy demands consists of a projected set of energy capacities and fuel requirements, conversion facilities, fuel distribution and delivery systems - and, if applicable, import accommodations. It also contains a description of the specific energy technologies employed. Finally, it documents the fuel imports into the region which represents in essence the loading on the external energy system. This representation of the regional energy system which utilizes many of the procedures described in the BNL/SUNY report - "User's Guide for Regional Reference Energy Systems"(5) is described in Chapter III.

The initial step in utilizing the procedures and data described in this workbook is to prepare a basic set of energy and land use data and information applicable to the area under consideration. Aside from the local input on projected land use activities and supply-distribution descriptors, all the other technical coefficients needed to assemble this data base are provided in the workbook in the form of tables, graphs, and charts. In certain cases, where verification of the technical coefficients is judged to be necessary, procedures are described for carrying this out. Once this basic data and information base has been established the user can then begin to evaluate the impacts of either land use development on the energy system or the reverse. In actual practice, the level of detail needed to assess these impacts will depend on the specific application.

B. Sample Problems and Issues Addressable by Land Use-Energy Analysis

There are several types of problems and concerns that may be addressed by the frameworks and data base described in this report.

1. Developing Guidelines for Energy-Efficient Land Use Developments: An increasing number of communities in the country are now acknowledging that they require guidelines to insure that the remaining developable land within their jurisdiction is utilized in a manner that coincides with community preferences and interests. One contributing factor to formulating such guidelines is the efficient use of energy in the management of these community resources. Communities or regions therefore, may wish to explore the energy use patterns associated with a variety of possible development scenarios.

2. Evaluating Utility Demand Projections on the Basis of Expected Trends in Community Land Use Development or Proposed Land Use Plans: Citizen and consumer participation in the planning for utility siting of new electrical generating stations has increased substantially over the past several years. A significant part of the dialogue between utility and consumer representative centers on the interplay between the projections for electrical demand and future community growth and development. Because of the central role that both energy and the use of land play in the life of the community, an analytical tool for examining the trade-offs between the two provides a useful structure on which to base these discussions. Thus, planning boards and/or utilities may wish to evaluate utility demand projections on the basis of expected trends in land use development or specifically proposed land use plans.

3. Responing to Federal and State Energy Legislation and Directives and Assessing their Land-Use Implications: The Federal Energy Conservation Act of 1976 stipulates that states must formulate plans for specific actions together with supporting data bases for reducing the demand on scarce fuel supplies. Implementation of this and other federal legislation will take a number of forms. Some states are considering

the enactment of legislation which will require local communities to compile their current energy and projected energy expenditure in order to ascertain specific measures which can reduce energy consumption. Others are in the process of reviewing highway construction plans and mass transit subsidies to take account of their energy implications. Building code revisions and tax abatement to encourage the use of new construction materials, installation of solar heating and cooling, and retrofiting of existing homes have been passed. Some of these state and federal energy conservation measures will require specific responses on the part of local governments and municipalities. Others will have long term impacts on local land use development patterns. The community or regional planning board, or officiating body, may therefore, wish to either set up a data base to monitor community or regional energy consumption patterns, assess the likely impacts of specific state and federal actions, or to respond to specific directives by appropriate state agencies. While the detailed approach used in each of these illustrative areas will vary, the procedures and information base described in this workbook offer local planners a starting point for their study. For example, if scenarios for future development can be documented in terms of even a crude approximation of their implied land use mixes and spatial arrangement, energy intensity coefficients calculated for local conditions and the worksheets can be used to estimate their energy and fuel budgets and correlate them with zoning policies in the residential, commercial, and industrial sectors.

Utility demand projections have traditionally not been based on demands derived from land use activity projections. On the other hand, they usually contain a great deal of region-specific data on such things as appliance saturation, seasonal use of electrical space conditioning devices, and the electrical demands due to local manufacturing processes. They are also more sensitive to economic factors which contribute to the final demand. Combining land use input with the traditional bases for electrical demand projections provides both a broader data base and a useful format for coupling these demands with a community's preference with respect to its future development. If access is available to local utility data, the energy intensity coefficients can be refined and validated in a more precise fashion. One can also include both the influence of developing energy end-use technologies, fuel substitution possibilities, and price elasticities to imprive the estimation of fuel requirements.

Although the use of the workbook for responding to federal and state policy is dependent on the specific policy and/or action, in general one must augment the approaches outlined above with those used in analyzing impacts in the individual land use sectors, if the desired outcome is a detailed response or impact evaluation. Building code modifications for example, retrofit measures, and use of solar technologies all will require the use of engineering and architectural models sensitive to energy use factors. Policies and legislation oriented toward the highway mass transit sectors will require transportation and economic models that deal with consumer choices. In many cases, however, a broad energy overview is desired either as a starting point for a more extensive detailed analysis or as a means of satisfying state and federal informational requirements.

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III. DEVELOPING A LOCAL ENERGY CONSUMPTION PROFILE OF LAND USE ACTIVITY

The initial step in attempting to perform an energy analysis of land use development is to assemble an energy consumption profile of land use activities that reflects both current and projected land use development, local climatic and building construction practices, mix of industries, and transportation use patterns. This profile consists of a set of energy intensity coefficients which express both total energy end use demand and, where possible, fuel specific demands. These coefficients are expressed in units traditionally employed by the planner to characterize how land is used. Once established, this set of energy intensity coefficients should be viewed as comparable with other types of planning design criteria e.g. land use requirements associated with commercial activities or pollutant loadings which accompany residential development. The utilization of these "energy design criteria" is also similar with other types of design parameters, i.e. just as planners employ such community averaged values to establish guidelines for commercial, residential, and industrial development consistent with an established set of objectives, so the energy profile set can be used to establish guidelines for both the mix and spatial patterns of development of these activities which are consistent with a set of energy goals. In some cases, such energy guidelines will operate to assess the impact of new area development on total regional energy needs; in others, it may stimulate discussion leading to the inclusion of energy conservation measures in community designs. As with all such planning design criteria, the energy profile set must be further refined if it is to be employed for site-specific architectural or engineering analysis similar to that used to satisfy subdivision standards or approval of specific planned unit developments. The role of the energy intensity coefficient profile, in such cases, is to act as a starting point for the detailed analysis; specific engineering models being employed to assess the degree of modification required in each individual evaluation.

In devising an approach for collecting and assembling data for the energy consumption profile, we have sought to satisfy the requirement that data normally available to the land use planner be utilized as basic input. At the same time, we wished to categorize land use activities in such a way that they reflected the essential variations in energy consumption characteristics arising from different functional end-uses of energy and the use of various end-use energy devices. A final requirement is the need to devise a classification scheme which is easily adaptable to region-specific land use and energy expenditure patterns, through the use of either engineering or statistical sub-models. The final forms we have adopted represent, of course, a compromise. The level of disaggregation of land use activity types in each energy end-use sector has been restricted to only the most energy-significant categories. Table 1 summarizes the local land use data required. The units expressing the level of land-use activities in each sector have been chosen to be consistent with available data sources. For the residential sector, we use the dwelling as the unit;square footage is used in the commercial sector; in the industrial sector both dollar value-added and the number employed are used; passenger-miles or ton-miles is adopted as the unit in the transportation sector. Regional variations in the energy intensity coefficients in the residential and commercial sectors in climatic and building construction types, average size, etc., are taken into consideration through the utilization of engineering sub-models. For the transportation sector, we employ a sub-model which accounts for region-specific variations in travel patterns as they relate to such traditional land use and economic variables as land use density and household income. Because industrial manufacturing processes are relatively uniform throughout the country, we adopt values based on nation-wide averages.

In the sections that follow we provide 1) a brief review of the primary energy consuming end-use services in each major land use sector, 2) a description of the energy intensity factors in each sector along with a worksheet for local use, and 3) a list of local data and informational sources which can be used to verify the local energy intensity profile set. For a further description of the analysis which underlies the calculation of these energy intensity coefficients the reader is referred to the publications in references listed in 5.

A. Residential Energy Intensity Coefficients

As shown in Table 1, residential dwelling types have been disaggregated into four basic types - single family detached, attached, low-rise, and high-rise. In addition to other considerations, this choice of residential categories reflects the fact that heating and cooling demands constitute the major component of residential energy end-use demands in most parts of the country. For example, Table 2 displays a breakdown of the typical energy end-use demands of a three bedroom house in the Northeast part of the country. Fuel consumption and approximate costs are also given in order to furnish a perspective of fuel consumption levels and relative operating costs. Space heating and cooling account for 72% of the total energy demands. Water heating demands constitute 15% of total household demands; cooking, 39%; refrigerator, lighting, and miscellaneous appliances - which would include both major appliances .. washer, dryer, dishwasher, freezer.. and minor appliances .. television, hair dryer, clock - 10%. While this breakdown of energy expenditures shows some variation from one housing type to another, since heating and cooling energy demands in general constitute considerably more than half of the total household energy use, it is possible to utilize engineering heat flow equations to modify the typical household energy profile for variations in size, construction type, and for local climatic conditions.

Energy flows into or out of a building in the form of heat through leakages or infiltration of air into or out of the unit around doors and windows and/or frames, and from heat flow out (or in) through glass, ceiling, walls, and floors. In both cases, the extent of the net loss (or gain) in energy for a given unit will depend on annual heating and cooling degree days for the area. It will also depend on open gap areas and on the type of construction of the unit, the presence of insulation and storm windows and doors, and orientation of the dwelling unit with respect to prevailing wind conditions and the sun. Table 3 shows heat loss/gain profile for an average three bedroom single family detached dwelling unit located in the Northeast. Heating and cooling transmission losses (or gains) in the table are expressed in annual Btu(British thermal unit) demand per degree-day.

TABLE 1

Summary of Land Use Information

Sector	Variable	Breakdown
Residential	Dwelling Units	Single-family detached Single-family attached (condos.) Low rise (garden apt.,condos.) High rise
Commercial	Floorspace	Office Retail mall Retail strip Other
Industrial	Employment or Dollar value added	Light industry Medium industry Heavy industry Energy-intensive process or Standard Industrial Code
Transportation	Trip generation Trip length Modal split	Transportation variables determined by Households, Household Income Level, Distance from Urban Core, and Transit Availability.

TABLE 2

RESIDENTIAL ENERGY PROFILE

Three-Bedroom Home in the Northeast Region

1300 square feet

5500 heating degree-days

1200 cooling degree-days

R-7 ceiling/R-5 walls[1]

	End Use Demand		Fuel Consumption	Approx. Cost[2]
Space Heat	77 million Btu (56%)		102 Mcf/850 Gal/18000 Kwh	$240/340/450
Central air-cond.[3]	22 million Btu (16%)		3200 Kwh	130
Water Heat	18 million Btu (15%)		27 Mcf/200 Gal/ 5500 Kwh	54/ 80/130
Range	4 million Btu (3%)		10 Mcf 1200 Kwh	48
Refrigerator	4 million Btu	(10%)	4100 Kwh	160
Lighting	3 million Btu			
Misc. Electric	7 million Btu			
	135 million Btu 104 thousand Btu/sq.ft.			$612 - 918

[1]Weighted averaged insulation values of existing New England housing stock as determined for internal FEA report by Insulation Manufacturers Association.

[2]Natural gas at $2/Mcf (thous. cu. ft.); oil at 40¢/Gal.; Electric at 2.5¢/Kwh heat; and 4¢/Kwh general use.

[3]Room air-conditioning (two units) would be 8.8 million Btu.

TABLE 3

TYPICAL RESIDENTIAL HEAT LOSS/GAIN PROFILE

Three-Bedroom Home in the Northeast Region

1300 square feet
5500 heating degree-days
1200 cooling degree-days
R-7 ceiling/R-5 walls[3]

	Loss			Gain		
	Btu/°day	Percentage	Cumulative Percentage	Btu/°day	Percentage	Cumulative Percentage
Infiltration	3120	22	22	3120	15	15
Glass	3120	22	44	3120	15	30
Ceiling	2880	21	65	9800	47	77
Wall	2400	17	82	2400	12	89
Floor	2400	17	100	2400	12	100
TOTAL	13920[1]	100		20840[2]	100	

[1] 5500 heating degree-days = 77 million Btu/yr.

[2] 1200 cooling degree-days = 25 million Btu/yr. for central air.

[3] Weighted average of insulation values of existing New England housing stock as determined for internal report at FEA by Insulation Manufacturers Association.

Although considerable care is required in order to utilize engineering heat flow equations to estimate annual heat loss and gain in individual residential dwelling units, for the purpose of estimating heating and cooling loads—in order to calculate average residential energy coefficients, we have adopted the following simplifying procedures. Results obtained from field measurement studies of heat loss and gain in standard types of single family dwelling units[7] are used as the starting point of a parametric analysis employing the ASHRAE formulation of the engineering heat flow equations. Parameters included are dwelling type, size and heating and cooling degree days. Statistical data on housing size and construction type for dwelling units in the single family detached category are then used to determine a weighted average energy intensity coefficient for heating and cooling loads in the region. A check on this figure is obtained utilizing local data sources. Heating and cooling energy demands for other dwelling types are then scaled using this value and using the same parametric formula and weighted regionally-averaged values for size of the dwelling unit, then checked against local data sources. For a sufficient number of units this approximate procedure provides reasonably accurate values for annual heating and cooling total energy demands on all four types of dwelling units. In the event that more accurate values are desired or the number of dwelling units being considered is limited, weighted-average values for each dwelling type should be utilized in place of the scaling procedures described above. Average energy demands for other than heating and cooling purposes[8] for each dwelling which can be estimated from local utility data are then added in to obtain the final residential energy intensity coefficient.

Residential Energy Worksheet

To make each of the procedures for the calculation and verification of a local energy intensity profile set more explicit, we have prepared a set of worksheets, graphs, and data sources. Taken together, they should permit the user to determine approximate values for local energy intensity coefficients in each primary land use sector.

Table 4 lists heating and cooling loads in terms of annual Btu consumption per heating and cooling degree day for a specified dwelling unit -

TABLE 4

TYPICAL RESIDENTIAL HEAT/COOL LOAD

1300 square feet

15% glass (plus door) area[1]

R-7 ceiling/R-5 will existing construction[2]

R-11 ceiling/R-7 wall new construction

	Existing Construction				New Construction			
	Heat		Cool		Heat		Cool	
	Btu/°day	Btu/°day per sq.ft.	Btu/°day	Btu/°day per sq.ft.	Btu/°day	Btu/°day per sq.ft.	Btu/°day	Btu/°day per sq.ft.
Single-Family Detached	14000	10.8	22000	17.0	10300	7.9	15500	12.0
Single Family Attached	10200	7.8	17700	13.6	7400	5.7	12500	9.6
Low Rise	7500	5.8	11200	8.6	5500	4.2	8100	6.2
High Rise	4300	3.3	5700	4.4	4000	3.1	5500	4.2

[1]Percent (glass and door) total wall area.

[2]Weighted average of insulation values of existing New England housing stock as determined for internal report at FEA by Insulation Manufacturers Association.

for existing and new residential construction. The values given in this table are the basis for carrying out the remaining calculations.

Figures 2 and 3 show the average number of heating and cooling days in different parts of the U.S.[9] When multiplied by the proper value in Table 4, they yield the annual heating and cooling loads for specific region under examination. Fuel consumption can then be determined using efficiency values given in the text.

Table 5 presents a suggested format for the calculations in the form of a worksheet. The parameters entering into the calcuations are described below.

Unit Demand (d)

1. Heat/Cool season (^{o}days),d_2: Annual average degree-days for heating and cooling seasons may be taken from the national degree day contour maps (Figures 2 & 3) or determined from local climatological data.

2. Heat/Cool Demand (Btu/yr per ^{o}dy),D: The energy required to heat or cool a dwelling unit per heating or cooling degree-day, respectively. The values shown are energy demands for a standardized dwelling unit (1300 sq. ft., R-7 ceiling/R-5 wall insulation, 15% glass (plus door) area, w/basement) or new construction taken from Table 4. Where dwelling units in the region differ significantly from this standard, region-specific heat and cool demand can be established using the calibration worksheet which follows.

3. Unit Energy Demand (Btu/yr),E: The per-dwelling unit demand for energy in each end-use category, E_u=d·D.

Energy Demand

4. Land Use Activity (dwelling units),a: The number of dwelling units of each structural type - single family detached homes, attached or row houses, low rise or garden apartment units, high rise - which have heating and air-conditioning demands shown; and the total number of dwelling units with water heat, range, and major and minor appliances.

5. Total Energy Demand (Btu/yr),E: The total demand for energy in each end use category, E=aE_u.

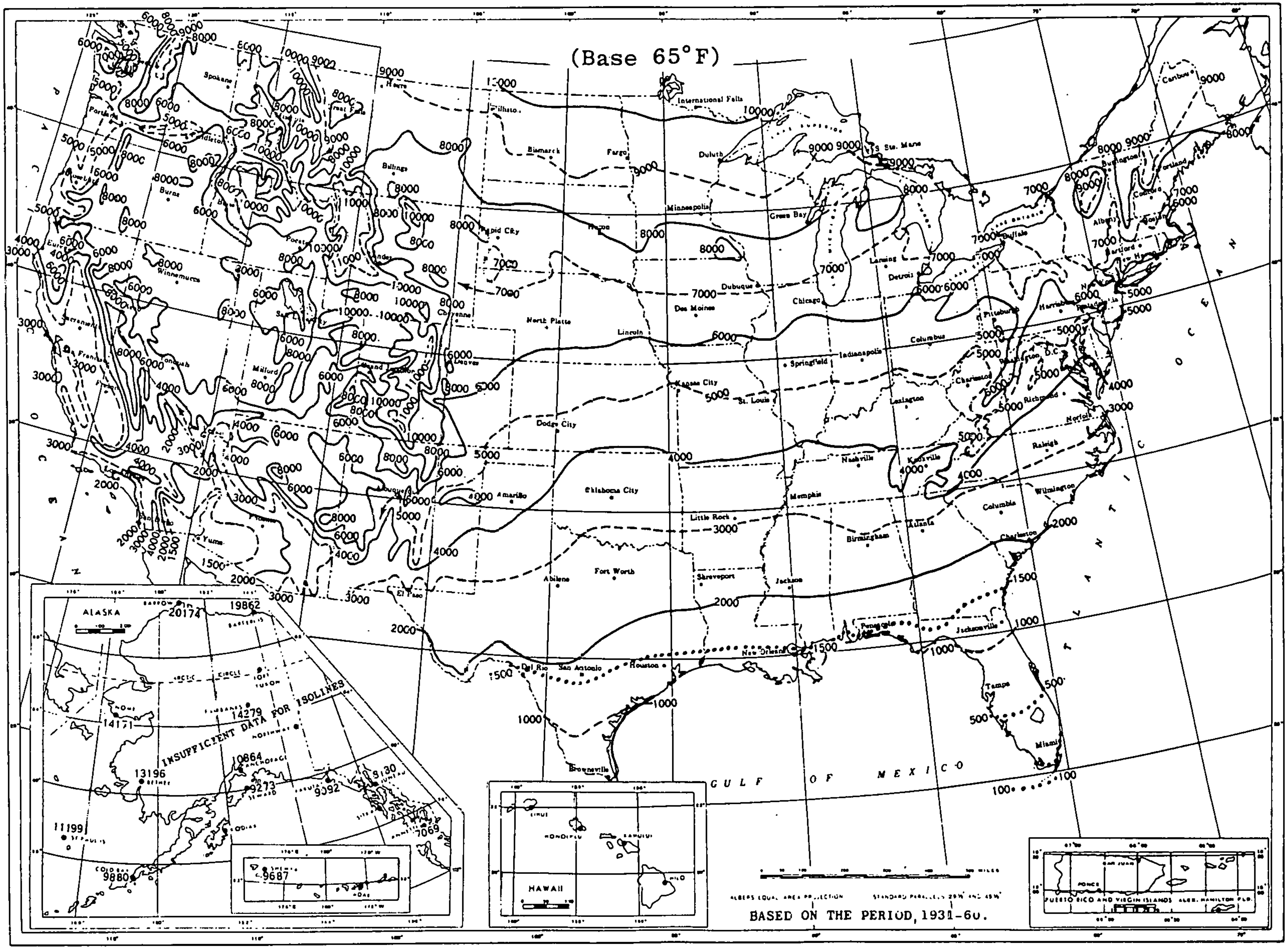


Figure 2. Mean annual total heating degree days.

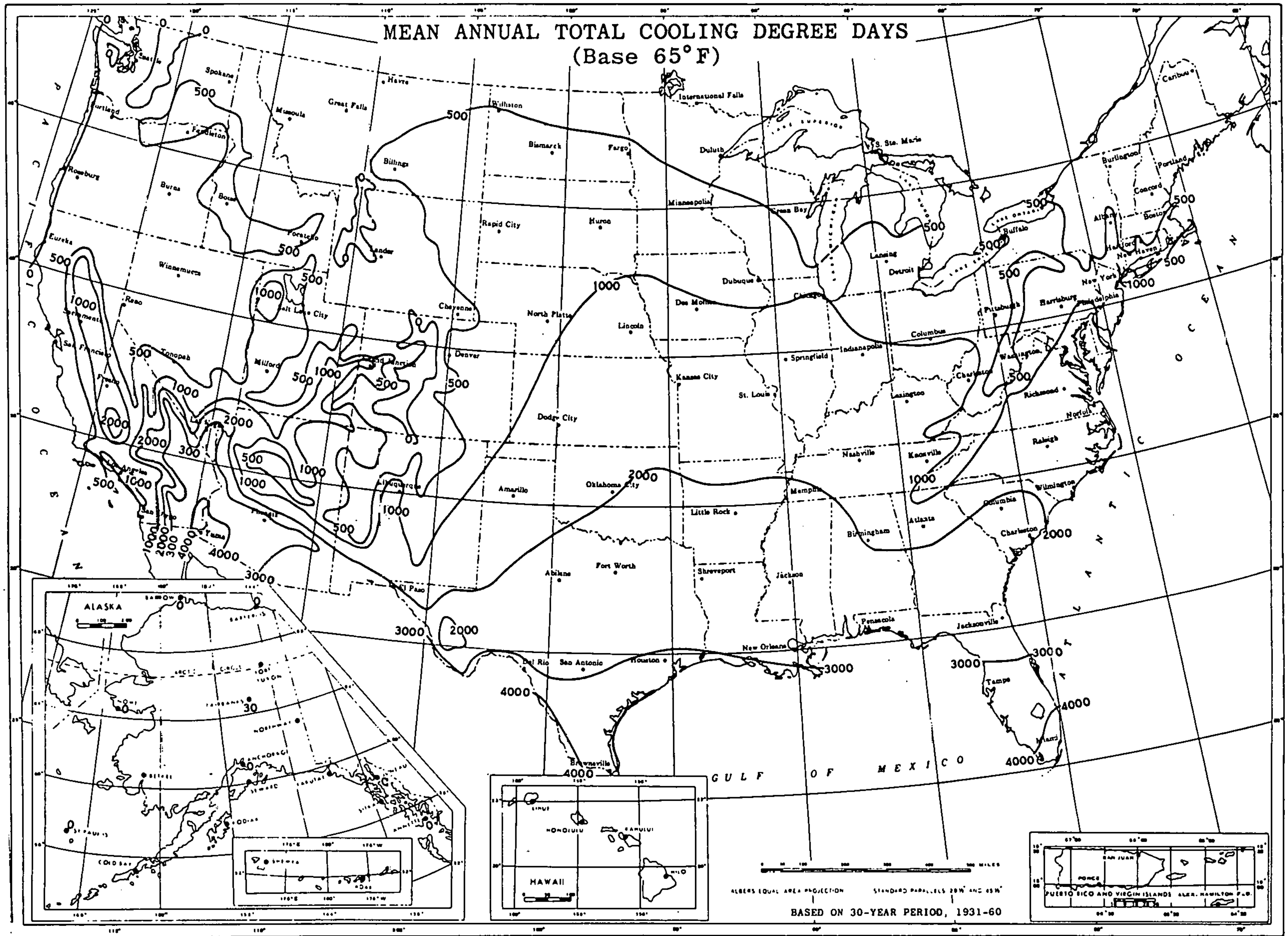


Figure 3. Mean annual total cooling degree days.

TABLE 5

RESIDENTIAL ENERGY WORKSHEET
("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E	F_u	b	F	F_u	b	F	F_u	b	F
			10^6											
Single Family Detached														
space heat		10,300												
air cond. -														
central		15,500												
room		6,200												
Single Family Attached														
space heat		7,400												
air cond. -														
central		12,500												
room		5,000												
Low Rise														
space heat		5,500												
air cond. -														
central		8,100												
room		3,200												
High Rise														
space heat		4,000												
air cond. -														
central		5,500												
room		2,200												
All Units														
water heat	-	-	18											
range	-	-	4											
electric appl.	-	-	21											
								Btu/yr (÷ 1.03 million Btu/Mcf) Mcf			Btu/yr (÷ 140 thousand Btu/Gal) Gallons			Btu/yr (÷ 3412 Btu/Kwh) Kwh

Fuel Consumption

6. Unit Fuel Demand(Btu/yr),F_u: The per-dwelling unit fuel required to meet the Unit Energy Demand (above). Fuel consumption depends upon the end-use technology employed, such as conventional burners, heat pump, etc. The efficiency, e, of each technology is the ratio of energy demand-to-fuel consumption. Then $F_u = E_u/e$.

   a. Natural gas technologies have the following efficiencies:

. Conventional burner	0.65
. Gas absorption residential central airconditioning	1.00
. Water heat	0.65
. Range	0.38

   b. Distillate oil burners have efficiency 0.65

   c. Electric technologies have the following efficiences:

. Resistance heating	1.00
. Heat pump - heat	2.00
- cool	2.50
. Central air-conditioning	2.50
. Room air-conditioning	2.00
. Water heat, range, appliances	1.00

In many regions of the country, all-electric homes are better insulated than gas or oil-fired homes. To account for this, we assign the overall system efficiencies for heating as:

. Electric resistance	1.25
. Heat pump-heat	2.50

7. Land Use Activity (dwelling units),b: The number of dwelling units which utilize natural gas, distillate oil, and electricity, respectively, for the end use category.

8. Total Fuel Consumption (Btu/yr),F: The total consumption of gas, oil, and electricity, respectively, in each end use category, $F = F_u \cdot b$.

9. MCF, Gallons, Kwh: These provide conventional measures of fuel consumption by taking column totals in Btu and conversion factors to indigenous measures of MCF (thousand cubic feet), gallons, and Kwh (kilowatt -hours) of gas, oil, and electricity, respectively.

For most purposes the Heat/Cool Demands (D) specified in Table 4 are suitable for general analysis of energy residential energy consumption characteristics. However, where housing units differ from the standardized construction, the calibration worksheet, Table 6, may be used to calculate heating and cooling loads appropriate to locally specified conditions. This table makes use of the fact that Btu/^{o}dy changes between actual dwelling units and the standard unit defined in Table 4, seldom differ by more than about 10-20% from the nominal heat/cool demand. Each parameter in the calibration worksheet shown in Table 6 is defined as follows.

1. Nominal Heat/Cool Demand (Btu/^{o}dy), D^{o}: The energy required to heat or cool a standard dwelling unit per heating or cooling degree day, respectively. (1300 sq. ft., R-7 ceiling/R-5 wall insulation, 15% glass area, w/basement). Values from Table 4.

2. Btu/^{o}dy per "x", $\partial D/\partial X$: The differential change demand for a unit change in size (sq. ft.) or insulation (ceiling R-value), or percent glass plus door area relative to total wall area including glass and doors. (Though ceiling R-value is stated for insulation, the differential value includes ceiling and wall insulation improvement typical in new construction. For ceiling only retrofit estimates, use 0.7 of the differentials given. To reflect decreasing heat savings at higher levels of insulation, use 0.7 of the differentials given for R-value increments greater than 15.)

3. Incremental "x", Δx: The difference in size, ceiling R-value, or percent glass (plus door) area between actual dwelling units and the standard dwelling unit indicated above.

4. Incremental Heat/Cool Demand (Btu/^{o}dy), ΔD: The required change in heat/cool demand to reflect region-specific dwelling unit size, insulation, and glass (plus door) area construction parameters. $D=(\partial D/\partial x)\Delta x$

TABLE 6

RESIDENTIAL REGION-SPECIFIC CALIBRATION

		SIZE			INSULATION			GLASS			
	HEAT Demand Btu/°dy	Btu/°dy Per sq. ft.	Size Increment	Incremental Heat Demand	Btu/°d per Ceiling R	Incremental Ceiling R	Incremental Heat Demand	Btu/°d Per 1%	Incremental %	Incremental Heat Demand	Region-Specific Heat Demand Btu/°dy
Existing Stock	(1)			(2)	(R-7)		(3)		(15%)	(4)	(1+2+3+4)
Single-family detached	14,300	7.6			240			200			
Single-family attached	10,200	6.0			180			110			
Low Rise	7,500	4.0			120			110			
High Rise	4,300	2.1			58			75			
New Construction					(R-11)						
Single Family Detached	10,300	5.6			110			200			
Single Family Attached	7,400	4.4			93			110			
Low Rise	5,500	2.9			58			110			
High Rise	4,000	1.6			30			75			
	COOL Demand Btu/°dy										
Existing Stock					(R-7)				(15%)		
Single-family detached	22,000	13.5			650			200			
Single family attached	17,700	12.0			620			110			
Low Rise	11,200	6.9			340			110			
High Rise	5,700	3.3			140			75			
New Construction					(R-11)						
Single-family detached	15,500	9.7			280			200			
Single family attached	12,500	8.5			260			110			
Low Rise	8,100	5.0			140			110			
High Rise	5,500	2.4			70			75			

5. Calibrated Heat/Cool Demand (Btu/^{o}dy),D: The region-specific energy required to heat or cool a dwelling unit per heating or cooling degree-day, respectively. $D=D^{o} + \sum_{x}(\partial D/\partial x)\Delta x$. This calibrated demand is used in the Residential Energy Worksheet. See Item 2 above and Table 5.

B. Commercial Energy Intensity Coefficients

Unlike the residential sector which can be divided into a limited number of building types and the industrial sector which can be classified by SIC groupings, the commercial sector traditionally has usually been defined to include all land use activities not included under residential and industrial use. This includes a variety of establishments ranging from the corner grocery store to large office complexes. In addition, architectural designs, construction materials, and practices in the commercial sector vary widely, and as a result, buildings which outwardly appear to be the same, may in fact, have energy consumption values which vary widely. Nevertheless, we have found that we can account for the major energy consumption differences in commercial structures by classifying them according to the activities occurring within these units. Therefore, to establish energy intensity coefficients in the commercial sector, we have disaggregated commercial building units into four primary groups: (1) office buildings, (2) dispersed retail establishments and other merchandizing activities, (3) centralized business district retail and shopping malls, and (4) other establishments including hotels, motels, schools, hospitals, recreational facilities, and religious institutions.

The energy consumption profile shown in Table 7 is typical of that found in commercial office space. The percentage breakdown of energy end-use demands closely parallels that in the residential sector with the important difference that whereas the unit energy demand in the residential sector was 104 thousand Btu/sq. ft., in the commercial sector land use activities, it is 157 thousand Btu/sq. ft. Direct costs per square foot for energy will be closer to that found in the residential sector since large commercial users generally have significantly lower energy charges on rate schedules in many areas of the country.

TABLE 7

COMMERCIAL ENERGY PROFILE

Office Space in the Northeast Region

5500 heating degree-days

1200 cooling degree-days

	End Use Demand per sq.ft.		Fuel Consumption per sq.ft.		Approx. Cost[2]	
Space Heat[1]	83 thous Btu	(53%)	.12 Mcf/.9 Gal/24 Kwh		$.24/.36/.60	
Air-Conditioning	42 thous Btu	(27%)	.04 Mcf	3.5 Kwh	.08	.20
Lighting	22 thous Btu	(20%)		9.4 Kwh		.38
Misc. Electric	10 thous Btu					
	157 thous Btu/sq/ft.				$.70 - 1.18	

[1] Includes water heat.

[2] Natural gas at $2/Mcf (thous. cu. ft.), Oil at 40¢/Gal., Electric at 2.5¢/Kwh heat and 4¢/Kwh general use.

Data concerning the levels of energy usage in the commercial sector are, in general, difficult to obtain. Furthermore, when available, these data are often intermixed with information relating to the residential or industrial sectors. Commercial sector energy data also comes assembled without specification for the energy usage for different types of commercial establishments, or occasionally is available for only one type of commercial establishment.(10) As in the residential sector analysis, our procedure in estimating heating and cooling energy demands makes use of engineering design calculations. To evaluate the relative heating and cooling loads of different size and type structures, we utilized field calibrations for heating demand in commercial-industrial single story light construction.(11) Unfortunately, air conditioning energy demands cannot be separately calibrated in the same fashion because of the lack of adequate measurements. Lighting demand is estimated from national standards as reflected in the Brookhaven National Laboratory data base.(12) Miscellaneous electric end uses include a wide variety of devices whose utilization patterns in the commercial sector are largely unknown. Using data on the electric requirements for the combined heating, air conditioning, and lighting demands available for a number of utility service areas and on total energy demand, the remaining balance was attributed to miscellaneous electric demand.(13) Energy demand in the commercial sector is stated in units of square footage of floorspace, rather than dollar sales, employment, or other possible variables, since floorspace relates most directly to energy needs and serves as a primary determinant in building design studies for most types of commercial structures.

Commercial Energy Worksheet

To account for differences in climatic conditions and to include region-specific variations in the mix of commercial activities, we have developed a simplified procedure for evaluating commercial sector energy intensity coefficients which makes use of

1) values of annual Btu consumption per heating and/or cooling degree-day for typical commercial land use activities, and

2) techniques and local data sources to verify the accuracy of energy intensity factors for the specific planning area.

The appropriate heating and cooling loads for existing and new commercial space are shown directly in the worksheet, Table 8. Within commercial buildings, there are substantial heat loads associated with both occupants and electric devices and lights. Since these internal loads are not subject to variations in weather conditions, the space heat and cooling demands for commercial buildings are written as a sum of weather-dependent load plus internal load, as shown in Table 8. The weather-dependent heating and cooling demands are used in conjunction with the heating and cooling degree-day contour maps shown earlier (Figures 2 & 3) to obtain the actual Btu requirements for commercial floorspace. The analysis then follows the same procedure as in the residential sector.

The analysis of energy demand and fuel consumption in the commercial sector is summarized in the worksheet. Each of the parameters that enter into the analysis is described below:

<u>Unit Demand</u>

1. <u>Heat/Cool Season (°days),d</u>: Annual average degree-days for heating and cooling seasons, which may be taken from the national degree-day contour maps or determined from local climatological data.

2. <u>Heat/Cool Demand (Btu/yr per °day),D</u>: The weather-dependent component of energy required to heat or cool commercial floorspace per heating or cooling degree-day, respectively.

3. <u>Internal Demand (Btu/°day),I</u>: The internal heat load associated with people and electricity use within commercial space, which acts to reduce total heating load and increase total cooling load.

4. <u>Unit Energy Demand (Btu/yr per sq.ft.),E_u</u>: The per-square foot demand for energy in each end use category. For heating demand, $E_u = (d \cdot D) - I$. For cooling demand $E_u = (d \cdot D) + I$. The values given are for standardized commercial floorspace. Since there can be wide variations in demand between individual buildings and between construction standards in different areas, region-specific unit energy demand should be verified using local data wherever possible.

TABLE 8

COMMERCIAL ENERGY WORKSHEET
("a" = square feet)

	UNIT DEMAND				ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/sq.ft. per °day)	Internal Demand (Btu/ sq.ft.)	Unit Energy Demand (Btu/ sq.ft.)	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	I	E_u	a	E	F_u	b	F	F_u	b	F	F_u	b	F
			10^3	10^3											
Office															
space heat		19	20												
air cond.		18	20												
electric				32											
Retail Mall															
space heat		18	20												
air cond.		20	20												
electric															
Retail Strip															
space heat		22	20												
air cond.		22	20												
electric				34											
Other															
space heat		16	15												
air cond.		15	15												
electric				32											
									Btu/yr (÷1.03 million Btu/Mcf) Mcf			Btu/yr (÷140 thousand Btu/Gal) Gallons			Btu/yr (÷ 3413 Btu/Kwh) Kwh

Energy Demand

5. Land Use Activity (sq.ft.), a: The commercial floorspace in each structural type--office, retail strip, retail mall, other--which have heating, air conditioning, and electric (lighting plus miscellaneous) demands shown.

6. Total Energy Demand (Btu/yr),D: The total demand for energy in each end use category, $E = a \cdot E_u$.

Fuel Consumption

7. Unit Fuel Demand (Btu/yr per sq.ft.),F_u: The per square foot fuel required to meet the Unit Energy Demand (3 above). Fuel consumption depends upon the end-use technology employed, such as conventional burners, heat pump, etc. The efficiency, e, for each technology is the ratio of energy demand-to-fuel consumption. Then $F_u = E_u/e$.

   a. Natural gas technologies have the following efficiencies:

. Conventional burner	0.65
. Gas absorption commercial air conditioning	1.00
. Water heat	0.65
. Range	0.38

   b. Distillate oil burners have efficiency 0.65

   c. Electric technologies have the following efficiencies:

. Resistance heating	1.00
. Heat pump - heat	2.50
cool	2.50
. Air conditioning	2.50
. Electric lighting plus misc.	1.00

8. Land Use Activity (sq.ft.),b: The commercial floorspace served by natural gas, distillate oil, and electricity for the end-use category.

9. Total Fuel Consumption (Btu/yr),F: The total consumption of gas, oil, and electricity, respectively, in each end-use category, $F = b \cdot F_u$.

10. MCF, Gallons, Kwh: These provide conventional measures of fuel consumption

by taking column totals in Btu and conversion factors to indigenous measures of MCF (thousand cubic feet), gallons, and Kwh (kilowatt hours) of gas, oil, and electricity, respectively.

C. Industrial Energy Intensity Coefficients

Industrial energy intensities vary substantially from one industry to another as shown in Table 9. Process energy, or heat utilized in manufacturing processes, constitutes a major demand in such industries as metal-working and food processing. Electronic equipment manufacturers use less process energy and have relatively large demands for space conditioning. Plastics and synthetic materials industries consume large quantities of feed stocks, that is, raw energy fuels - such as oil and gas - which are converted directly into product inputs. Nevertheless, patterns exist in industrial energy utilization which can be used to establish a set of industrial energy intensity coefficients.

Although the problem of categorizing and aggregating industrial activities is a difficult one, the use of the two-digit SIC group has come to be regarded as the most common method of categorizing industry for regional economic and land use planning. Energy utilization practices, however, vary significantly from one industry to another within these two-digit SIC groups, depending upon the age of plant, capital invested in energy-consuming industrial processing equipment, and other factors involved in the production process. For example, within SIC group 26 (paper and allied products) are contained both pulp processing and cardboard box manufacturing, which differ by a factor of ten in their energy demand levels.[14] The need for a different disaggregation scheme has lead us to adopt the following procedure.

We start with a base of nationally-averaged industrial energy utilization with 101 industrial sector classifications.[15] By combining certain industrial types, a 57-sector BEA Level (shown in Table 10) is obtained which retains distinctions between many of the industries normally subsumed under a two-digit SIC Code. Using cluster analysis techniques,[16] we examine energy use patterns with respect to energy per dollar-value added and energy per employee. This allows us to identify five major industrial groups which are both appropriate for land use planning purposes and which also characterize the major differences in energy intensity

TABLE 9

INDUSTRIAL ENERGY PROFILE

(Btu/Dollar Product Output)

	Feedstock	Process Energy	Space Heat[1]	Air Condition	Misc. Electric
Plastics and synthetic materials	23400	26100	780	2800	3000
Food and Kindred Products	100	5600	640	60	1000
Radio, Television, and Communication Equipment	-	30	1300	560	810
Paper and Allied Products Except Containers	220	44000	950	270	5200
Paperboard Containers and Boxes	-	3700	1100	90	1200

[1]Includes water heat.

TABLE 10

ENERGY COEFFICIENTS FOR INDIVIDUAL INDUSTRIES

Bureau of Economic Analysis Code	Industry Name	Employee Per $ Million Value Added	Thousand Btu Per $ Value Added
5	Iron and ferroalloy ores mining	36.73	80.0
6	Nonferrous metal ores mining	53.23	63.0
9	Stone and clay mining and quarrying	62.41	52.2
10	Chemical and fertilizer mineral mining	32.39	128.0
13	Ordanance and accessories	82.40	10.5
14	Food and kindred products	68.75	26.8
15	Tobacco manufactures	36.96	4.7
16	Broad and narrow fabrics, yarn and thread mills	196.27	37.2
17	Miscellaneous textile goods and floor coverings	94.39	26.5
18	Apparel	170.63	6.0
19	Miscellaneous fabricated textile products	138.27	12.2
20	Lumber and wood products, except containers	108.22	27.4
21	Wooden containers	142.92	14.6
22	Household furniture	131.65	7.9
23	Other furniture and fixtures	100.16	9.4
24	Paper and allied products except containers	67.87	125.0
25	Paperboard containers and boxes	98.56	11.1
26	Printing and publishing	93.71	5.6
27	Chemicals and selected chemical products	45.46	253.0
28	Plastics and synthetic materials	58.83	158.0
29	Drugs, cleaning and toilet preparations	20.05	13.3
30	Paints and allied products	70.10	37.1
31	Petroleum refining and related industries	58.36	1894.0
32	Rubber and miscellaneous plastics products	83.64	27.9
33	Leather tanning and industrial leather products	103.73	38.5
34	Footwear and other leather products	161.28	6.1
35	Glass and glass products	76.96	76.0
36	Stone and clay products	85.09	133.0
37	Primary iron and steel manufacturing	73.93	451.0
38	Primary nonferrous metal manufacturing	63.90	86.1
39	Metal containers	61.45	15.1
40	Heating, plumbing and structural metal products	98.[illegible]8	14.0
41	Stampings, screw machine products and bolts	80.24	11.8
42	Other fabricated metal products	86.01	15.9
43	Engines and turbines	75.03	16.[illegible]
44	Farm machinery and equipment	80.84	16.0
45	Construction, mining and oil field machinery	74.23	14.1
46	Materials handling machinery and equipment	85.01	7.1
47	Metalworking machinery and equipment	77.13	7.3
48	Special industry machinery and equipment	86.63	7.9
49	General industrial machinery and equipment	80.60	10.4
50	Machine shop products	92.85	10.0
51	Office, computing and accounting machines	69.24	5.1
52	Service industry machines	83.44	9.5
53	Electric industrial equipment and apparatus	84.17	10.1
54	Household appliances	87.08	15.6
55	Electric lighting and wiring equipment	81.65	10.4
56	Radio, television and communication equipment	83.91	5.7
57	Electronic components and accessories	110.73	10.2
58	Miscellaneous electrical machinery, equipment, and supplies	82.08	11.7
59	Motor vehicles and equipment	55.19	12.3
60	Aircraft and parts	84.67	8.1
61	Other transportation equipment	101.32	10.7
62	Scientific and controlling instruments	96.38	6.7
63	Optical, ophthaimic and photographic equipment	52.66	5.3
64	Miscellaneous manufacturing	112.20	7.6

coefficients among industrial sector activities.

Light Industry

This group includes all of the light manufacturing industries. The very lowest energy consumers include the manufacturing of optical equipment, printing, and various apparel producers.

Medium Industry

This group is composed of a miscellany of personal consumption industries including food and kindred products, textile goods, rubber and plastics, lumber and wood production, paint and leather production.

Mining and Metals

This group includes four industries: stone and clay mining, non-ferrous metal ore mining and manufacturing, iron ore mining and glass products.

Paper and Chemicals

This group includes chemical and fertilizer production, paper and allied production, and manufacturer of stone and clay products.

Synthetics

These industries include plastics and synthetic materials production, chemical and chemically-related production, paving mixture, asphalt felts and coatings production. Most of their energy use appears indirectly in feedstock consumption. Primary iron is also included in this group. Most of its energy is derived from the energy product sector of coke (ore-reduction) feed stocks.

The industrial energy intensity coefficients adopted for each industry group are shown in Table 11. We have also found it useful to include information on energy consumption per acre. However, these figures are based upon planning design criteria utilizing employees/acre as a unit which may vary for different regions.[17] Although the variation in the energy intensity coefficients within each of the industry groups described above is fairly large, these values offer a useful starting point for evaluation of local energy demands in the industrial sector.

TABLE 11

INDUSTRIAL ENERGY - EMPLOYMENT - LAND USE
BY INDUSTRY GROUP

Industry Group	Energy Per Dollar Value Added (Thous. Btu/$)	Employees Per Dollar Value Added (Emp/Mill. $VA)	Energy Per Employee (Million Btu/Emp)	Energy Per Acre (Mill. Btu/Acre)	Employee Per Acre
Light Industry	10.5	90	120	3360	28
Medium Industry	32	100	310	8680	28
Mining and Metals	72	59	1170	9360	8
Paper and Chemicals	129	62	1710	13680	8
Synthetics[1]	-	46	-	-	16

[1]Energy intensity depends upon specific industrial process, plant characteristics, etc.

Where detailed data is available on existing and projected industrial and employment mixes, more precise energy intensity coefficients for each of these industrial sector categories can be estimated using the information in Table 10. Although we have noted the difficulties associated with the use of SIC groups as the basis for energy analysis in the industrial sector, it offers an alternative method for using regional land use and economic activity data to calculate local industrial energy intensity coefficients. Table 12 which lists the energy intensity coefficients according to SIC groupings is provided for this purpose.

Industrial fuel mixes are also difficult to characterize because the fuels used are dependent on both the industrial processes employed[18] and local prices and availability of specific fuels. In certain industries use can be made of the knowledge that the manufacturing processes employed requires "clean" flame energy derived, normally, from natural gas (or propane). Likewise, many industrial operations in food processing and other product manufacturing are mandated by various government regulations to use gas. For many other process heat and space heat applications, however, both gas and oil fossil fuels may be used and industrial plants will often have alternative fuel capabilities. As a result our analysis of fuel mix in the industrial sector is based on identifying, in so far as possible, the combination of functional end uses for which energy is used - process heat, space conditioning, lighting, etc. Such information makes it possible to establish at least ranges of values for fossil fuel and electrical demand. For the remaining categories information on fuel requirements must be obtained using knowledge of local manufacturing processes and fuel use practices.

In the case of more energy intensive industrial activities, the fuel mix becomes too industry-and-plant specific to use this procedure. Where detailed fuel information is desired in such cases, we cite sources below which will provide the requisite local industrial fuel breakdown.

TABLE 12

INDUSTRIAL-ENERGY-EMPLOYMENT-LAND USE

by SIC GROUP

SIC		Thousand Btu Per $ Value Added	Employee Per $ Million Value Added	Million Btu Per Employee
20	Food & kindred products	286.6	75.7	3545.6
21	Tobacco Manufacturers	46.5	22.4	2075.1
22	Textile goods, floor coverings, yarns & threads	350.5	120.7	2903.4
23	Miscellaneous fabricated textile products	127.4	138.6	919.7
24	Lumber & wood products plus containers	268.5	133.6	2010
25	Household & other furniture & fixtures	94.7	112.6	841.2
26	Paper & allied products plus containers & boxes	966.8	80.9	11957.6
27	Printing & publishing	57.0	101.3	562.5
28, 29	Chemical, plastic, paint, drugs, cleaning & petrol. products	35.4	58.2	608.2
30	Rubber & miscellaneous plastic products	219.0	84.1	2604
31	Leather footware & industrial products	115.4	163.9	703.9
32	Glass, stone & clay products	1166.5	90.0	12957.2
33	Nonferrous, iron & steel manufactur.	1691.6	73.2	23108.7
34	Fabricated metal products	143.8	89.2	1611.7
35	Engines, Construction & industrial machinery	114.5	86.2	1327.7
36	Electrical equipment, appliances & machinery	92.4	93.7	983.5
37	Transportation vehicles & equipment	105.9	75.9	1395.6
38	Professional, scientific photo. equipment	60.1	85.5	702.6
39	Miscellaneous Manufactur.	76.4	119.8	637.7

INDUSTRIAL ENERGY - FUEL MIX

Industry Group		Energy Per Dollar Value Added (Thousand Btu/$)		Energy Per Employee (Million Btu/EMP)	
Light Industry					
. Fossil		7.5		83	
. Electric		2.8		31	
. Feedstock		.2		6	
	Total		10.5		120
Medium Industry					
. Fossil		21.8		218	
. Electric		5.8		58	
. Feedstock		4.4		34	
	Total		32.0		310

Industrial Energy Worksheet

The analysis of energy demand and fuel consumption in the industrial sector is summarized on the worksheet, Table 13. Each of the parameters that enter into the analysis is described below.

Unit Demand

1. Heat/Cool Season (^{o}days),d: Annual average degree-days for heating and cooling seasons, which may be taken from the national degree-day contour maps or determined from local climatological data.

2. Heat/Cool Demand (Btu/yr per ^{o}dy),D: The energy required to heat or cool industrial plant space per heating or cooling degree-day respectively. The values given are energy demands per employee for standardized industrial space. Since there can be wide variations in demand between individual buildings and between construction standards in different areas, region-specific heat and cool demands should be verified using local data where-ever possible.

3. Unit Energy Demand (Btu/yr per sq. ft.),E_u: The per-employee demand for energy in each end-use category, $E_u = d \cdot D$.

4. Land Use Activity (sq. ft),a: The employment for each type of industry.

TABLE 13

INDUSTRIAL ENERGY WORKSHEET
("a" = per employee)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/Cool Season (°days)	Heat/Cool Demand (Btu/°dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E	F_u	a	F	F_u	a	F	F_u	a	F
Light Industry process space heat air cond. electric			120million											
Medium Industry process space heat air cond. electric			310million											
Heavy Industry process space heat air cond. electric			1170million											
Energy-intensive process			-specific-											
								Btu/yr (÷1.03 million Btu/Mcf) Mcf			Btu/yr (÷140 thousand Btu/Gal) Gallons			Btu/yr (÷3413 Btu/Kwh) Kwh

5. Total Energy Demand (Btu/yr), E: The total demand for energy in each end use category, $E=aE_u$.

Fuel Consumption

6. Unit Fuel Demand (Btu/yr per sq. ft), F_u: The per-employee fuel required to meet the Unit Energy Demand (3 above). Fuel consumption depends upon the end-use technology employed, such as conventional burners, heat pump, etc. The efficiency e, of each technology is the ratio of energy demand-to-fuel consumption.
Then $F_u=E_u/e$.

   a. Natural gas technologies have the following efficiencies:

. Conventional burner	0.65
. Gas absorption industrial air conditioning	1.00

   b. Distillate oil burners have effiency 0.65

   c. Electric technologies have the following efficiencies:

. Resistance heating		1.00
. Heat pump	- heat	2.50
	- cool	2.50
. Air conditioning		2.50
. Electric (lighting plus miscellaneous)		1.00

7. Land Use Activity (sq. ft), b: The industrial plant space served by natural gas, distillate oil, and electricity for the end-use category.

8. Total Fuel Consumption (Btu/yr), F: The total consumption of gas, oil, and electricity, respectively, in each end-use category, $F=b\cdot F_u$.

9. MCF, Gallons, Kwh: These provide conventional measures of fuel consumption by taking column totals in Btu and conversion factors to indigenous measures of MCF (thousand cubic feet), gallons, and Kwh (kilowatt hours) of gas, oil, and electricity, respectively.

D. Transportation Energy Intensity Coefficients

To estimate the energy intensity coefficients in the transportation sector one must establish the major determinants of travel, evaluate their relationship to prevailing spatial patterns of land use, and assess the accuracy of available transportation demand data for different regions of the country. Based on these findings, one can then adopt a heuristic procedure for evaluating the energy intensity coefficients utilizing both national and local data sources. This approach implicitly assumes that the spatial distribution of land use activities plays a dominant role in influencing both the frequency and length of local work and shopping trips. This is borne out in studies of personal travel demands in a number of urban centers around the country.[19 thru 21]

Personal travel accounts for about 70% of all travel in most areas of the country - the remainder being evenly divided between heavy truck traffic and air, train, and ship movements.[22] Because non-personal travel is generated by the levels and types of local commercial and industrial activities and is more difficult to estimate, we restrict our attention in this section to personal travel by automobile and mass transit modes. The breakdown of personal travel purposes, based on nationally averaged values[23], shown in Table 14 indicates that the significant travel demand parameters which determine total energy consumption are -

- trips per household
- trip length
- modal split
- vehicle occupancy rate

For any individual area the variation of the values for these parameters will depend on such factors as distribution of income levels, distance from urban centers, population density, local access to commercial sites, etc. For example, Figure 4 shows that the total daily number of household trips increases for low residential densities[24] and Figure 5 shows that trip length increases for larger shopping areas, a reflection

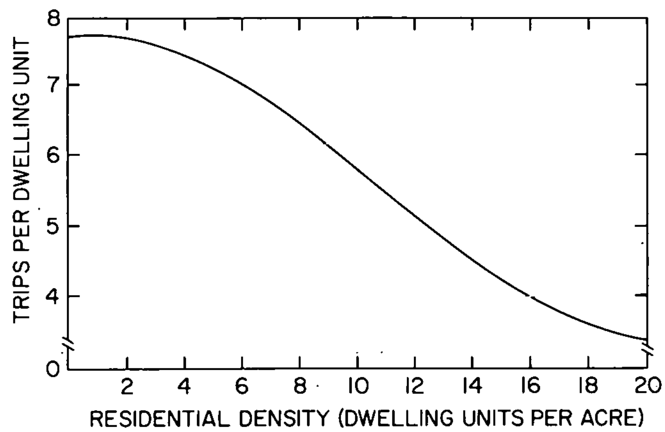
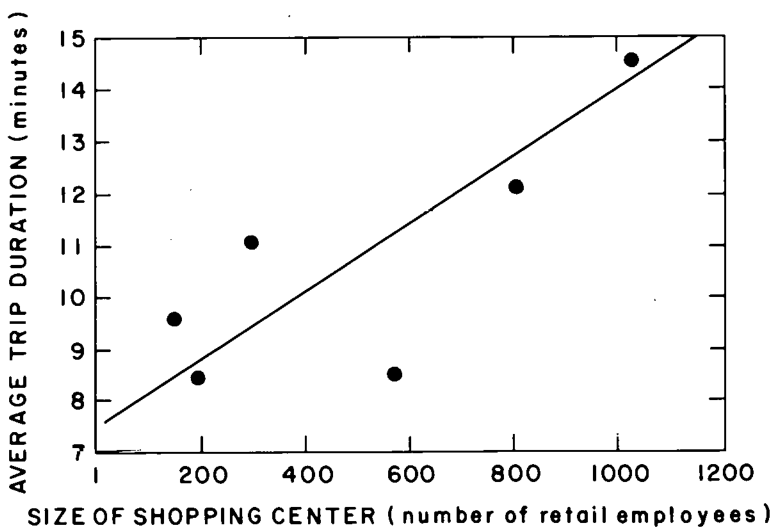


Figure 4. Residential density and daily transportation trips.



Source: Virginia Penninsula Transportation Study

Figure 5. Trip duration and shopping center size.

TABLE 14

TRANSPORTATION ENERGY PROFILE

Trip Purpose	Daily Number of Person Trips Per Household	Average Trip Length	Annual Passenger Miles per Household	Auto Occupancy Rate	Annual Vehicle Miles per Household
Work	2.03 (37%)	10.2	7300 (44%)	1.2	6100 (49%)
Shop	1.65 (30%)[1]	5.6	3200 (19%)	1.4	2300 (19%)
Other[2]	1.79 (33%)	9.9	6200 (37%)	1.6	3900 (32%)
	5.47 (100%)	8.8	16700 (100%)	1.5	12300 (100%)

[1]Excluding children under 6.

[2]Excluding an average 160 vehicle miles for vacation trips.

of the larger catchment areas being served.

Although the range of data sources and transportation demand models is extensive, they are lacking in certain specifics.[25] For example, trip length studies vary in their categorization of trip functions and are, therefore, difficult to intercompare. Studies which have concentrated on urban areas also have tended to aggregate data for different categories of trips. The models which have been developed to simulate personal travel patterns are often large and difficult and expensive to apply to a specific region.

Our procedure to establish the determinants of transportation energy intensity reflects the correlation of studies of urban areas,[26-30] utilization of the land use-energy model developed for this project,[31] and parametric analyses of the relation between density, distance from city centers, and travel preferences. Since vehicle occupancy rates determined in urban-suburban studies in various locales and in the National Personal Transportation Survey (NPTS) for different trip purposes show only small differences, those from the NPTS were adopted for use here. The trip generation rates were taken from the Urban Transportation Planning System[32] which are based upon nationally-averaged study results. The dependence of trip lengths upon local land use density was explored through simulation runs of the computer land use-energy utilization model. These results combined with studies of the population distributions of metropolitan areas give trip lengths which are based primarily on population and employment density variations with distance from central cities.[32] The proper choice of appropriate trip lengths is then further simplified utilizing a graphical representation (Figure 6) of these results.[33]

Finally, to include the dependence of trip generation and trip lengths, on community income levels, we utilize the NPTS data to estimate percentage shifts in these two parameters for varying income levels.

Transportation Energy Worksheet

The analysis of energy demand and fuel consumption in the transportation sector is summarized on the worksheet given in Table 15. Each of the parameters that enter into the analysis is described -

TABLE 15

TRANSPORTATION ENERGY WORKSHEET

	UNIT DEMAND			ENERGY DEMAND							FUEL CONSUMPTION					
	Vehicle Energy Demand (Btu/veh.mi)	÷ Vehicle Occupancy Rate	Unit Energy Demand (Btu/pass.mi.)	Land Use Activity (no. household)	Daily trips per household	Daily Pass Trips	Average Trip Length	Annual Pass.Mi. per trip* (*364 days)	Modal Split	Total Energy Demand (Btu/yr)	Unit Oil Demand (Btu/pass.mi.)	Total Pass. Mi.	Total Oil Consump. (Btu/yr)	Unit Elect. Demand (Btu/pass. mi.)	Total Pass. Mi.	Total Electric Consump. (Btu/yr)
	E_v	V	E_u	a	O	T	L	M	S	E	F_u	b	F	F_u	b	F
Trip Purpose/Mode																
Work					2.03		10.2	3710								
Auto	1840	1.2	1530								7700					
Bus	4630	20.	230								1150					
Rail/diesel	53200	40.	1330								4430					
electric	18100	40.	450								—					
Shop					1.65		5.6	2040								
Auto	1840	1.4	1320								6600					
Bus	7050	23.	310								1550					
Other					1.79		9.9	3600								
Auto	1840	1.6	1150								5750					
Bus	7050	23.	310								1550					
													Btu/yr (÷140 thousand Btu/Gal) Gallons			Btu/yr (÷3412 Btu/Kwh) Kwh

1. Vehicle Energy Demand (Btu/vehicle-mile), E_v: The per vehicle mile demand for energy of each transportation vehicle type utilized for each type of trip.

2. Vehicle Occupancy Rate, V: The average number of riders per vehicle. A brief comparison between ridership and capacity for work trip is given below.

	Occupancy	Capacity	Saturation
Auto	1.2	4	30%
Bus	20.	50	40%
Railcar	40.	120	30%

Where available, local data on occupancy rates should be used.

3. Unit Energy Demand (Btu/passenger-mile), E_u: The per passenger-mile demand for energy of each transportation mode utilized for each type of trip, $E_u = E_v / v$.

Energy Demand

4. Land Use Activity (households), a: The number of households in the region.

5. Daily trips per household, o: The average number of daily trips of each type from a household which will vary with community income level. The values given are nationally averaged trip generation rates. Daily trips per household for region-specific analysis should be taken from Table 16. Local survey data also may be used, where available, to establish region-specific daily trips per household.

6. Daily Passenger Trips, T: The total daily number of trips by purpose-by mode, $T = a \cdot o$.

7. Modal Split, s: The fraction of passenger trips for each purpose which are made by each mode. The values shown are national-averages for urban areas. For region-specific analysis, the modal split is best obtained through local data.

8. Trip length, L: The one way distance for each trip purpose. The values given are nationally averaged trip lengths. However, trip length depends upon distance from urban center and community income levels. Region-

TABLE 16

TRIP PRODUCTION RATES

(daily person trips per household, excluding children under 6)

Trip Purpose	Income Level 1	Income Level 2	Income Level 3	Average
Work	1.18	2.20	2.54	2.03 (37%)
Shop	.90	1.75	2.20	1.65 (30%)
Other	.95	1.88	2.44	1.79 (33%)

Note: Income Level 1: Low income
Income Level 2: Middle income
Income Level 3: High imcome

specific trip length should be determined as follows;

a. The work trip length may be estimated from Figure 6. In areas where population is more widely and uniformly dispersed relative to work opportunities (Los Angeles, Seattle, etc.), trip lengths tend to be longer; and vice versa.

b. The Shop, Other, and Truck trip lengths should be scaled by:

Shop trip length = .55xWork trip length
Other trip length = .97xWork trip length
Truck trip length = .73xWork trip length

c. Where community income levels vary significantly from national averages, the work, shop, and other trip lengths may be increased or decreased by the percentages noted in Table 17.

(This region-specific trip-length analysis assumes the region itself is a small part of some larger urban area. Where the region under study has a wide variation in density of land use, it may be best to break up the study area into several pieces with more uniform land use densities. For regions possessing unusual travel characteristics e.g. commuting is almost exclusively to an urban core by express rail service, trip lengths may be estimated using local data. A more detailed analysis can be carried out using the land use-energy simulation model and transportation analyses found elsewhere.)

9. Annual Passenger Miles per Trip, M: The per daily-passenger trip annual miles traveled, $M=364 \cdot S \cdot L$. Note that this is not the annual miles per household. Since the demand for travel - trip origins - determines the average number of travelers leaving the home - daily passenger trips - the actual annual passenger miles per household for the various trip purposes is $M_P=364 \cdot o \cdot S \cdot L$. Similarly, the actual annual vehicle miles per household is $M_V=364 \cdot (o/v) \cdot S \cdot L$.

10. Total Energy Demand (Btu/yr), E: The total demand for energy in each transportation purpose-mode category, $E_u \cdot T \cdot M$.

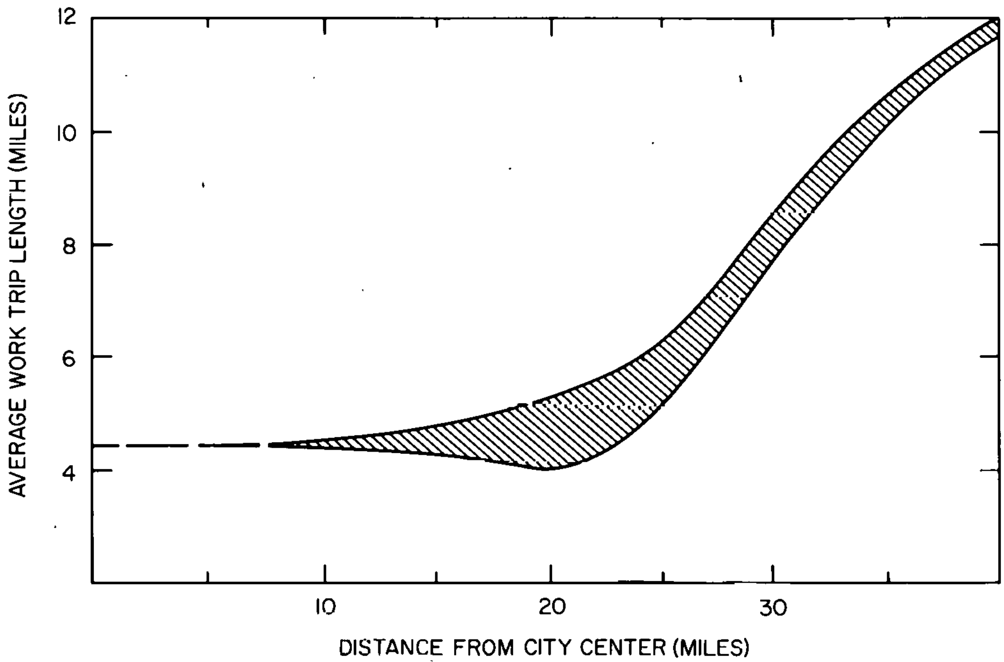


Figure 6. Work trip lengths & distance from the core.

TABLE 17

TRIP LENGTH

(miles)

Trip Purpose	Income Level 1	Income Level 2	Income Level 3	Average
Work	8.5 (-17%)	10.2 (-1%)	12.7 (+23%)	10.2
Shop	6.2 (+7%)	5.6	5.4 (-4%)	5.6
Other	8.9 (-10%)	10.8 (+9%)	9.9	9.9
Average	8.3 (-6%)	8.9 (+1%)	9.7 (+10%)	8.8

Note: Income Level 1: Low income
Income Level 2: Middle income
Income Level 3: High income
The ( ) denotes the percentage change from the average trip length for each purpose.

Fuel Consumption

11. Unit Fuel Demand (Btu/veh.mi.),F_u: The per passenger-mile fuel required to meet the Unit Energy Demand (1 above). Fuel consumption depends upon the end-use technology employed, such as internal combustion engines, diesel engines, etc. The efficiency, e, of each technology is the ratio of demand to fuel consumption.

Then, $F_u = E_u / e$.

a. Oil technologies have the following efficiencies:

. Internal combustion engine	(gasoline)	0.20
	(diesel)	0.30
. Diesel locomotive		0.30

b. Electric technologies have the following efficiencies:

. Electric auto/truck/bus	0.70
. Electric rail	1.00

12. Total Passenger Miles,b: The total passenger-miles traveled utilizing oil and electric driven vehicles, respectively.

13. Total Fuel Consumption (Btu/yr),F: The total consumption of oil and electricity, respectively, in each end-use category. $F = b \cdot F_u$.

14. Gallons,Kwh: These provide conventional measures of fuel consumption by taking column totals in Btu and conversion factors to indigenous measures of gallons and Kwh (kilowatt-hours) of oil and electricity, respectively.

E. Data Sources for Verifying Local Energy Intensity Coefficiients

There are several basic references which are useful in the construction of energy consumption for land use and transportation. These are "Patterns of Energy Consumption in the United States",[34] "Sourcebook for Energy Assessment," BNL 50483[35] the FEA Project Independence reports,[36] reports by the National Bureau of Standards,[37] and Hittman Associates,[38] and the Brookhaven "Energy Model Data Base".[39] The first two are basic documents which should be referred to in order to understand technical features of energy conversion efficiencies. The Brookhaven "Energy Model Data Base," a recently completed compilation of data on energy conversion efficiencies, process costs, and pollutant emission coefficients, is a particularly useful reference source since it has been designed to provide data on technology descriptors in a format compatible with the worksheets developed above. Much of the data in this file are for the year 1970 and are based on national average numbers.

Region specific data on the residential sector may be obtained from census publications including the County and City Data Book,[40] Detailed and General Housing Characteristics,[41] Public Use Samples,[42] County Business Patterns,[43] and Department of Commerce, Bureau of Labor Statistics.[44] For example, the Public Use Sample (PUS) of the 1970 Census may be used as a primary source of data on appliance ownership and household characteristics. The PUS differs from other forms of U.S. Census information. It is a representative sample of the records directly from census questionnairies, and therefore, many variables related to energy may be cross-tabulated. The household characteristics described include: appliance ownership; household income; size, type, and value of dwelling; county of residence; size of family, race, age, and characteristics of household members. The Public Use Samples can be used independently to generate useful basic data on energy, economic, and socially related variables, particularly the breakdown of number of households by structural type and by type of fuel for entry into the Residential Worksheet.

The best sources of energy data to validate energy consumption in homes utilizing natural gas and electricity are the local utilities. They will generally have available a household profile along the lines of that shown in Table 18. Often, however, the gas and/or electric space heat values from such sources reflect older, smaller, and perhaps seasonal housing and the indicated consumption values may not be appropriate for general use in the region. Testing the accuracy of oil-fired home unit energy demands is difficult in most regions because the home heating fuel business is extremely diverse and competitive. Local fuel dealers will often provide sufficient data. A second validity test on all data is by checking separate values in

TABLE 18

ANNUAL HOUSEHOLD ELECTRICITY DEMANDS - 1972

Residential	10^6 Btu Per Unit	Kwh per Household	Saturation	Kwh per Household
(Space Heat)	(51.2)[1]	(15000)		
Water Heat	16.4	4800	.04	190
Air Conditioning				
Central	11.0	3200	.081	260
Room	1.5	440	.73	320
Lighting	4.4	1300	1.00	1300
Refrigerator	5.1	1500	1.00	1500
Major Appliances[2]	10.1	3000	.39	1200
Miscellaneous[3]	4.9	1400	1.00	1400
		Total, non-space heat		6670 Kwh

[1] Single family

[2] Washer, dryer, dishwasher, freezer

[3] Heating plant, TV, small appliances

each category against aggregated residential sector energy demands. Local utilities can provide such data for natural gas and electricty in their service territory, and oil companies or industry institutes, the equivalent values for oil.

Comparable energy data for the commercial sector are difficult to obtain. The Project Independence reports noted above contain land use inventories for commercial floorspace and energy consumption data for different types of commercial establishments. More detailed engineering data on commercial structure energy consumption is available through consulting firms.[45] The "E Cube" programs of the American Gas Association[46] also provide technical specifications for buildings. The natural gas and electricity sales data from local utilities prove less valuable since most utilities generally classify users by amount of consumption rather than type of establishment and do not normally monitor the use patterns of individual customers. However, their aggregate regional sales do provide overall reference points for the worksheet analysis.

Energy consumption data for the industrial sector are available from many sources. Quantities and types of fuels consumed by SIC Code in SMSA's and by state are summarized in the "Special Fuels Report" of the Census of Manufacturers.[47] Industrial usage can also be estimated by applying the regional percentage of industrial earnings by a SIC Code to the national fuel consumption of each industry group (shift/share method). Where data are available on industrial group dollar output, similar scaling can be applied. Other publications include detailed industry-by-industry and process-by-process descriptions of energy utilization.[48] An EPA environmental data base contains consumption data by fuel type at the regional office level.[49] State and local agencies concerned with industrial development, energy management, or environmental protection sometimes collect regional data on industrial fuel use. Finally, gas and electric utilities often have fuel consumption profiles for individual, as well as classes or users. This data is often, however, not normally available to the public.

The Clean Air Act of 1970 has resulted in a great deal of pertinent information being gathered for a number of urban centers throughout the country. Estimates of transportation energy use and emissions, as well as fuel use for non-transportation purposes is provided in the "Air Quality Implementation Plans".[50] In addition the U.S. Department of Transportation, through publications such as "Highway Statistics" and "Nationwide Personal Transportation Survey,"[51] provides excellent data on automobile and truck usage in the U.S. The U.S. Census of Transportation[52] is another useful basic data source dealing with energy usage in the transportation sector.

To validate energy use involving public transportation, there is a variety of source material. Interstate railroads are generally required to file yearly reports to state public utility commissions.[53] These reports contain information on diesel fuel and electricity consumed. The Army Corps of Engineers collects data on vessel movements in and out of ports.[54] The Federal Aviation Administration, the Civil Aeronautics Board, the U.S. Department of Transportation and states' Department of Transportation all collect data on flight operations at all major commercial airports. In addition, because gasoline, jet fuel, and other motor vehicle fuels usually incur state taxes, the state departments of taxation and finance usually maintain monthly fuel consumption figures for each of these fuel types.

F. Description of the Energy Supply-Distribution System

The characterization of the regional or community energy supply-distribution system requires the assembly of data on the capacities and locations of import facilities, electric generating stations, and refineries, pipelines, transmission lines, and storage units. It also contains information on flow of fuels, mode and location of entry, and existing inventories. Accompanying this region-specific data base are coefficients which describe environmental emissions per unit of our energy production of consumption, and the efficiencies of the energy production, conversion, and consumption technologies employed.

The level of detail required to describe the local energy supply-distribution will depend on the policy question it is intended to deal with. Data relating to the mode of fuel entry into the region is important if the issues being examined involve the assessment of area-imposed constraints on regional energy supplies. The imposition of such constraints interacts with local land use decisions through zoning and environmental regulations. Fuel inventory data can provide a picture of the region's resilience to future shortages of specific fuel types. Environmental emission coefficients are useful in assessing the influence of energy production and consumption on overall air and water quality.

In what follows we present a series of tables and graphs which are intended to illustrate the types of results which can be anticipated in characterising the energy supply-distribution system. We also identify local and national sources of information and data which may be used in constructing a local data base. The reader is referred to the "User's Guide for Regional Reference Energy Systems"[5] for constructing a data base describing the regional energy supply-distribution system.

Fossil Fuel Supplies

Tables 19 and 20 offer illustrative examples of gas and oil flow summary sheets used in the analysis of regional energy supplies. The data sources used in their preparation were both local and national and required estimation of the distribution of imported supplies throughout the service area. Fuel supply data by fuel type and by state are available from the U.S. Bureau of Mines,[55] National Gas Association,[56] and the National Coal Association.[57] The U.S. Corps of Engineers maintains the most comprehensive set of data on ship and barge movements of energy supplies.[58] Interstate shipments of oil products and natural gas are reported by pipeline companies to the Interstate Commerce Commission,[59] the American Petroleum Institute,[60] Association of Oil Pipelines,[61] and the Federal Power Commission.[62] In addition, other excellent initial starting sources include the FEA "Monthly Energy Review",[63] Oil and Gas Journal,[64] and "Historical Energy Flows" by Jack Faucett Association.[65]

It is worth noting that the process of assembling information on regional fuel supplies is not a straight-forward one in most cases. Much of the required data lies in the private sector which limits accessability and even in cases where it is available, it is either not sufficiently disaggregated or the categories used do not correspond to neighboring political jurisdictions. The same limitations apply to many types of utility data, although in these cases utility regulatory overseers can be used as intermediaries in

TABLE 19

NATURAL GAS BALANCE - 1972

(Billions of Cubic ft.)

Supply		Sales	
Purchases	67.221	Residential	28.148
Storage Withdrawal	0.599	Commercial	13.129
Manufactured Gas	0.210	Terminable	1.576
Intersystem Exchange	0.243	Interruptible	6.130
Subtotal	68.273	Subtotal	48.983
Placed in Storage	-9.109	Internal Use	4.308
Unaccounted for	-2.844	Sales to Other Utilities	3.029
Subtotal	-11.953	Subtotal	56.320
Net Supply	56.320		56.320

TABLE 20

NASSAU-SUFFOLK OIL BALANCE - 1972

(millions barrels)

Supply	Distillate	Residual	Gasoline
Waterborne	17.7	18.6	26.8
Pipeline (cap. 70.1 mill. bbl/yr)	35.6	-	-
Subtotal	53.3	18.6	26.8
Less estimated flow through	7.7	-	-
Total	45.6	18.6	26.8
Demand			
End Use Sales	37.4	1.0	28.3
Sales to Utilities	1.2	19.7	-
Total	38.6		
Net Supply Unaccounted for			
Excess (deficit)	7.0	(2.1)	(1.5)
Storage Capacity			
Oil Distributors	- - - -	8.2 total	- - -
Residential	5.7	-	-
Commercial-Industrial	5.7*	-	-
Utility	negl.	2.4	-

*Since commercial-industrial annual oil consumption is approximately equal to that of the residential sector, we estimate storage capacity as the same also.

obtaining the required data.

The natural gas balance sheet, Table 19, is indicative of the aggregate data obtained directly from utility annual reports to the state regulatory agency. It is worth noting in this regard that the derivation of the sales, or supply figures in more disaggreated form turns out to be difficult and not very useful for the purposes dealt with here. For example, although residential sales can be disaggregated by class of user based upon amount of their consumption, this does not, in general, correlate well with a structural breakdown of housing types.

Data on oil movements are shown in Table 20. As noted earlier, waterborne shipments are obtained from the Corps of Engineers' reports. Pipeline crude oil movements, in this case, were established through private conversations with the major local oil handler. "Flow through," which represents oil deliveries into the region for use outside the local area apparently does not appear in any records and can only be established from the personal knowledge of local company officials. In general, however, such sales information is closely guarded because of the highly competitive state between oil distributors. Our estimates, shown in Table 20, are based upon a worksheet analysis used to establish end use demands. Finally, while total storage capacity is readily available (for example in reports to the state environmental control agency) the distribution of fuels in storage at any one time or on an annual basis is, for the most part, difficult to establish with precision.

It is important to note that the problems cited here are not necessarily typical of all regions. For example, the New England Regional Commission has established a set of petroleum flow accounts which contain detailed information for many of the New England states on oil movements from entry into the region to end use deliveries. In this case, working relationships between the oil industry and appropriate governmental units in the region have allowed the construction of a useful data base.

Electricity Generation and Distribution

The intermediate conversion of raw fuels to electricity for delivery to consumers is an essential part of the regional energy supply system.

The description of annual electricity production is the information tied most directly to the energy demand analysis contained in the worksheets. However, in other instances peak and off-peak generation requirements associated with specific patterns of development or with introduction of new technologies may be of interest. Similarly, environmental issues in electric power generation may come to the fore which would necessitate the collection of specific data on individual central generating stations in the region.

The basic system-wide data required to describe the electric generation sector are shown in Table 21. The Federal Power Commission publishes detailed annual data on the operations of electrical and gas utilities by company,[66] but these data should be supplemented by more detailed information normally available from state utility regulatory agencies.[67] The general data on fuel consumption and generating characteristics are most useful in constructing a picture of current dependency upon fuels which may be subject to shortages. Power pool information reflects the extent to which electric generating facilities within the region are more (less) than sufficient to service the local community and, consequently, export (import) electricity. The residential-commercial-industrial sales mix is an important determinant of land patterns and of rate structures of utility systems. Large commercial-industrial users often have predictable time-of-day consumption patterns which may permit efficient scheduling of the utilization of generating facilities.

Information on individual electricity generating stations is available from the same data sources cited above. Such data include fuel type, heat rate (efficiency of fuel use), sulfur emissions, etc., which may be utilized to begin to assess environmental effects. We should note, however, that emissions are critically dependent upon a large number of technical design and operating parameters of the plants, and detailed studies must rely upon integration of plant specifics, local climatology, and pollutant dispersion models. Basic data and approaches to such environmental concerns are addressed in the RES User's Guide noted earlier.

TABLE 21

ELECTRIC SYSTEM DATA

Installed capacity, Kw	(% Baseload, % Intermediate, % Peak)
Annual Fuel Consumption	(Fuel type, Btu content, sulfur, ash)
Annual Electricity Generation, Kwh	
Transmission Efficiency	
Power Pool: Imports/Exports	
Sales: Residential	(Kwh, avg. customers, rates by customer class)
Commercial	(Kwh, avg. customers, rates by customer class)
Industrial	(Kwh, avg. customers, rates by customer class)
Railroad	
Street & Highway Lighting	
Public Authorities	

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IV. REGION AND COMMUNITY LAND USE - ENERGY ASSESSMENTS; TWO EXAMPLES

We have chosen two cases to illustrate the procedures described above. One - the Nassau-Suffolk area of Long Island is representative of major suburban regions throughout the U.S. which have undergone and continue to undergo major growth and development. Land use activity patterns have occurred in these areas which are typified by low population densities and zoning which has lead to a wide-spread dispersal of residential, commercial, and industrial activities and heavy reliance on automobile travel. The economies in many of these areas, while still heavily dependent on the presence of nearby major metropolitan centers, are undergoing a transition to a more self-reliant character. From an energy perspective, such regions are usually strongly dependent on energy imports, either in the form of primary fuels, processed forms such as electricity and refined oil products, or in energy embodied in metals and plastic used in manufacturing, construction materials, and consumer products. Land use activities in these suburban areas are generally characterized by their high energy consumption per unit activity level.

The changing national energy picture has provided the opportunity to planners and public officials in these areas to reconsider their land use plans and zoning policies, particularly as they pertain to policies of new regional development. It has also brought about a recognition on the part of a number of consumer groups that the deleterious effects and increased risks that may accompany the importation, processing, and consumption of energy are all tied to existing and future patterns of land use development, as well as increasing their awareness of the vulnerability of their economies to the onset of fuel shortages. Land use planners and public officials realize the basic character of short and long term energy and fuel expenditures will be established by virtue of land use patterns. Although the application of land use/energy analysis considered for the Nassau-Suffolk region is centered on the examination of the energy demands associated with two specific development scenarios, the data and informational base developed provide interested parties with a means for assessing other patterns of development. Energy/land use analyses similar to that given below have already been carried out for the Washington Metropolitan area,[2] and the greater New York City area[10] using somewhat analagous procedures.

An urban renewal design for Census tracts 6 & 7 in Tucson, Arizona, was chosen as an example of the use of the manual worksheets and procedures in connection with a specific design for a smaller community.* While a principal element in the design objectives for this study relates to the goal of achieving a significant reduction in energy expenditures per unit of land use activity growth, the procedures used to evaluate the energy-sensitive features of the proposed design are applicable to a wide range of land use design situations. In such cases, the accompanying energy expenditure "budgets" may be used to specify, for example, the expected increase in electrical demands that would accompany the changes in land use, or the impacts of such changes on the demand for fuels in short supply in the surrounding region.

In this connection we have noted that the notion of requiring an energy impact statement to accompany proposed land use designs is being considered by a number of states and municipalities. Several federal agencies, from whom approval or support is required before such designs can be implemented, are also discussing such impact evaluations. The fact that energy impact statements can serve as a means for allowing federal, state, and local regulatory units and public utilities to anticipate and regulate future energy demands argues for their becoming a part of future design impact assessments.

A. The Long Island Nassau-Suffolk Region

The Nassau-Suffolk region of Long Island contains all the land area to the east of the boroughs of Queens and Brooklyn in New York City. The

* We acknowledge the permission of Conklin & Rossant, and Flack & Kurtz to make generous use prior to publication of their background material, energy data, and designs which are part of a F.E.A. sponsored study on "The Interaction of Land Use and Energy Conservation."

entire area has developed rapidly since the end of World War II, stimulated in part by an exodus of people, and to a lesser extent of industry, from New York City. The current population in the two counties is approximately 2,500,000. By the year 2000, this figure is expected to be 4,000,000. The region now contains some relatively high population density areas close to New York City in Nassau County and the western part of Suffolk County.

The eastern part of the area though still semi-rural in character, is the area which is undergoing substantial development. Large areas in this eastern sector that were once entirely agricultural are being replaced by single and multi-family housing developments, shopping centers, retail strips, and industrial parks. This growth is following the current overall pattern of urban sprawl in the region, which consists mostly of detached single-family homes interspersed with a variety of retail businesses, commercial office buildings, and light industries scattered along major highways and interconnecting roads. (See Table 24 for a summary of the current mix of land use activities.) This spatial dispersion covers a wide area of residential, commercial, and industrial activities make it difficult for mass transit to compete with the private automobile as a means of personal travel. Although, as noted above, land use development in the Nassau-Suffolk region is typical of many such areas surrounding major metropolitan areas in the U.S., the presence of its large coastal areas have - and will continue to - influence its development. These coastal regions have, in the main, been used for residential and leisure/recreational purposes, which serve both the needs of local residents and those from the greater New York area. They also provide the Island with one of its major income producing industries. The coastal areas also are the source of a major shell fish industry. Planning for the use of the undeveloped and underdeveloped portions of the coast reflect a strong interest on the part of both public and private groups to insulate these coastal areas from any further deleterious impacts of development in other parts of the Island. Such concerns relate directly to regional decisions now taking place regarding the location of large nuclear-powered electric generating facilities on the coast and the construction of additional facilities for waterborne deliveries of fuel oil products.

Our application of energy/land use analysis in the Nassau-Suffolk case is directed toward several specific issues and indirectly to a larger number of more general questions. The specific issues pertain in part to the existing Bi-County Master Plan for future development of the area.* This plan, prepared by the Nassau-Suffolk Regional Planning Commission, opts for a comparatively new pattern of land use development in the underdeveloped portions of the region as an alternative to the continuation and extension of Urban Sprawl (US). Labeled as Corridors, Clusters, and Centers (CCC) in the scenario description below, this plan would not only seek to retain the undeveloped coastal areas for recreational, commercial, and shell fishing purposes, but it would stimulate the development of a few relatively high population density centers connected by highway and mass transport networks. The energy/land use analysis, which is built around the examination of the projected energy demands associated with the Urban Sprawl and Corridor, Clusters and Centers scenarios for development, are intended to provide input to decisions now being taken by local planning boards bearing on these alternative patterns of development.

Related to the above,are the choices facing the region for insuring an "adequate" long term supply of energy. The conflict between alternative patterns of regional growth and the required regional energy system infrastructure are the focal points of the debate by utilities, governmental units, and public and private interests. These debates focus on the construction of additional nuclear facilities, the exploitation of off-shore oil, and the construction of deepwater port and storage facilities for oil and liquid natural gas. To the extent that the use of land limits both the options for constructing these facilities or utilizing their availability (as in the case of off-shore oil) and the increases in projected final energy demand, the scenario analyses enter directly into these deliberations.

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* We are indebted to the staff of the Nassau-Suffolk Regional Planning Commision and the Nassau and Suffolk County Planning Boards for their time and efforts spent in familiarizing us with the results and analysis that went into producing the master plan. We are especially thankful to Dr. Lee Koppelman for the interest he has shown in our study.

The general issues surrounding these specific concerns are numerous and complex. They involve not only the control of growth but its restriction. While the future availability of adequate sewage facilties, schools, roads, recreational areas, and water resources, have been enumerated as factors in support of the adoption of such controlled or no-growth policies, regional energy considerations are also involved. The knowledge that energy-based arguments can be used as a supportive argument for limiting population influx is becoming apparent to many communities and suggests a further use for energy/land use analysis. Thus the results obtained in the case example, while specific to the Nassau-Suffolk region, can have significant implications for the country as a whole.

The general outline we have used to present the Nassau-Suffolk results are intended to detail the operations and procedures that would be used in any region. A basic data base is prepared describing the existing patterns of regional energy expenditures using the worksheets outlined in Chapter III. Data and information are collected and assembled in tabular form which establish the projected mix of land uses and the basic transportation sector descriptors* for each of the scenarios. New energy worksheets are prepared for each scenario. Taken together, the worksheets and accompanying tables and graphs serve as the basic energy informational base for evaluating and assessing developmental options.

It is important to emphasize that the case example developed here for the Nassau-Suffolk region is designed primarily as a means of illustrating the practicality of utilizing the methodology developed in the workbook. Thus, while we have attempted to adopt realistic values for our scenario parameters, the results and findings should only be treated as preliminary in nature. It is clear that were the region to undertake its own energy/land use assessment, further efforts would be needed in establishing refined sets of these input values.

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* To the extent the official planning boards in this region have expended considerable effort in examining future economic development in the region, the level of detail of our informational input may not be typical of similar regions around the country. Where such specific information is not available to express regional goals and preferences, other means have to be used to generate starting values for this kind of analysis.

Characteristics of the Region's Energy Supply & Distribution System*

The patterns of energy fuel use in the Nassau-Suffolk region as shown in Figure 1, is typical of that of a number of major metropolitan regions in the Northeast. Its primary supply of energy is derived from oil imported into the area from foreign sources. As shown in Table 20 (Chapter III), almost all of this oil is in the form of refined oil products delivered to the region by either waterborne shipments using local ports, pipelines traversing the central core of the region, or by truck for local distribution. Because the 1973-74 oil embargo demonstrated the extreme vulnerability of the region's economy and life-style to sudden disruption in this supply, expanded centralized storage capacities are being given serious consideration. When and if off-shore oil becomes available, its use would also involve a further expansion of port facilities. The natural gas used in the region is far below national averages, due in part to the increased transmission costs of natural gas from its domestic sources and the historical dependence on fuel oil for home heating that developed in the era of inexpensive oil. Coal use in the region has been limited by both the difficulties attendent to its delivery from distant sources and the presence of environmental standards which limit pollutant emission levels.

Essentially all the electricity supplied to the Nassau-Suffolk region is produced by a single utility - the Long Island Lighting Company - with electric generating facilities located on the Island. The 1972 breakdown of electricity sales by customer categories is shown in Table 22 and average fuel mix used to generate this electricity in Table 23, where the comparable fuel mix averages are shown for New York State and the U.S. As shown in Table 23, the residential sector accounts for a much great fraction of electrical use in the region than it does either in New York State or in the nation as whole. This is due both to the absence of major industries using electricity and the presence of a sizable number of "bedroom" residential areas on the Island. As noted in Table 23, almost all electricity in the region is produced by fossil steam using oil. Gas turbines are used to meet peak demands.

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* This section is based, in part, on work being performed by BNL for ERDA and the Long Island Lighting Company.

TABLE 22

ELECTRICITY SALES BY CUSTOMER CATEGORY - 1972

(Percent of Total Sales)*

Category	U.S.	N.Y. State	LILCO
Residential	32.4	29.3	46.5
Commercial	23.0	29.0	51.8
Industrial	40.5	29.8	
Other	2.7	7.6	1.7

*Totals may not add to 100% because of rounding.

Sources: Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry for 1972.

LILCO Annual Reports to the NY Public Service Commission.

TABLE 23

FUEL MIX FOR ELECTRICAL GENERATION

U.S., N.Y. STATE AND LONG ISLAND

(Percent)

Fuel	U.S.	N.Y. State	Long Island
Hydro	15.6	26.9	0
Fossil Steam	80.9	66.5	95.2
Nuclear Steam	3.1	6.3	0
Gas Turbine	0.4	0.2	4.8

Note: Totals may not add to 100% because of rounding.

As noted above, LILCO, the regional utility, has undertaken a major program to construct several large nuclear generating facilities as a means of reducing the region's substantial dependence on foreign oil imports. Nuclear-fueled electricity is thus due to become the major source of the region's electrical supply over the next several decades, if these facilities are approved and built as planned.

Scenarios for Future Land Use Development in the Nassau-Suffolk Region

We adopt two basic scenarios to describe the outside range of future land use development in the Nassau-Suffolk region through the year 2000. The projected values for the basic regional development parameters are the same for both scenarios. These include population, commercial floorspace, industrial employment, number of housing units to be required, and trip generation rates. These parameters are listed in Table 24 . 1972 was used as the base year from which all projections were made.

Scenario I: "Continuation of Urban Sprawl" (US)

This scenario assumes the continuing growth of existing regional patterns of land use development. More specifically, this means a continuation of the present division of housing types between single-family detached and the various types of multi-family dwellings. With respect to the projected mix of industries, we assume the present slightly increased trend toward the development of medium energy intensive industries will persist. We assume a growth rate of 2%/yr in commercial floorspace in the region which reflects a continuation of past trends. We further assume the spatial pattern of development of this additional commercial floorspace will correspond to what has occured in the past, i.e. it is widely dispersed along primary and secondary roads. In the US scenario, new road construction is assumed to develop in the quasi-random pattern of past years with no substantial changes in mass transit systems.

Scenario II: Corridors, Clusters and Centers" (CCC)

This scenario is based on the design for new area development published in the 1985 Master Plan by the Nassau-Suffolk Regional Planning Commission. Future development is seen as occuring primarily in the undeveloped eastern portion of Long Island, where it will be confined for the most part to clustered residential neighborhoods and medium and large multi-use centers which will provide the service, commercial, transporation, educational, health, recreational, and some of the employment needs of the region's inhabitants. In order to preserve the coastal area of this region for recreational purposes, major transit corridors are restricted to the center spine of the Island.

The basic location of the corridors, clusters, and centers which will serve the needs of the projected population in the newly developed areas of the Nassau-Suffolk region are set down in the regional master plan. The plan also specifies the approximate size of the clusters and centers and mix of activities.

To obtain detailed values for the projected mix of types in the residential, commercial, and industrial sectors, we have utilized straight-line extrapolation of the land use designated in the 1985 Master Plan to obtain a base of information for the year 2000. This procedure allows us to arrive at a set of year 2000 projected land use activities which are basically consistent with the type and character of the land use design suggested in the Master Plan. For the residential sector, this places a restriction on both the number and the location of single-family detached dwellings. We have allocated new construction of the other dwelling types equally into each of the other residential categories -- single family attached, low rise and high rise apartments. We have limited their location to the designated centers and clusters. With respect to the commercial sector, the major difference between the two scenarios is the shift of all retail commercial floorspace development to malls located in or near the centers and

TABLE 24

REGIONAL DEVELOPMENT PARAMETERS

	1972	2000
Population	2,674,000	4,080,000
persons/household	3.58	3.09
number of households	747,600	1,320,000
Commercial Floorspace 10^6 sq.ft.	345.7	601.9
Number of Industrial Employees	160,000	189,000
Total Passenger Miles Traveled (x 10^9)	16.0	30.0

	Projected Land Use Growth*		
	Existing Land Use	Urban Sprawl	Corridors, Clusters and Centers
Housing Mix (%)			
Single family detached	84	84	25
Single family attached	7	7	25
Low rise	5	5	25
High rise	4	4	25
Residential Heating Fuel Mix (%)			
Oil	79	100	100
Electric	2	-	-
Gas	19	-	-
Commercial Floorspace (million sq.ft.)			
Office	35.7	26.5	26.5
Retail (total)	(108.0)	(80.0)	(80.0)
Mall	5.4	4.0	80.0
Attached	27.0	20.0	-
Strip	75.6	56.0	-
School	66.2	49.1	49.1
Hospital	27.2	20.2	20.2
Other	108.6	80.5	80.5
Retail Land Use (Percent of additional space)			
Mall		5	100
Attached		25	-
Strip		70	-
Industrial Employment Mix (%)			
Light Industry	90	90	95
Medium Industry	10	10	5
Vehicle Miles Traveled by Mode and Purpose (%)			
Work			
Auto	60	60	40
Bus	10	10	30
Car	30	30	30
Shop			
Auto	100	100	50
Bus	-	-	40
Walk	-	-	10
Other			
Auto	100	100	60
Bus	-	-	30
Walk	-	-	10

*Represents characteristics of the growth between 1972 and 2000.

clusters. We assume, however, the same 2%/yr overall growth rate for commercial floorspace in both scenarios. The presence of projected centers and clusters in this scenario is consistent with our assumptions regarding the substantially increased use of mass transportation. It also leads to changes in the total vehicle miles traveled brought about by the greater density of land use activities.

Base Case and Scenario Energy Worksheets

The collection and assembly of data in the energy worksheet form required to characterize the energy end use demands for the base case and two land use development scenarios are outlined in this section. For the most part, the data sources are those listed in the pertinent sections of Chapter III. Where such sources were either missing or inappropriate, parameters were estimated using procedures described in the footnotes to the worksheets. A summary of data and information sources used here, as well as specific page, table, and other citations to items utilizing these sources are catalogued in the worksheet footnotes.

There are several general aspects of the data collection effort which should preceed the presentation of the worksheets. In most areas of the country, the planner will find that residential sector analysis is straightforward. Data sources are abundant and sufficiently disaggregated. These have been used in our preparation of the residential worksheet and are footnoted. In the commercial sector, floorspace allocations by type of establishment - office, retail mall, retail strip, other - are seldom available in the desired form and level of detail. In the Nassau-Suffolk analysis we relied on a number of independent studies of commercial floorspace breakdowns to form a composite estimate. We have also utilized local utility and consulting firm studies that contained information on fuel usage in the commercial sector. However, since the information on commercial floorspace and fuel usage varies from one region to another, the estimates on floorspace and fuels shown below for the commercial sector in the Nassau-Suffolk region may not be applicable in other areas.

Employment breakdown by industry type is available in published form for most areas. We have used information obtained from the Census of Manufacturers and the U.S. Department of Commerce, County Business Patterns, 1971. Fuel mix in industry has been estimated from a knowledge of end use purposes for fuel consumption in the region.

Basic transportation parameters are obtained utilizing the calibration procedures outlined in Chapter III. As with most areas, available transportation surveys in the region are not recent. They can be utilized, as we have done here, to provide baseline data. More recent local surveys are then used to check these results. (In general, it is difficult to detail transportation usage beyond this point without the generation of new data. This is particularly true if recent increases in gasoline prices have produced marked changes in personal transportation habits of individuals and households.)

Base Case Worksheets are given in Tables 25,26,27, and 28 for the residential, commercial, industrial, and transportation sectors. These worksheets were prepared using the 1972 land use information provided in Table 24 and the coefficients and procedures described in Chapter III. The breakdown of fuels used in the Nassau-Suffolk region are shown in Table 29. Noteworthy is the heavy use of energy in the residential sector which is substantially above the national average and the comparatively small use of energy in industry, which is far below the national average. Transportation, which accounts for only 11% of total energy end use demand accounts for 40% of the oil consumed in the region - which reflects the inefficiency of automobiles and other transportation equipment. Oil is the primary fuel used for heating in both residential and commercial structures.

The current (1972) energy end-use demand and fuel usage in the Nassau-Suffolk region as revealed in the worksheets summary Table 29, is typical of heavily suburban regions in the Northeastern part of the country. Space conditioning and personal transportation are the primary purposes for which energy is consumed. Oil is the basic fuel used which is derived mostly from foreign sources. Although small changes have taken place over the last four years in energy expenditure patterns, the overall pattern of energy use in the region has remained relatively constant.

Worksheets for the incremental change in energy and fuel use associated with the Urban Sprawl (US) and Corridors, Clusters, and Centers (CCC) scenarios for regional development are presented in Tables 30,31,32,33, and

TABLE 25

1972 Nassau-Suffolk

RESIDENTIAL ENERGY WORKSHEET
("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/Cool Season (°days)	Heat/Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a"	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D thousand	E_u	a thousand	E	F_u	b thousand	F	F_u	b thousand	F	F_u	b thousand	F
Single Family Detached	(1)	(2)	(3)	(5)	(7)	(8)	(12)	(13)	(8)	(12)	(13)	(8)	(12)	(13)
space heat	5500	14.0	77.0	628	48.4	118	119	14.13	118	496	59.8	62	13	0.8
air cond. - central	500	22.0	11.0	(6) 50	0.6	-	-	-	-	-	-	4 (9)	50	0.2
room		8.8	4.4	48	0.2	-	-	-	-	-	-	2 (10)	48	0.1
Single Family Attached														
space heat	5500	10.2	56.1	52	2.9	86	10	0.85	86	41	3.6	45	1	.05
air cond. - central	500	17.7	8.9	5	0.04	-	-	-	-	-	-	4	5	.02
room		7.1	3.5	43	0.2	-	-	-	-	-	-	2	43	.08
Low Rise														
space heat	5500	7.5	41.3	38	1.5	63	8	0.50	63	33	2.1	33	0.8	.03
air cond. - central	500	11.2	5.6	0.2	0.001	-	-	-	-	-	-	2	0.2	.0004
room		4.5	2.2	28	.06	-	-	-	-	-	-	1	28	.03
High Rise														
space heat	5500	4.3	23.7	30	0.7	36	6	0.21	36	24	0.9	19	0.6	.01
air cond. - central	500	5.7	2.9	0.1	0.008	-	-	-	-	-	-	1	0.1	.001
room		2.3	1.1	22	.02	-	-	-	-	-	-	0.6	22	.01
All Units				(4)		(10)			(10)					
water heat	-	-	18.0	747	13.5	28	164	4.60	28	553	15.5	18 (10)	30	.6
range	-	-	4.0	747	3.0	11 (11)	142	1.50	-	-	-	4	606	2.4
electric appl.	-	-	21.0	747	15.7	-	-	-	-	-	-	21	747	15.7
					86.8			21.8 Btu/yr (÷ 1.03 million Btu/Mcf) 21.1 Mil. Mcf			80.7 Btu/yr (÷ 140 thousand Btu/Gal) 576 Mil. Gallons			20.1 Btu/yr (÷ 3412 Btu/Kwh) 5883 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^6 Btu/yr per dwelling unit.

(1) Taken directly from Figures 2 & 3 ("Selected Climatic Maps", Environmental Sciences Services Administration, U.S. Dept of Commerce, Ref. 9)
(2) Taken from Table 4; values for existing housing stock (this report).
(3) $E_u = d \cdot D$
(4) Total number of dwelling units taken directly from RPA (Ref. 10).
(5) Percentage of homes of each structural type taken from 1970 Census, Detailed Housing Characteristics (Ref. 41)
(6) Percentage breakdown for air conditioning, all units, (Ibid. Table 49, pp 34-206) applied to 1972 total dwelling units given in Note 4 above.
(7) $E = a \cdot E_u$
(8) Space heating $F_u = E_u / e$; e=.65 oil, gas & 1.25 electricity.
(9) Air conditioning $F_u = E_u / e$; e=2.5 central, 2.0 room
(10) Water heating $F_u = E_u / e$; e=.65 oil, gas & 1.00 electricity.
(11) Range $F_u = E_u / e$; e=.38 gas & 1.00 electricity.
(12) Percentage of homes heated by different fuels taken from Op. Cit. Note 5 (Table 50) was applied to 1972 dwelling units given in Note 4 above.
(13) $F = b \cdot F_u$

TABLE 26

1972 -Nassau-Suffolk

COMMERCIAL ENERGY WORKSHEET
("a" = square feet)

(12)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per °dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a million	E	F_u	b million	F	F_u	b million	F	F_u	b million	F
Office														
space heat	5500 (1)	26. (2)	143.0 (3)	35.7 (4)	5.[illegible]0 (5)	220 (6)	4.6 (7)	1.02 (8)	220	31.1	6.84	-	-	- (8)
air cond.	500	25.	12.5 (2)		.45	-	-	-	-	-	-	5 (9)	35.7 (11)	.18
electric	-		32.00 (2)		1.[illegible]4	-	-	-	-	-	-	32 (10)	35.7	1.14
Retail Mall														
space heat	5500	15.	82.5	32.4	2.[illegible]7	127	4.2	.54	127	28.2	3.58	-	-	-
air cond.	500	29.	14.5		.[illegible]7	-	-	-	-	-	-	5.8	38.4	.19
electric	-		34.0		1.[illegible]4	-	-	-	-	-	-	34	32.4	1.10
Retail Strip														
space heat	5500	21.	115.5	75.6	8.[illegible]3	178	9.8	1.75	178	65.8	11.71	-	-	-
air cond.	500	40.	20.0		1.51	-	-	-	-	-	-	8	75.6	.61
electric	-		34.0		1.[illegible]0	-	-	-	-	-	-	34	75.6	2.57
Other														
space heat	5500	15.	82.5	202.0	16.67	127	26.3	3.33	127	175.7	22.31	-	-	-
air cond.	500	29.	14.5		2.93	-	-	-	-	-	-	5.8	202.0	1.17
electric	-		32.0		6.46	-	-	-	-	-	-	32	202.0	6.46
					48.[illegible]7			6.64	Btu/yr (÷1.03 million Btu/Mcf) Mcf		44.44	Btu/yr (÷140 thousand Btu/Gal) Gallons		13.42 Btu/yr (÷ 3413 Btu/Kwh) Kwh
								6.4 million MCF				317 Million Gallons		3932 Million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^3 Btu/yr per square foot.

Footnotes:
(1) Taken directly from Figures 2 & 3 ("Selected Climatic Maps", Environmental Sciences Services Administration U.S. Department of Commerce, Ref. 9.
(2) Taken from Table 9 of this report.
(3) E_u=d·D.
(4) Floorspace estimates as follows: Total non-residential floorspace was taken from Ref. 10. Industrial floorspace was estimated using floorspace per worker design criteria, Ref. 10 and industrial employment in Nassau and Suffolk counties, Ref. 10. This was subtracted from total non-residential floorspace leaving commercial floorspace as the remainder. Office floorspace was subtracted from total commercial floorspace. Retail floorspace was estimated by subtracting 90% of the office floorspace from the floorspace in the "commercial" category which includes retail establishments, services and "most of office floorspace" in Ref.10. Based on the land use inventory for the region, Ref.36 , 30% of retail floorspace is in strip development. Floorspace for hospitals and health institutions was estimated at 8%, the 1970 national average, Ref. , of the total commercial floorspace. Floorspace for schools and educational institutions was estimated using floorspace per pupil design criteria, Ref . and school enrollment in Nassau and Suffolk counties, Ref. . The remaining commercial floorspace which was not allocated to office, retail, hospital, or school floorspace was designated as "other" floorspace.
(5) E=a·E_u.
(6) Space heating F=E_u/e; e=.65 gas, oil.
(7) Fuel mix is estimated from Current and Future Energy Use in the Nassau-Suffolk Region (Phase I report to LILCO, BNL 20683).
(8) F=F_u·b.
(9) Air conditioning F_u=E_u/e; e=2.0 central.
(10) Electric F_u=E_u/e; e=1.0.
(11) Virtually all commercial space is air conditioned.

(12) The unit demand was based upon an earlier methodology which does not distinguish between heat/cool and internal heat. (See Table 8).

TABLE 27

1972 Nassau-Suffolk

INDUSTRIAL ENERGY WORKSHEET
("a" = per employee)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/°dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a") thous.	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a") thous.	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a") thous.	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a") thous.	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	$E=aE_u$	F_u	a	F	F_u	a	F	F_u	a	F
Light Industry process space heat air cond. electric			120million (1)	139.2 (2)	16.70 (3)	21.6 (4)	139.2 (5)	3.0 (6)	163.0 (4)	139.2 (5)	22.6 (6)	31 (4)	139.2 (5)	4.315 (6)
Medium Industry process space heat air cond. electric			310million	18.5	5.75	462.	18.5	8.5	14.9	18.5	.3	58	18.5	1.073
Heavy Industry process space heat air cond. electric			1170million											
Energy-intensive process			-specific-											
					22.5			11.5 Btu/yr (÷1.03 million Btu/Mcf) Mcf 11.2 million MCF			22.9 Btu/yr (÷140 thousand Btu/Gal) Gallons 164 million Gallons			5.39 Btu/yr (÷3413 Btu/Kwh) Kwh 1579 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^{6} Btu/yr per employee.

Industrial FootNotes:

(1) Taken directly from Table 11.

(2) From Census of Manufacturers & U.S. Department of Commerce, County Business Patterns, 1971. The number of industrial employees can be grouped into low & medium industries by SIC Group.

(3) $E=E_u \cdot a$.

(4) Fuel mix estimated from Current and Future Energy Use in the Nassau-Suffolk Region (Phase I report to LILCO, BNL 20683)

(5) Same as "a" in Energy Demand

(6) $F=F_u \cdot a$.

TABLE 28

1972 Nassau-Suffolk

TRANSPORTATION ENERGY WORKSHEET

Trip Purpose/Mode	UNIT DEMAND: Vehicle Energy Demand (Btu/veh.mi) E_v	÷ Vehicle Occupancy Rate V	Unit Energy Demand (Btu/pass.mi.) E_u	ENERGY DEMAND: Land Use Activity (no. household) a thousands	Daily trips per household D	Daily Passenger Trips T million	Average Trip Length L	Annual Pass.Mi. per trip* (*364 days) M	Modal Split S	Total Energy Demand (Btu/yr) E	FUEL CONSUMPTION: Unit Oil Demand Btu/pass.mi.) F_u	Total Pass. Mi. b	Total Oil Consump. (Btu/yr) F	Unit Elect. Demand (Btu/pass. mi.) F_u	Total Pass. Mi. b million	Total Electric Consump. (Btu/yr) F
Work																
Auto	1840 (1)	1.4 (2)	1320 (3)	747.6 (4)	2.54 (5)	1.90 (6)	12.7 (7)		.60 (8)	6.95 (10)	6600 (11)	5268 (12)	34.76 (13)	=	=	=
Bus	4630	20.	230						.10	.20	1150	877	100			
Rail/diesel	53200	40.	1330						.05	.58	4430	439	194	- (11)	- (12)	=
electric	18100	40.	450						.25	.99	-	-	-	450	2195	.99 (13)
Shop																
Auto	1840	1.4	1320	747.6	2.20	1.64	5.4		1.00	4.27	6600	3234	21.34	-	-	-
Bus	7050	23.	310						-	-	1550	-	-	-	-	-
Other																
Auto	1840	1.6	1150	747.6	2.44	1.82	9.9		1.00	7.56	5750	6574	37.80	-	-	-
Bus	7050	23.	310						-	-	1550	-	-	-	-	-
										20.55			96.84 Btu/yr (÷140 thousand Btu/Gal) Gallons			.99 Btu/yr (÷3412 Btu/Kwh) Kwh
													692 million gallons			290 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.

Footnotes: (1) See Ref. 35; see also "Characteristics of Urban Transportation Systems", Urban Mass Transportation Administration, U.S. Department of Transportation (prepared by DeLew, Cather, & Co., May '75)
(2) BFTS and LTPS, see Ref. 23.
(3) $E_u = E_v / V$.
(4) Total number of dwelling units taken from Regional Planning Association, Ref. 24.
(5) Taken from Table 16 for high income areas.
(6) $T = a \cdot D$.
(7) Taken from Figure 6 for distances greater than 20 miles from urban core.
(8) Taken from Ref. 24; rail information from BNL memo on Long Island Railroad travel patterns and energy consumption (unpublished)
(9) $M = 364 \cdot L \cdot S$
(10) $E = E_u \cdot T \cdot M$.
(11) $F_u = E_u / e$; e = .20 auto, bus, .30 diesel rail, 1.0 electric rail.
(12) $b = T \cdot M$; diesel/electric rail passenger miles taken from memo in Note 8 above.
(13) $F = F_u \cdot b$.

TABLE 29

NASSAU-SUFFOLK ENERGY CONSUMPTION SUMMARY

(1972)

Sector	Energy Demand	Fuel Consumption		
	(10^{12} Btu)	Gas(10^6 Mcf)	Oil (10^6 gal.)	Electric.(10^6Kwh)
Residential	8.7 (49%)	21.1 (55%)	576 (33%)	5900 (50%)
Commercial	48.8 (27%)	6.4 (17%)	317 (18%)	3900 (33%)
Industrial	23. (13%)	11.2 (28%)	164 (9%)	1600 (14%)
Transporation	2.1 (11%)	-	69 (40%)	290 (3%)
	17.9	39.4	1749	11,690

Tables 34,35,36,37 for each land use sector. The breakdown of fuel increments for the two scenarios is given in Tables 38 and 39. Energy-related data input for the scenario worksheets are essentially the same as those used for the base case with the following notable exceptions.

1) Energy intensity factors in the residential, commercial, and industrial sectors have been reduced to reflect expected changes in building materials and practices for new construction, and the greater use of central and room air conditioning

2) In both scenarios, natural gas has been excluded as a potential fuel. This is consistent with the continuation of current utility policy which does not permit the use of natural gas for heating and air conditioning purposes in new residential and commercial construction.

3) Fuel calculations in the residential and commercial sectors reflect assumed increases in the use of electricity for space heating.

4) In the transportation sector, fuel efficiencies of automobiles are assumed to have doubled by the year 2000. Increased use of mass transportation is assumed in the CCC calculation and trip lengths are modified to reflect the change in land use patterns.*

There are a number of features in the US and CCC worksheets and the summary tables that pertain to the specific and general issues raised in

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* We should emphasize that these adjustments in the energy-sensitive parameters are not the results of independent evaluations. They represent the estimated effects of national and regional trends. The use of fuel specific end-use devices such as heat pumps and electric powered vehicles as well as the choice of fuel types in situations where alternative fuels can be considered, will depend on the comparitive prices and availability of fuels and end-use devices in the intervening period. Construction materials and practices will be affected by revisions in building codes and the passage of new federal and state legislation. Inview of these uncertainties and the limited ability of the planner to predict such developments, particularly on a regional scale, the results are best viewed as projections not forecasts. The primary purpose in introducing these technical parameter adjustments into the Nassau-Suffolk land use/energy analysis is to demonstrate both the ability of the methodology to accommodate them and the interdependence of land use and the technical and economic factors associated with energy production and consumption.

TABLE 30

Nassau-Suffolk

Urban Sprawl (US)(1)

RESIDENTIAL ENERGY WORKSHEET

("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D thousand	E_u	a thousand	E	F_u	b (5)	F	F_u	b thousand	F	F_u	b thousand	E
Single Family Detached														
space heat	5500	10.5(2)	56.7	481	27.2				87	385	33.5	45	96	4.4
air cond. - central	500	15.5	7.8	96(4)	0.7				-	-	-	31	96	0.3
room		6.2	3.1	385	1.2				-	-	-	16	385	0.6
Single Family Attached														
space heat	5500	7.4	40.7	40	1.6				63	32	2.0	33	8	0.3
air cond. - central	500	12.5	6.3	8	0.05				-	-	-	3	8	0.02
room		5.0	2.5	32	0.08				-	-	-	1	32	0.04
Low Rise														
space heat	5500	5.5	30.3	29	0.9				47	23	1.1	24	6	0.1
air cond. - central	500	8.1	4.1	6	0.02				-	-	-	2	6	0.01
room		3.2	1.6	23	0.04				-	-	-	0.8	23	0.02
High Rise														
space heat	5500	4.0	22.0	23	0.5				34	18	0.6	18	5	0.08
air cond. - central	500	5.5	2.8	5	0.01				-	-	-	1	5	0.001
room		2.2	1.1	18	0.02				-	-	-	0.6	18	0.01
All Units														
water heat	-	-	18	572(3)	10.3				28	286	8.0	18	287	5.2
range	-	-	4	572	2.3				-	-	-	4	572	2.3
electric appl.	-	-	21	572	12.0				-	-	-	21	572	12.0
					57						45.2			25.3
								Btu/yr (÷ 1.03 million Btu/Mcf) Mcf			Btu/yr (÷ 140 thousand Btu/Gal) Gallons			Btu/yr (÷ 3412 Btu/Kwh) Kwh
											323 million gallons			7440 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^6 Btu/yr per "a".

Footnotes: (1) Data and procedures follow those in Table 25 (1972 Residential Worksheet) with the exception of number of dwelling units and heating and cooling parameters.
(2) Taken from Table 4.
(3) Projected total number of dwelling units taken from Comprehensive Plan for the Nassau-Suffolk Region.
(4) All new residential floorspace is air conditioned; 20% central air.
(5) New gas installations prohibited.
(6) Electric space heat in 20% of new homes.

TABLE 31

Nassau-Suffolk

Urban Sprawl (US)(1)

COMMERCIAL ENERGY WORKSHEET
("a" = square feet)

	UNIT DEMAND (7)			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (^{o}days)	Heat/ Cool Demand (Btu/yr per ^{o}dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u thous.	a million	E	F_u	b million	F	F_u thous.	b million	F	F_u thous.	b million	F
Office														
space heat	5500 (2)	20 (3)	107 (4)	26.5	2.84				165	21.2	3.49	107	5.3	0.567
air cond.	500	19	9.5		0.25				-	-	-	3.8	26.5	0.101
electric			24.0 (3)		0.63		(6)		-	-	-	24.0	26.5	0.636
Retail Mall														
space heat	5500	11	50.5	24.0	1.45				95.2	19.2	0.18	61.8	4.8	0.297
air cond.	500	22	11.0		0.26				-	-	-	4.4	24.0	0.106
electric			24.0		0.57				-	-	-	26.0	24.0	0.624
Retail Strip														
space heat	5500	16	37.0	56.0	4.37				134.0	44.8	6.0	87.0	11.2	0.974
air cond.	500	30	15.0		.34				-	-	-	6.0	56.0	0.448
electric			24.0		1.34				-	-	-	26.0	56.0	1.460
Other														
space heat	5500	11	50.5	150.0	9.08				95.2	120.0	11.4	61.8	30.0	1.850
air cond.	500	22	11.0		1.55				-	-	-	4.4	150.0	0.660
electric			24.0		3.60				-	-	-	24.0	150.0	3.600
					27.4						21.1 Btu/yr (÷140 thousand Btu/Gal) Gallons 151 million gallons			11.3 Btu/yr (÷ 3413 Btu/Kwh) Kwh 3317 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^3 Btu/yr per square foot.

Footnotes:
(1) Data and procedures follow those in Table 26 (1972 Commercial Worksheet) with the exception of the number of square feet of specific commercial floorspace and other changes noted below.
(2) Taken from Figures 2 and 3 ("Selected Climatic Maps," Ref. 9.)
(3) Reduced by 25% from values given in Table 9 of this report.
(4) E_u = d · D.
(5) Floorspace projections are estimated to increase 2% per year per sector uniformly, Ref. 10.
(6) New gas installations prohibited.
(7) The unit demand was based upon an earlier methodology which does not distinguish between heat/cool and internal load. (See Table 8).

TABLE 32

Nassau-Suffolk
Urban Sprawl (US)[2]

INDUSTRIAL ENERGY WORKSHEET[1]
("a" = per employee)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/°dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a") thousand	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a") thousand	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a") thousand	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E	F_u	a (4)	F	F_u	a	F	F_u	a	F
Light Industry process space heat air cond. electric			102 million	26[3]	2.65				117[5]	26	3.04	25.5[5]	26	0.66
Medium Industry process space heat air cond. electric			280 million	3[3]	0.840				304	3	.91	70	3	.21
Heavy Industry process space heat air cond. electric			1170 million											
Energy-intensive process			-specific-											
					3.45						3.95 Btu/yr (÷140 thousand Btu/Gal) Gallons 28.2 million gallons			.87 Btu/yr (÷3413 Btu/Kwh) Kwh 254 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^{6} Btu/yr per employee.

Footnotes:
(1) This worksheet calculates the incremental energy needed for the Nassau-Suffolk region for the addition industrial activity of the region above the 1972 level.
(2) Data and procedures follow those in Table 27 (1972 Industrial Energy Worksheet), except for the number of industrial employees and their fuel mixes.
(3) The incremental industrial employees for 2000 are expected to be 29,000. (1972 - 160,000, 2000 = 189,000) Of which 90% are expected to be light energy intensive industries. 10% medium energy intensive industries (Extrapolated 1985 figures from RPA for forcasts).
(4) New gas installations prohibited.
(5) Fuel mix determined from Chapter III.

TABLE 33

Nassau-Suffolk

(1)

Urban Sprawl (US)

TRANSPORTATION ENERGY WORKSHEET

Trip Purpose/Mode	UNIT DEMAND: Vehicle Energy Demand (Btu/veh.mi) E_v	÷ Vehicle Occupancy Rate V	Unit Energy Demand (Btu/pass.mi.) E_u	ENERGY DEMAND: Land Use Activity (no.household) a thousand	Daily trips per household O	Daily Passenger Trips T thousand	Average Trip Length L	Annual Pass.Mi. per trip* (*364 days) M	Modal Split S	Total Energy Demand (Btu/yr) E	FUEL CONSUMPTION: Unit Oil Demand (Btu/pass.mi.) F_u	Total Pass. Mi. b million	Total Oil Consump. (Btu/yr) F	Unit Elect. Demand (Btu/pass. mi.) F_u	Total Pass. Mi. b million	Total Electric Consump. (Btu/yr) F
Work				572.4 (3)	2.54	1454	12.7									
Auto	920 (2)	1.4	660						.60 (4)	2.7	3300	4030	13.3	-	-	-
Bus	2315	20.	115						.10	.08	575	670	0.4	-	-	-
Rail/diesel	53200	50.	1330						.05	.4	4300	340	1.5	450	1680	0.8
electric	18100	40.	450						.25	.8	--	-	-	-	-	-
Shop				572.4	2.20	1259	5.4									
Auto	920	1.4	660						.80	1.3	3300	1980	6.5	-	-	-
Bus	3525	23.	155						.20	.8	775	500	.4	-	-	-
Other				572.4	2.44	1397	9.9									
Auto	920	1.6	575						.80	2.3	2835	4030	11.4	-	-	-
Bus	3525	23.	155						.20	.2	775	1000	.8	-	-	-
										8.5			34.3 Btu/yr (÷140 thousand Btu/Gal) Gallons			.8 Btu/yr (÷3412 Btu/Kwh) Kwh
													245 million gallons			222 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.

Footnotes: (1) Data and procedures follow those in Table 28 (1972 Transportation Worksheet), with the exception of fuel consumption of vehicles and projected number of dwelling units.

(2) Based upon 26 mpg average for ICE vehicles.

(3) Taken from Comprehensive Plan for the Nassau-Suffolk Region, Ref. 24.

(4) Modal split same as existed in 1972.

TABLE 34

Nassau-Suffolk

Corridors,Clusters,Centers (CCC) (1)

RESIDENTIAL ENERGY WORKSHEET
("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D thousand	E_u	a thousand	E	F_u	b (6)	F	F_u	b thousand	F	F_u	b thousand	F
Single Family Detached														
space heat	5500	10.3 (2)	56.7	143 (4)	8.1				87	115 (7)	10.0	45	29	1.3
air cond. - central	500	15.5	7.8	29 (5)	0.2				-	-	-	3	29	0.09
room		6.2	3.1	115	0.4				-	-	-	2	115	0.2
Single Family Attached														
space heat	5500	7.4	40.7	143	5.8				63	115	7.2	33	29	0.9
air cond. - central	500	12.5	6.3	29	0.2				-	-	-	3	29	0.07
room		5.0	2.5	115	0.3				-	-	-	1	115	0.1
Low Rise														
space heat	5500	5.5	30.3	143	4.3				47	115	5.3	24	29	0.7
air cond. - central	500	8.1	4.1	29	.1				-	-	-	2	29	0.05
room		3.2	2.5	115	.2				-	-	-	1	115	0.09
High Rise														
space heat	5500	4.0	30.3	143	3.1				34	115	3.9	18	29	0.5
air cond. - central	500	5.5	4.1	29	.08				-	-	-	1	29	0.03
room		2.2	1.6	115	.1				-	-	-	1	115	0.06
All Units				(3)										
water heat	-	-	18	572	10.3				28	286	8.0	18	286	5.2
range	-	-	4	572	2.3				-	-	-	4	572	2.3
electric appl.	-	-	21	572	12.0				-	-	-	21	572	12.0
					47.5						34.4			23.7
								Btu/yr (÷ 1.03 million Btu/Mcf) Mcf			Btu/yr (÷ 140 thousand Btu/Gal) Gallons			Btu/yr (÷ 3412 Btu/Kwh) Kwh
											246 million gallons			6940 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^{6} Btu/yr per dwelling unit.

Footnotes: (1) Data and procedures follow those in Table 25 (1972 Residential Worksheet), with the exception of number of dwelling units, disaggregation of dwellings into structural type, and heating and cooling parameters.
(2) Taken from Table 4.
(3) Projected total number of dwelling units taken from Comprehensive Plan for the Nassau-Suffolk Region.
(4) Percentage breakdown by structural type allocates equal numbers of dwelling units to each housing category.
(5) All new residential floorspace is air conditioned; 20% central air.
(6) New gas installations prohibited.
(7) Electric space heat in 20% of new homes.

TABLE 35

Nassau-Suffolk

Corridors, Clusters, Centers (CCC)(1)

COMMERCIAL ENERGY WORKSHEET
("a" = square feet)

	UNIT DEMAND (7)			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per °dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E	F_u	b	F	F_u	b	F	F_u	b	F
				million						million			million	
Office														
space heat	5500 (2)	20 (3)	107 (4)	26.5 (5)	2.84		(6)		165.0	21.2	3.40	107.0	5.3	0.570
air cond.	500	19	9.5		.251							3.8	26.5	0.189
electric			24.0		.636							24.0	26.5	0.636
Retail Mall														
space heat	5500	11	60.5	80.0	4.84				95.2	64.0	6.09	61.8	16.0	0.989
air cond.	500	22	11.0		0.88							4.4	80.0	0.352
electric			24.0		1.92							26.0	80.0	2.08
Retail Strip														
space heat	5500	16	87.0	-	-				134.0	-	-	87.0	-	-
air cond.	500	30	15.0									6.0	-	-
electric			24.0									26.0	-	-
Other														
space heat	5500	11	60.5	150.0	9.08				95.2	120.0	11.4	61.8	30.0	1.85
air cond.	500	22	11.0		1.65							4.4	150.0	.66
electric			24.0		3.60							24.0	150.0	3.60
					25.7						20.9			10.9

20.9 Btu/yr (÷140 thousand Btu/Gal) Gallons
149 million gallons

10.9 Btu/yr (÷ 3413 Btu/Kwh) Kwh
3201 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^6 Btu/yr per square foot.

Footnotes:
(1) Data and procedures follow those in Table 26 (1972 Commercial Worksheet) with the exception of the number of square feet of specific commercial floorspace and other changes noted below.
(2) Taken from Figures 2 and 3 ("Selected Climatic Maps," Ref. 9.
(3) Reduced by 25% from values given in Table 9 of this report.
(4) $E_u = d \cdot D$.
(5) Floorspace projections are estimated to increase [illegible]% per year for other and office space, but all additional retail space is projected to be retail mall and retail strip and is projected to remain at 1972 levels.
(6) New gas installations are prohibited.
(7) The unit demands was based upon an earlier methodology which does not distinguish between heat/cool and internal load.

TABLE 36

Nassau-Suffolk

Corridors, Clusters, Centers (CCC)[(2)]

INDUSTRIAL ENERGY WORKSHEET[(1)]
("a" = per employee)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/°dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E	a thous.	E	F_u	a (4)	F	F_u	a thous.	F	F_u	a thous.	F
Light Industry process space heat air cond. electric			102 million	27.5[(3)]	2.81				117[(5)]	27.5	3.20	25.5[(5)]	27.5	0.70
Medium Industry process space heat air cond. electric			280 million	1.5	.42				304	1.5	.46	70.0	1.5	0.11
Heavy Industry process space heat air cond. electric			1170 million											
Energy-intensive process			-specific-											
					3.23			Btu/yr (÷1.03 million Btu/Mcf) Mcf			3.66 Btu/yr (÷140 thousand Btu/Gal) Gallons 26.1 million gallons			.81 Btu/yr (÷3413 Btu/Kwh) Kwh 237 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.
Unit Energy Demand of Consumption in 10^{6} Btu/yr per employee.

Footnotes: (1) This worksheet calculates the incremental energy needed for the Nassau-Suffolk region for the additional industrial activity of the region above the 1972 level.
(2) Data and procedures follow those in Table 27 (1972 Industrial Energy Worksheet), except for the number of industrial employees and their fuel mixes.
(3) The incremental industrial employees for 2000 are expected to be 29,000 (1972=160,000, 2000=189,000) Of which 95% are expected to be light energy intensive industries. 5% medium energy intensive industries (Extrapolated 1985 figures from RPA for forcasts).
(4) New gas installations prohibited.
(5) Fuel mix determined from Chapter III.

TABLE 37

Nassau-Suffolk

Corridors, Clusters, Centers (CCC)[1]

TRANSPORTATION ENERGY WORKSHEET

Trip Purpose/Mode	UNIT DEMAND: Vehicle Energy Demand (Btu/veh.mi) E_v	÷ Vehicle Occupancy Rate V	Unit Energy Demand (Btu/pass.mi.) E_u	ENERGY DEMAND: Land Use Activity (no. household) a thousands	Daily trips per household 0	Daily Passenger Trips T millions	Average Trip Length L	Annual Pass.Mi. per trip* (*364 days) M	Modal Split S	Total Energy Demand (Btu/yr) E	FUEL CONSUMPTION: Unit Oil Demand (Btu/pass.mi.) F_u	Total Pass. Mi. b million	Total Oil Consump. (Btu/yr) F	Unit Elect. Demand (Btu/pass. mi.) F_u	Total Pass. Mi. b million	Total Electric Consump. (Btu/yr) F
Work				572.4[3]	2.54	1.45	9.6[4]									
Auto	920[2]	1.4	660						.40[5]	1.34	3300	2033	6.70	1320	-	-
Bus	2315	20.	115						.30	.18	575	1524	.87	230	-	-
Rail/diesel	5320	40.	1330						.05	.34	4430	254	1.12	-	-	-
electric	18100	40.	450						.25	.57	-	-	-	450	1271	.57
Shop				572.4	2.20	1.26	5.1									
Auto	920	1.4	660						.50	.77	3300	1169	3.85	-	-	-
Bus	3525	23.	155						.40	.14	775	936	.72	-	-	-
Other				572.4	2.44	1.40	9.3									
Auto	920	1.6	575						.60	1.63	2875	2835	8.15	-	-	-
Bus	3525	23.	155						.30	.22	775	1418	1.09	-	-	-
										5.19			22.5 Btu/yr (÷140 thousand Btu/Gal) Gallons			.57 Btu/yr (÷3412 Btu/Kwh) Kwh
													161 million gallons			168 million Kwh

Note: Energy Demand of Consumption in 10^{12} Btu/yr.

Footnotes: (1) Data and procedures follow those in Table 28 (1972 Transportation Worksheet), with the exception of fuel consumption of vehicles, projected number of dwelling units, and trip length and modal split.

(2) Based upon 26 mpg average for ICE vehicles.

(3) Taken from Comprehensive Plan for the Nassau-Suffolk Region, Ref. 24.

(4) With development of centers, 40% of travel to work is within centers (average trip length 5 miles) and 60% of travel to work remains at present patterns (average trip length 12.7 miles). Weight average work trip length (.4)5.1+(.6) 12.7=9.6 miles
shop trip length = .55(9.6)=5.1 miles. Other trip length = .97(9.6)=9.3 miles.

(5) Higher employment density within centers (e.g. 40% of work travel above) permits more efficient utilization of bus transportation. Similarly, shop and other trips are more frequent by bus and walking. Percentage shift from auto travel in US to other modes in CCC are the following:
- work - 20% of passenger miles to bus
- shop - 20% of passenger miles to bus
  - 10% of passenger miles to walk.
- other - 10% of passenger miles to bus
  - 10% of passenger miles to walk.

TABLE 38

Nassau-Suffolk Energy Consumption Summary
Urban Sprawl Scenario - Increment
(2000)

Sector	Energy Demand (10^{12}Btu)	Fuel Consumption Gas(10^6 Mcf)	Oil(10^6 gal.)	Electric.(10^6Kwh)
Residential	56.9 (59%)	-	323 (43%)	7378 (66%)
Commercial	27.4 (28%)	-	151 (20%)	3317 (30%)
Industrial	3.45(4%)	-	28 (4%)	254 (2%)
Transportation	8.50(9%)	-	245 (33%)	222 (2%)
	96.25		747	11,171

TABLE 39

Nassau-Suffolk Energy Consumption Summary
Corridors, Clusters, & Centers Scenario - Increment
(2000)

Sector	Energy Demand (10^{12}Btu)	Fuel Consumption Gas(10^6Mcf)	Oil(10^6 gal.)	Electric.(10^6Kwh)
Residential	47.5 (58%)	-	246 (42%)	6940 (66%)
Commercial	25.7 (31%)	-	149 (26%)	3201 (30%)
Industrial	3.2 (4%)	-	26 (4%)	237 (2%)
Transportation	5.2 (7%)	-	161 (28%)	168 (2%)
	81.6		582	10,540

the introduction of the Nassau-Suffolk case. Some of these are evident from the figures in the Tables, others are less evident. With respect to the Master Plan that has been presented for developement of the eastern portion of the Island, it is evident that implementation of this Plan will result in a significant reduction in the incremental energy needed to meet the demands of the additional population. In terms of per capita energy consumption, there is a 15% reduction in total incremental energy demand afforded by the Corridors, Clusters, and Centers scenario over that of the continuation of Urban Sprawl projected land use development. This reduced demand results mainly from lowered demands in the residential and transportation sectors. Direct energy expenditures in the commercial and industrial sectors are only weakly dependent on the development scenarios, although the projected increase of retail establishments in malls indirectly contributes to savings in the transportation sector. Also noteworthy, is the continuing minor role played by industrial demands. In both scenarios, industrial energy demand constitutes only a small fraction of total energy use, as it did in the base case. These energy reduction figures given here are for the year 2000. Beyond that period, these reductions will increase as the urban sprawl pattern of land use present at the beginning of the planning period exerts less and less influence on total demand.

The energy supply options afforded to the region resulting from the form of its projected pattern of land use development is more apparent from the fuel consumption listings. As shown in the worksheets, most of the demands in the residential and commercial sectors are attributable to end use functions such as space conditioning, which are non-fuel specific. That is, these needs may be satisfied by a variety of end-use devices and fuel types. A similar situation exists to a more limited extent in the transportation sector, where mode shift changes and the use of electric-powered vehicles exist as possible alternatives to the increased use of the conventional oil-based automobiles and buses. Thus, to the extent the region wishes to be able to consider the trade-offs between reducing its dependence on oil imports or increasing the number of coal-fired and nuclear-powered electric generating stations in the region, land use patterns which promote the flexibility for using increased amounts of electricity should be considered more desirable.

Thus, interdependence is shown in a calculation of the increased electrical demand resulting from our assumption that 20% of newly constructed residential and commercial structures will be heated by electricity. As shown in the worksheets this results in a doubling of electrical demands in the year 2000 over that existing in 1972. Had further assumptions been included regarding the greater use of electrically-powered mass transit vehicles and automobiles, this figure would be substantially increased. On the other hand retaining current fuel usage patterns for space heating purposes in residential and commercial structures would result in approximately a 40% increase in the incremental oil requirements over that given in Tables 38 and 39. The difference in incremental oil requirement between the U.S. scenario and the CCC case amounts to 3.9 million barrels, which corresponds roughly to 10% of current oil usage for space heating purposes.

The CCC scenario of projected land use development in the Nassau-Suffolk region is clearly more compatible with opportunities for shifting to the greater use of electricity than the US scenario. Its greater reliance on multi-family units to house the population increase is likely to increase all-electric installations, which can minimize first costs and lead to reduced maintenance. Those installations will be further encouraged as more and more state utility regulatory authorities move to require metering of individual apartments' electrical usage.

In the transportation sector, the higher population densities and the increased interspersion of residential, commercial,and industrial activities in the CCC development scenario, will substantially improve the opportunities for utilization of mass transit systems, and short-haul electric automobiles and buses, primarily through the associated reductions in average trip lengths and the limited set of high density activity centers. Quantifying the projected increases in electrical demands that will accompany these developments for any particular region requires separate studies. Estimates can be made, however, utilizing existing transportation models and the results inserted in the appropriate energy worksheets.

With respect to regional energy supplies, one further point should be noted. This relates to impacts of projected restrictions in natural gas supplies to the region. It is clear from the worksheets that such restrictions will not seriously impact the region, with the possible exception of a selected set of industries which require "clean" fuels. In part this situation derives from the relatively low existing use of this fuel in the region. It also is based on the ability to easily substitute other fuels for natural gas in residential and commercial sectors.

Conclusions

Although the land use/energy analysis we have carried out for the Nassau-Suffolk region should be viewed as preliminary in nature, it can be used to draw a number of interesting conclusions.

1) Insofar as the Nassau-Suffolk regional Master Plan (as presented in the Corridors, Clusters, and Centers Scenario) represents a target design for patterning the major outlines of future land use activities, it will provide this area with both a reduced energy expenditure budget and an increased flexibility in considering alternative elements in its energy supply system.

2) While the final land use mix and arrangements in this region will not, in themselves, determine the detailed characteristics of the energy demand and fuel usage, the extent to which certain energy supply and end-use technologies are utilized is tied to the ensuing pattern of development particularly in the residential and transportation sectors.

3) The effort required to include energy considerations in the regional land use planning process does not require a major investment of manpower. Most of the data sources utilized are available to planning agencies and energy consumption in each sector can be calculated from the basic energy intensity coefficients provided in these worksheets. Furthermore, once the basic set of land use-energy data is obtained, individual elements can be refined over a period of time as more information becomes available from national, state, or local sources. This means that regional planning agencies should be able to set up a basic

land use-energy information and analytical system with relative ease.

B. A Community Redevelopment Design in Tucson

Aided in part by national demographic trends which have seen large shifts of population to the southwest sunbelt, the City of Tucson and its surrounding area is growing at a very rapid rate. Assuming the continuation of these trends, the current population of the area which is 450,000 is due to increase to 800,000 by the year 2000. As is typical in such cases where rapid and major land use development occurs in the environs of an existing city, numerous changes in the inner core of Tucson are also taking place. Industries and businesses are following the population shifts and in some areas of Tucson this has led to actual losses in population and a deterioration of neighborhoods in some parts of the city. Tucson proper has developed in such a way as to promote low density residential areas surrounding more dense commercial areas. Laid out in the traditional grid structure, it provides ample streets and road networks for movement by automobile throughout the city, and from the city to its surrounding conventionally structured suburban areas. The rapidity of development and the large and relatively low-cost open lands available more distant from the core have resulted in a situation in which sizeable parcels of land remain vacant within the inter city.

Both from the perspective of maintaining a contained growth policy for the region and as a means of encouraging conservation of energy resources, further development and redevelopment of inner-city areas of Tucson is desirable. Not only would such development provide greater amenities to population groups now living in the inner city, but it would increase the attractiveness of the inner-city areas to incoming residents, many of whom are retired and have been attracted to the Tucson area because of its climate and recreational opportunities. The renewal design study by Conklin & Rossant/Flack & Kurtz[68] provides an example for achieving desirable forms of urban revitalization which are compatible with more efficient uses of available energy supplies.

Census tracts 6 and 7, the areas chosen for study, are adjoining tracts located on the southern edge of the center city area which together consist of 960 acres. The University of Arizona, a focal point of retail business is located just west of the area. The present population trend in the study area is one of decline. The combined population in both tracts decreased by approximately 10% between 1970 and 1975. At present, 61% of the land area in these tracts is occupied by single family units. Commercial activities account for 11%; industrial activities 2%. Tract 6 is basically a single family community with multi-family units scattered throughout. Commercial development is mostly located along major east-west thoroughfares with greater concentrations at intersections with north-south streets. Tract 7 has two significiant differences in its land use pattern. There is a large quadrant of single family units fully built-up in long suburban subdivision blocks, and the area contains a significant amount of business-industrial development.

As noted above, the major intent of the Conklin & Rossant/Flack & Kurtz study was to explore land use designs which were both consistent with "good" design criteria and long-term reduced energy expenditures. In assessing the energy implications of such community designs one should differentiate between energy consumption as it occurs within the selected area due to on-site activities and those originating outside the area and making use of commercial and industrial facilities within the area. One should also consider the indirect energy impacts occurring in areas surrounding the selected census tracts. In the land use/energy analysis presented here, attention is restricted to the differences in on-site energy consumption that would result from a so-called "planned" and "unplanned" development of the two census tracts. The omission of the direct and indirect impacts on energy consumption patterns of activities occurring outside the area is justified in this case only because of the relatively small size and population involved.

The outline used to present the Tucson results is similar to the Nassau-Suffolk case. Data sources have been confined to those normally available in any region of the country. Worksheets have been prepared for existing, planned, and unplanned development of the two tracts utilizing sets of parameters describing land usage and transportation in the three cases. The results are presented in terms of comparative differences in the land use and energy usages.

Once again, we point out the instructional nature of this case example. Clearly other alternative designs could be prepared for the redevelopment of these neighborhoods. To the extent each of these can be characterized by a set of input parameters of the type given in the worksheets, their associated energy expenditures can be dealt with by the same procedures.

Characteristics of Community Energy Supplies

The role of the energy supply-distribution system considerations in a land use/energy analysis of a community level design is usually different from that found in a regional land use/energy analyses. The small size of the land area involved and the resulting total energy demand seldom allow one to consider energy supply options other than those locally available to the larger surrounding region. Thus, the characterization of the supply-distribution system should be included primarily as a reflection of the constaints imposed on the land use designs considered. To this extent, it is usually sufficient to define an existing fuel supply breakdown and estimates of any bounds which may be imposed on this fuel supply as a result of actions being contemplated by local utilities or state regulatory agencies. One should also include information, to the extent it is available, of likely shifts in the comparative prices of fuels. Exceptions to viewing community energy supplies in this light do occur, such as those where unique opportunities may exist for considering the use of decentralized energy supply technologies such as solar energy, integrated utility systems, solid waste heat recovery, etc. In such cases, a wider range of community energy supply options exist which may be of interest to both community and higher level governmental units. This was the case for the study area in Tucson.

Because of the existence of high insolation levels in this part of the country and the proximity of industrially-zoned areas, the potential energy savings derivable from the use of combined heat recovery and central heating and cooling facilities and solar production of hot water were considered in the Conklin & Rossant/Flack & Kurtz design. Their inclusion in the land use/energy analysis is not intended to substitute for a detailed engineering and cost analysis, but to present the results of utilizing such supply systems in terms of their overall land use-energy implications. More specifically, estimates were made of the possible reduction in conventional fuel loadings in the residential and commercial sectors and the parameters used in preparing the worksheets were adjusted accordingly. The estimates were prepared as part of the Conklin & Rossant/Flack & Kurtz study and the reader is referred to their study for details of the calculations.

Current Patterns of Energy Utilization

The assembly of demographic information on the Tucson area for use in the energy worksheets is quite straightforward and follows the patterns outlined previously for the Nassau-Suffolk case. The data sources are largely those listed in Chapter III. Where basic information is unavailable, various estimation procedures were utilized which are described in footnotes to the worksheets. A summary of all data and information sources, with specific citations, are catalogued in the worksheet footnotes.

Some unique aspects of the data collection effort in the Tucson area are directly related to earlier comments concerning the Nassau-Suffolk case and the discussion of data sources in Chapter III. In general, following the pattern of data collection efforts elsewhere, the residential sector data are easily obtained, as is some general information on commercial, industrial, and transportation sectors. However, as might be typical in many areas of the country, there are specific organizations in the Tucson area which have relevant data. For example, the Tucson Planning Department carries out special census surveys at various times. The results of such a census contain some detailed information on housing stock, office and retail activity in the commercial sector, industrial employment, and modal split characteristics of the transportation system. In addition to such planning department information, a local bank maintains some information on commercial floorspace in the area. The local utility provided estimates of the fuel mix in the commercial sector, which is often difficult to obtain. Other date were derived from the U.S. Census and other standard references noted earlier. Where information was lacking, it is noted on the worksheet that estimates were based upon the procedures outlined in Chapter III.

The calibration and verification of the energy calculations of this small area of Tucson prove quite difficult. For such small communities, it is often difficult to obtain utility data which relate specifically to the area of study. The data generally available from the utility will be aggregated to much larger regions. Similarly, it is difficult to obtain energy inputs to the transportation sector, so that while the basic parameters which determine energy consumption in the area may be compared against planning department estimates and the like, no direct energy consumption figures for transportation are available as a verification of the end result of the calculation. These considerations serve merely to emphasize that the absolute levels of energy consumption are difficult to verify. At the same time, the way in which energy consumption associated with alternative land use patterns is established, the relative energy changes associated with alternative land use patterns can be estimated with more certainty.

The worksheets were constructed utilizing the 1975 land use information shown in Table 40, which was taken from the Conklin & Rossant/Flack & Kurtz study as well as the planning department and other agency sources noted above. The base case worksheets are given in Tables 41, 42, 43, and 44 for the residential, transportation, commercial, and industrial sectors, respectively. Since housing units in the area tend to be somewhat larger than the 1300 square feet defined as the standard house earlier, the residential calibration sheet in Table 41A includes the adjustment for this size increment. The overall current pattern of energy consumption for the area is summarized in the Table 45. The industrial energy use in the region is quite small because the region contains little industrial employment, and that employment present in the area is light industry. The pattern of transportation energy consumption reflects the use of the automobile for virtually all transportation in such areas. Overall, the pattern of current energy use is not unlike that of suburban communities elsewhere.

Development Scenarios

The Conklin & Rossant/Flack & Kurtz study describes two scenarios for future development through the year 1995. One is a projection of development as it is likely to occur assuming a continuation of current trends. This is labeled as "unplanned". The other is based on the Conklin & Rossant/Flack & Kurtz design; this is labeled as "planned". The projected growth or decline in land use activities for both scenarios is shown in Table 40.

Because of the small size of the area under consideration, the constraint of maintaining an equality in regional development parameters imposed in the Nassau-Suffolk scenarios was considered too restrictive. Instead, land use development parameters for the two scenarios were derived independently

TABLE 40

CURRENT AND PROJECTED LAND USE IN TUCSON STUDY AREA

	Current (1975)	Unplanned (1995)	Planned (1995)
Population	9760	9255	12000
Housing			
single-family	3540 (80%)	3062 (80%)	3540 (68%)
multi-family	900 (20%)	780 (20%)	1650 (32%)
	4400	3842	5190
Commercial floorspace	870 thous. sq. ft.	870 thous. sq. ft.	1340 thous. sq. ft.
Industrial employment (local)	435	1030	1030
Total Passenger Miles	41 million mi.	36 million mi.	48 million mi.

Modal Split	Work/other	Shop	Other/work	Shop	Other/work	Shop
auto	97	97	97	97	80	60
bus	3	3	3	3	10	10
walk	-	-	-	-	10	30

TABLE 41

1975 TUCSON

Census Tract 6 & 7

RESIDENTIAL ENERGY WORKSHEET
("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/Cool Season (°days)	Heat/Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D Thousand	E_u Million	a	E 10^9	F_u Million	b	F 10^9	F_u	b	F	F_u 10^6	b	F 10^9
Single Family Detached														
space heat	1776 [1]	14.8 [3]	26.2 [5]	3540 [6]	92.2	40.3 [9]	3363 [13]	136 [16]		[17]		21.0 [9]	177	3.7 [16]
air cond. - central	3500 [2]	23.4 [3]	81.7	318 [7]	25.9		-			-		32.7 [18]	318	10.4
room		9.3 [4]	32.7	920 [7]	29.9		-			-		16.4 [18]	920	15.1
Single Family Attached														
space heat														
air cond. - central														
room														
Low Rise														
space heat	1776	6.7	11.9	900 [6]	10.7	18.3	855	15.6		-		9.5	45	.4
air cond. - central	3500	9.8	34.4	81 [7]	2.8		-			-		13.8	81	1.1
room		3.9	13.7	234 [7]	3.2		-			-		6.9	234	1.6
High Rise														
space heat														
air cond. - central														
room														
All Units														
water heat	-	-	18	4440 [8]	79.9	28 [10]	4262 [14]	119		-		18 [1]	178	3.2
range	-	-	4	4440	17.8	11 [11]	2975 [15]	33		-		4 [11]	1465	5.9
electric appl.	-	-	21	4440	93.2		-			-		21 [12]	4440	93.2
Totals					356 x 10^9 Btu/yr			304 x 10^9 Btu/yr (÷ 1.03 million Btu/Mcf) 295 thous. Mcf			Btu/yr (÷ 140 thousand Btu/Gal) Gallons			134.6 x 10^9 Btu/yr (÷ 3412 Btu/Kwh) 39.4 mill. Kwh

NOTES TO TABLE 41

1. Data from Figure 2 and Ref. 68, p.37.

2. Data from Figure 3.

3. Data calculated from Residential Region Specific Calibration Sheet.

4. Room air conditioner demand 40% of central.

5. $E_u = d \cdot D$

6. 1975 Special Census Ref. 68, p. 36.

7. 1970 Census, Detailed Housing Characteristics - Arizona p. 4-71, 7-74, applied City of Tuscon, Room/ Central/none/A/C/mix to Census Tracts 6&7's 4400 dwelling units.

8. Total number of dwelling units with water heat, range and electric appliances (4440 = 3540 single family & 900 mulitfamily).

9. Space heating $F_u = E_u/e$; e = .65 gas, 1.25 electric.

10. Water heat $F_u = E_u/e$; e = .65 gas, 1.00 electric.

11. Range $F_u = E_u/e$; e = .38 gas, 1.00 electric.

12. Electric appliances $F_u = E_u/e$; e = 1.00 electric.

13. 95% of Single family (and Low rise) space heat by gas, op. cit. Note 7.

14. 96% of water heat supplied by gas, op. cit. Note 7.

15. 67% of all cooking by gas, op. cit. Note 7.

16. $F = F_u \cdot b$.

17. Allocated 35 oil heated homes to gas.

18. Air conditioning $F_u = E_u/e$; e = 2.5 central, e = 2.0 room.

TABLE 41A

1975 Tucson

RESIDENTIAL REGION-SPECIFIC CALIBRATION [1]

		SIZE			INSULATION			GLASS				
HEATING	Nominal Heat Demand Btu/°dy	Btu/°dy Per sq. ft.	Size Increment	Incremental Heat Demand	Btu/°d per Ceiling R	Incremental Ceiling R	Incremental Heat Demand	Btu/°d Per 1%	Incremental % (15%)	Incremental Heat Demand	Region-Specific Heat Demand Btu/°dy	Room A/C
Existing Stock	(a)			(b)	(R-7)		(c)			(d)	(a+b+c+d	
Single-family detached	14,000	7.6	+100[2]	+760[4]	240	-		200			14,000 + 760 = 14760[5]	
Single-family attached												
Low Rise	7,500	4.0	-200[3]	-800[4]	120	-		110			7,500 - 800 = 6700	
High Rise												
New Construction												
Single Family Detached	10,300	5.6	+100	+560	(R-11) 110	-		200			10,300 + 560 = 10860	
Single Family Attached								110			5,500 - 580 = 4920	
Low Rise	5,500	2.9	-200	-580	58	-						
High Rise												
COOLING [6]												
Existing Stock												
Single-family detached	22,000	13.5	+100	+1350							22,000 + 1350 = 23350	9340
Low Rise	11,200	6.9	-200	-1380							11,200 - 1380 = 9820	3930
New Construction												
Single-family detached	15,500	9.7	+100	+970							15,500 + 970 = 16470	6598
Low Rise	8,100	5.0	-200	-1000							8,100 - 1000 = 7100	2840

1. To exhibit calibration worksheet utilization, we assume 1400 sq.ft. single family homes and 1100 sq.ft. low rise homes.
2. Size increment is actual: 1300 = 1400-1300 = +100
3. Same as 2 except 1200-1300 = -100.
4. Incremental heat demand is Btu/°day/sq.ft. multiplied by size increment.
   Single-family: 7.6 x +100 = +760; Low rise: 4.0 x -200 = -800.
5. Region-specific heat demand Btu/°day is the sum of the nominal heat demands and the adjustments being made.
   Single-family: 14,000 +760 = 14760; low rise 7500 +(-800) = 6700.
6. The same methodology is applied to new construction and the adjustments for cooling demands.

Table 42

1975 Tucson Existing

TRANSPORTATION ENERGY WORKSHEET

Trip Purpose/Mode	UNIT DEMAND: Vehicle Energy Demand (Btu/veh. mi) E_v	÷ Vehicle Occupancy Rate V	Unit Energy Demand (Btu/pass - mi) E_u (1)	ENERGY DEMAND: Land Activity (no. household) a	Daily Trip origins per household o	Daily Passenger Trips T (2)	Average Trip Length (round trip) L	Modal Split (%) S	Pass. Annual Miles M (3)	Total Energy Demand (Btu/yr) E (4) (x 10^9)	FUEL CONSUMPTION: Unit Oil Demand F_u	Total Pass. Miles b 10^6	Total Oil Consump. (Btu/yr) F 10^9	Unit Elect. Demand F_u	Total Pass. Miles b	Total Electric Consump. (Btu/yr) F
Work																
Auto	1840	1.2	1540	4440 (5)	2.20 (6)	9768	5.1 (7)	.97 (8)	1800	27.7	7700 (9)	17.6 (10)	135.5 (11)			
Bus	4630	20.	230					.03	56	.1	1150	.5	.6			
Rail/diesel	53200	40.	1330					–	–		–	–	–			
electric	18100	40.	450					–	–		–	–	–			
Walk																
Shop																
Auto	1840	1.45	1270		1.75	7735	2.8	.97	989	10.1	6600	7.6	50.2			
Bus	7050	23.	310					.03	31	–	1550	.2	.3			
Walk								–	–							
Soc/Recr.																
Auto	1840	1.76	1040		1.88	8310	4.9	.97	1730	16.5	5750	14.4	82.8			
Bus	7050	23.	310					.03	54	–	1550	.4	.7			
Walk																
Commercial																
Truck																
Total										54×10^9 Btu/Yr			270×10^9 Btu/yr (÷ 140 thousand Btu/Gal) 1.9 million Gallons			Btu/yr (÷ 3412 Btu/Kwh) Kwh

(1) $E_u = E_v \div V$

(2) $T = a \cdot 0$

(3) $M = 364 \cdot S \cdot L$

(4) $E = E_u \cdot T \cdot M$

(5) 4440 Dwelling Units

(6) Passenger Trips - Table 16 - Medium Income

(7) Average Trip Length - Table 17 - Income Level 2

(8) Modal Split - (Ref. 68) - 97% Auto, 3% Bus.

(9) $F_u = E_u / e$; e = .20 Auto + Bus, .30 diesel

(10) $b = T \cdot M$

(11) $F = F_u \cdot b$

TABLE 43

1975 Tucson

COMMERCIAL ENERGY WORKSHEET
("a" = square feet)

	UNIT DEMAND				ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/sq.ft. per °day)	Internal Demand (Btu/ sq.ft.)	Unit Energy Demand (Btu/ sq.ft.)	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	I 10^3	E_u 10^3	a 10^3	E 10^9	F_u 10^3	b 10^3	F	F_u	b	F	F_u 10^3	b 10^3	F 10^9
Office															
space heat	1776	19	20	54 (1)	636 (2)	34	83 (4)	127 (5)	10.5 (6)				54 (4)	509 (5)	27.5 (6)
air cond.	3500	18	20	83	477 (3)	40	–	–					33	477	15.7
electric				32	636	20							32	636	20.3
Retail Mall															
space heat		18	20				–	–	–				–	–	–
air cond.		20	20				–	–	–				–	–	–
electric															
Retail Strip															
space heat	1776	22	20	59	212 (2)	13	91	42	3.8				59	170	10.0
air cond.	3500	22	20	97	159	15	–	–	–				39	159	6.2
electric				34	212	7	–	–	–				34	212	7.2
Other															
space heat	1776	16	15	43	22 (2)	1	66	5	.3				43	17	0.7
air cond.	3500	15	15	68	17	1	–	–	–				27	17	0.5
electric				32	22	1	–	–	–				32	22	0.7
					132 x 10^9 Btu				14.6 x 10^9 Btu/yr (÷1.03 million Btu/Mcf) 14.1 Thous. Mcf gas			Btu/yr (÷140 thousand Btu/Gal) Gallons			88.8 x 10^9 Btu/yr (÷ 3413 Btu/Kwh) 26 million Kwh

1. $E_u = d \cdot D + I$
2. Commercial space 870,000 sq.ft., 22,000 sq.ft. Institutional (Census), 75% of Non Institutional is office, 25% Retail (Ref. 68).
3. 75% of all commercial space air conditioned.
4. $F_u = E_u \div e$; e = .65 gas and oil, 1.00 electric heat and electric, 2.5 air conditioning.
5. Assumed 20% of commercial space gas heated, 80% electrically heated.
6. $F = F_u \cdot b$.

TABLE 44

1975 Tucson

INDUSTRIAL ENERGY WORKSHEET
("a" = per employee)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/°dy)	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E 10^9	F_u 10^6	a	F 10^9	F_u	a	F	F_u 10^6	a	F 10^9
Light Industry process space heat air cond. electric			120million(1)	435(2)	52.3(3)	134(4)	435	58.3(5)				31(4)	435	13.5(5)
Medium Industry process space heat air cond. electric			310million							none				
Heavy Industry process space heat air cond. electric			1170million											
Energy-intensive process			-specific-											
					52.2×10^9 Btu			58.3×10^9 Btu/yr (÷1.03 million Btu/Mcf) 56.6 Thous. Mcf			Btu/yr (÷140 thousand Btu/Gal) Gallons			13.5×10^9 Btu/yr (÷3413 Btu/Kwh) 4.0 million Kwh

1. Taken from Table 11 and assume all light industry.
2. Given 182,000 sq.ft. of Industrial floorspace (Ref. 68, Census Trace 7) and assuming floorspace needed per employee equal to that of the Nassau-Suffolk area, implies 435 light industrial employees. (Floorspace/Employee (N-S) = $67 \times 10^6 / 16 \times 10^4$ = 419 = 182,000/# Tuscon Industrial Employees.)
3. $E = E_u \cdot a$
4. From Table 12.1, Fossil is million Btu of fuels, and $F_u = E_u/e$, with e = .65 fossil and 1.0 electric.
   Fossil $F_u = 83 \div .65 + 6$(Feedstock) = 134 million Btu
   Electric E_u = 31 million Btu (Table 12.1).
5. $F = F_u \cdot a$

TABLE 45

CURRENT TUCSON ENERGY PROFILE

(1975)

Sector	Energy Demand 10^9 Btu	Fuel Consumption: Gas 10^3 mcf	Oil 10^3 Gal	Electric 10^6 kwh
Residential	356 (60%)	295 (80%)	-	39 (56%)
Commercial	132 (22%)	14 (4%)	-	26 (38%)
Industrial	52 (9%)	57 (16%)	-	4 (6%)
Transportation	54 (9%)	-	1900 (100%)*	-
Total	594	366	1900	69

*Given the assumption about the very low consumption in the residential sector.

from previous studies of development in the general area for the unplanned scenario and the final land use design for the planned scenario.

The scenario for planned development is based on the elements entering into the Conklin & Rossant/Flack & Kurtz design which are summarized below.

1. To reduce the need for reliance on the automobile, and enhance personal travel via walking, biking, and the use of public transportation, street patterns are to be revised by eliminating some east-west and north-south thoroughfares and creating a number of greenways through the community.

2. To take advantage of the opportunity for the sharing of energy supply systems, new construction is focused on multi-family housing concentrated at a few density intensification nodes located at either side of the main shopping street. These nodes are designed to provide living unit sizes, open space, views, and facilities competitive with single family units in the area.

3. In order to decrease the need for travel to distant recreational centers, and to provide additional amenities to neighborhood residents, additional facilities are provided at a city recreational center in the immediate area.

4. Additional commercial growth is limited to existing areas located on principal automobile routes or integrated into higher density residential areas, with one exception. An area at the south-western edge of the community is proposed for intensive combined commercial-industrial use. This area contains a solid waste incinerator whose waste heat can serve both newly built industrial facilities and nearby commercial and multi-family structures.

In addition to these projected changes in the patterns of land use and transportation in the area, the community design includes energy considerations. The potential utilization of waste heat recovery systems in district heating was mentioned. Both the use of heat pumps, and of solar hot water heating are also expected, and these developments are reflected in the worksheets.

The unplanned scenario assumes a continuing loss of population and business activity in the area. The character of energy utilization, aside from the general decline associated with population and business loss, will undergo no significant change.

The dominant shifts in energy consumption patterns between "planned" and "unplanned" development will occur in the residential and transportation sectors. In the residential sector, the planned development scenario includes the construction of multi-family housing at density nodes, which would draw a larger population into the area. In addition, this multi-family housing leads to lower energy consumption and facilitates the introduction of a district heating system. The introduction of solar hot water heating in new construction also leads to reduction of demand for energy in the residential sector. The patterns of new commercial growth in the region as well as the revision of street traffic patterns will encourage shifts toward the use of non-energy intensive modes of travel, including walking and more extensive use of a bus system. The changing character of land use and transportation in the study area is reflected in the residential and transportation worksheets for unplanned development, Tables 46 and 47, and in those for planned development, Tables 48 and 49, respectively.

A comparison of the pattern of energy consumption between "planned" and "unplanned" development is shown in the summary Table 50. We noted earlier that in a small area of community development, it is difficult to assume constant levels of residential and commercial growth under alternative future development. The differences in energy consumption are related to the changes in population and other characteristics of land use as shown in Table 50.

In unplanned development, the level of energy demand for heating, that is natural gas consumption, declines with the number of households, while the consumption for the individual household remains the same. However, air conditioning continues to grow and leads to the 60% increase in electricity demand while the number of dwelling units decreases by 13%. Similarly, there are no major changes assumed in individual or family travel patterns under unplanned development so that concurrent with population loss is a 13% decrease in passenger miles and a corresponding 10% decrease in gasoline consumption.

TABLE 46

1975 Tucson(1)

RESIDENTIAL ENERGY WORKSHEET
("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E	F_u	b	F	F_u	b	F	F_u	b	F
Single Family Detached		10^3	10^6		10^9	10^5		10^9				10^6		10^9
space heat	1176	14.5 (6)	26	3080 (3)	80	40	2816 (8)	113				21	264 (9)	6
air cond. -	3500													
central		22.8	80	1232	99	-	-	-				32	1232	39
room		9.1	16	1232	20	-	-	-				8	1232	10
Single Family Attached														
space heat														
air cond. -														
central														
room														
Low Rise														
space heat	1776	6.6 (6)	12	783 (5)	9	18	720 (8)	13				10	63 (9)	1
air cond. -	3500	9.6 (7)	34	312 (4)	11	-	-	-				14	312	4
central		3.8	13	312	4	-	-	-				7	312	2
room														
High Rise														
space heat														
air cond. -														
central														
room														
All Units														
water heat	-		18	3863 (2)	70	28	3410 (8)	95				18	453 (9)	8
range	-		4	3863	15	11	2380 (8)	26				4	1483	6
electric appl.	-		21	3862	81	-	-	-				21	3863	81
					389×10^9 Btu			247×10^9 Btu/yr (÷ 1.03 million Btu/Mcf) 240 Thou. Mcf			Btu/yr (÷ 140 thousand Btu/Gal) Gallons			157×10^9 Btu/yr (÷ 3412 Btu/Kwh) 46 million Kwh

NOTES TO TABLE 46

1. Data and procedures follow those in Table 41.

2. Total number of homes from Ref. 68 (unplanned case).

3. Replacement rate of 1%/year (1975 to 7995; 20%) from 1975 level. Single family existing in 1975 is 3540 therefore 2832 single family homes in 1995 from 1975. Given an overall 13% reduction in dwelling units, it is estimated that there would be 3080 single family homes of which 2816 are existing and 264 are new.

4. Estimated that 40% of all homes would have central A/C and 40% of all homes would have room A/C.

5. Same procedure as Note 3 above yields 720 existing and 63 new low rise units.

6. Weighted average of new and existing heat/cool demands. From Residential Calibration Sheet:

$$\frac{2816}{3080}(14.8) + \frac{264}{3080}(10.9) = 14.5$$

$$\text{L.R.} \quad \frac{720}{783}(6.7) + \frac{63}{783}(4.9) = 6.6$$

7. Same procedure as Note 6 for air conditioning and in central and room proportions.

8. Assumed all removals are gas and no additional gas customers.

9. Number of single family (low rise) homes less gas appliance homes result in balance of homes by electric.

TABLE 47

1995 Tucson Unplanned

TRANSPORTATION ENERGY WORKSHEET

	UNIT DEMAND			ENERGY DEMAND							FUEL CONSUMPTION					
	Vehicle Energy Demand (Btu/veh. mi)	÷ Vehicle Occupancy Rate	Unit Energy Demand (Btu/pass - mi)	Land Activity (no. household)	Daily Trip origins per household	Daily Passenger Trips	Average Trip Length (round trip)	Modal Split (%)	Pass. Annual Miles	Total Energy Demand (Btu/yr)	Unit Oil Demand	Total Pass. Miles	Total Oil Consump. (Btu/yr)	Unit Elect. Demand	Total Pass. Miles	Total Electric Consump. (Btu/yr)
Trip Purpose/Mode	E_v (2)	V	E_u	a	O	T	L			E	F_u	b	F	F_u	b	F
Work																
Auto	920	1.2	770	3863	2.20	8500	15.2	97 (1)	1801	11.8	3850	15.3	58.9			
Bus	2315	20.	115					3	56	.01	575	.5	.2			
Rail/diesel	53200	40.	1330					-	-	-	4•30	-	-			
electric	18100	40.	450					-	-	-	-	-	-			
Shop																
Auto	920	1.4	660		1.75	6760	2.8	97	989	4.4	3350	6.7	25.8			
Bus	3525	23.	115					3	31	.02	775	.2	.2			
Other								-	-	-	-	-	-			
Auto	920	1.6	575		1.88	7262	4.9	97	1730	7.2	2375	12.6	36.2			
Bus	3525	23.	155					3	54	.06	775	.4	.3			
Commercial																
Truck	-		-													

23.5×10^9 Btu/Yr.

121.6×10^9 Btu/yr
(÷ 140 thousand Btu/Gal)
.87 million Gallons

Btu/yr
(÷ 3412 Btu/Kwh)
Kwh

(1) No change in modal split

(2) Values reflect increased auto and bus efficiency

TABLE 48

1995 PLANNED

RESIDENTIAL ENERGY WORKSHEET[1]
("a" = number of dwelling units)

	UNIT DEMAND			ENERGY DEMAND		FUEL CONSUMPTION								
	Heat/ Cool Season (°days)	Heat/ Cool Demand (Btu/yr per "a")	Unit Energy Demand (Btu/yr per "a")	Land Use Activity ("a")	Total Energy Demand (Btu/yr)	Unit Gas Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Gas Consump. (Btu/yr)	Unit Oil Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Oil Consump. (Btu/yr)	Unit Electric Consump. (Btu/yr per "a")	Land Use Activity ("a")	Total Electric Consump. (Btu/yr)
	d	D	E_u	a	E	F_u	b	F	F_u	b	F	F_u	b	F
Single Family Detached			10^6		10^9	10^6		10^9				10^6		10^9
space heat	1776	14.0[5]	25	3540[3]	89	37	2690[6]	100				15[11]	850[8]	13
air cond. - central	3500	22.0[5]	77	1416[4]	109	-	-	-				31	1416	44
room		8.8	31	1416	44	-	-	-				16	1416	23
Single Family Attached														
space heat														
air cond. - central														
room														
Low Rise														
space heat	1776	5.0	10	1630[4]	16	18	684[6]	12				8	36[9]	.3
air cond. - central	3500	8.3	29	652	19	-	-	-				12	660	8
room		3.3	12	652	8	-	-	-				6	660	4
High Rise														
space heat														
air cond. - central														
room														
All Units														
water heat	-	-	18	5170[2]	93	22[12]	3410[7]	75				14[12]	850[10]	12
range	-	-	4	5170	21	11	2380[7]	26				4	2790	11
electric appl.	-	-	21	5170	109							21	5170	109
Totals					508 x 10^9 Btu[13]			213 x 10^9 Btu/yr (÷ 1.03 million Btu/Mcf) 207 x 10^3 Mcf			Btu/yr (÷ 140 thousand Btu/Gal) Gallons			224 x 10^9 Btu/yr (÷ 3412 Btu/Kwh) 65.6 million Kwh

NOTES TO TABLE 48

1. Data and procedures follow those in Table 41.

2. From Ref. 68.

3. Assumed removal rate equals replacement rate for single family homes at 1% per year and balance of new homes are low rise.

4. 40% of homes with central A/C; 40% with room air conditioning.

5. Weighted average of nominal heat demands as in unplanned case.

   Single Family
   - Space heat $.80(14760) + .20(10860) = 14.0 \times 10^3$
   - A/C $.80(23350) + .20(16470) = 22.0 \times 10^3$

   Low Rise (900(.8) = 720 exist, so 720/1630 = 45% existing, 55% new
   - Space heat $.45(6700) + .55(4920) = 5.7 \times 10^3$
   - A/C $.45(9820) + .55(7100) = 8.3 \times 10^3$

6. In 1975 there were 3363 single family and 855 low rise gas heated homes. It's expected that the removals will be these homes as the number of gas heated homes are reduced by 20% and the balance of the homes are heated with some form of electricity (3363 (1975) → 2690 single family; 855 (1975) → 684 low rise).

7. The same 20% removal rate applies to the gas cooking and water heat units.

8. Total number of single family homes 3540, less gas heated 2690, leaves 850 for electric.

9. Total low rise homes 1630, less gas heated 684. leaves 946 electric heated homes, but given a DISTRICT CENTRAL HEATING SYSTEM for all new low rise dwellings (the number of new dwellings are 1630-900(1-.2) = 910. So 946-910 = 36 are electric heated and the 910 new units supplied with central district waste heat systems.

10. There are 910 new low rise dwellings using DISTRICT SPACE HEATING that will also provide hot water demand for these dwellings, therefore, of the total of 5170 units, 3410 are gas hot water supplied and 910 central district heating leaving 850 units for electric hot water.

11. HEAT PUMPS for half of the single family homes at a C.O.P. of 2.0 reducing unit demand to (E_u = 25, e = 1.25, F_u = 20 w/o h.p.; (resist) 20 x .50 + (h.p.)10 x .50 = 15.

12. SOLAR WATER HEAT to provide 70% of the hot water for 30% of all homes, reducing the fuel demand by 21%; (1.0 - .21 = .79).

    gas: $18 \div .65 \times .79 = 22$

    elec.: $18 \div 1.0 \times .79 = 14$

13. Does not reflect new technologies as listed.

TABLE 49

TRANSPORTATION ENERGY WORKSHEET

Trip Purpose/Mode	UNIT DEMAND: Vehicle Energy Demand (Btu/veh. mi) E_v (1)	÷ Vehicle Occupancy Rate V	Unit Energy Demand (Btu/pass - mi) E_u	ENERGY DEMAND: Land Activity (r.o. household) a	Daily Trip origins per household O	Daily Passenger Trips T	Average Trip Length (round trip) L	Modal Split (%) $S^{(2)}$	Pass. Annual Miles M	Total Energy Demand (Btu/yr) E	FUEL CONSUMPTION: Unit Oil Demand F_u	Total Pass. Miles b 10^6	Total Oil Consump. (Btu/yr) F 10^9	Unit Elect. Demand F_u	Total Pass. Miles b	Total Electric Consump. (Btu/yr) F
Work																
Auto	920	1.2	770	5170	2.20	11380	5.1	80	1485	13.0	3850	16.9	65.1			
Bus	2315	20.	115					10	185	.2	575	2.1	1.2			
Rail/diesel	53200	40.	1330					–	–	–	4430	–	–			
electric	18100	40.	450					–	–	–	–	–	–			
Walk	–	–	–					10	185	–						
Shop																
Auto	920	1.4	660		1.75	9050	2.8	60	610	3.6	3300	5.5	18.2			
Bus	3525	23.	155					10	100	.1	775	0.9	0.7			
Walk	–	–	–					30	305	–	--					
Other																
Auto	920	1.6	575		1.88	9720	4.9	80	1430	8.0	2875	13.9	40.0			
Bus	3525	23.	155					10	180	.3	775	1.7	1.3			
Walk	–	–	–					10	180	–		1.7				
Commercial																
Truck																
										25.2×10^9 Btu/Yr.			127×10^9 Btu/yr (÷ 140 thousand Btu/Gal) 904 Thousand Gallons .90 million Gallons			Btu/yr (÷ 3412 Btu/Kwh) Kwh

(1) Reflects increased Auto and Bus efficiencies

(2) Modal Split now represents land use planning permitting wider use of walking and buses.

TABLE 50

ALTERNATIVE ENERGY CONSUMPTION PROFILES

IN THE TUCSON STUDY AREA

	1975		1995			
	19		Unplanned		Planned	
Residential	Gas	Electric	Gas	Electric	Gas	Electric
Consumption (10^9 Btu)	295	39	247	157	213	224
% change			-13%	+60%	-32%	+140%
Dwelling Units	4400		3842		5190	
% change			-13%		+16%	
Transportation	Oil (Gasoline)		Oil (Gasoline)		Oil (Gasoline)	
Consumption (10^9 Btu)	135[1]		122		127	
% change			-10%		-6%	
Passenger Miles	41 million		36 million		48 million	
% change			-13%		+16%	

[1] adjusted for doubling of miles per gallon between 1975 and 1995.

Planned development in the Tucson study area offers many opportunities for energy savings which were noted earlier. The construction of multi-family housing leads to a 16% increase in total dwelling units. Reconstruction of the area includes demolition of about 20% of existing housing stock which is heated by natural gas. Because of natural gas shortages, new multi-family housing is projected to rely upon electricity for all uses. The demand for electricity would soar, if not reduced by district heating and solar energy utilization. The district heating project encompassed most of new multi-family construction and supplies the heating and hot water needs for 20% of the total number of dwelling units in 1995. Solar energy use for water heating reduces this energy demand substantially, though water heating itself forms a smaller part of the total energy demand picture. Again, air-conditioning utilization continues to rise substantially, which contributes to large increases in the demand for electricity. Associated with redevelopment of this central city area in Tucson, we noted the decreasing demands for transportation which follow from enhanced job opportunities and improved residential-commercial land use mixes. Overall, these produce a 6% decline in transportation fuel requirements at the same time that passenger miles traveled increases by 16%. The detailed relation between the character of mode choice induced by the changing land use patterns and energy savings for various trip purposes can be explored in Table 49. The total reduction in residential and transportation fuel needs in the Tucson redevelopment study area is 24% while, at the same time, land use activity increases by 16%. The average savings based upon constant dwelling units is about 40%. Finally, the energy savings in area redevelopment of 40% are projected under modest community design considerations and are indicative of both the range of potential savings and the need to explore opportunities for energy-saving community designs.

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V. FINAL COMMENTS

The planner's energy workbook presented in this report should be viewed as an initial effort. As more experience is developed in applying this and similar methodologies to specific regions and communities, and more region-specific data on land use/energy consumption become available from other studies and evaluations, they should be encorporated into updated versions. Computer models which allow quick accessing of the data and routine land use-energy impact analyses should also be included in later versions. Given such efforts, over a period of time the data, procedures, and illustrative examples included in the workbooks can become more comprehensive and will find greater use by the planning profession.

We make no claim that the approach used here is either unique or necessarily more appropriate than others that have been suggested and applied to specific regions. Insofar as the approach used here does have an advantage, it lies in its ability to be adapted to a variety of land use situations by planners lacking a strong background in the technical aspects of energy production and consumption.

Aside from the extended effort which will be required to improve the technical aspects of land use/energy analysis, there is a need for substantially increasing the dialogue between energy managers and technical analysts and land use planners. As noted in the introductory paragraphs of this report, energy as an issue in local land use planning is still a relatively new concept. Even more undeveloped among energy policy-makers is the notion that land use development must be considered in their management of the nation's energy resources. To the extent that the methods and applications outlined in this report allow both groups to understand more fully their respective points of view, it should help foster these much needed discussions.

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