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MAJOR MODELS AND DATA SOURCES FOR RESIDENTIAL AND COMMERCIAL SECTOR ENERGY CONSERVATION ANALYSIS

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HITTMAN

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FINAL REPORT

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9190 Red Branch Road
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INTRODUCTION

This report reviews several of the major models and data sources that can be used for energy conservation analysis in the residential and commercial sectors. The objective is to provide an introduction to the various analytical and data tools that are or can be available to the Department of Energy and its Conservation Policy Office in order to further their efforts in analyzing and quantifying their policy and program requirements. By bringing together information on the analytical structure, data detail, policy applications, and access procedure for the models and data sources in the residential and commercial sector, this document is designed to acquaint the potential users with the resources they have on hand, to aid them in selecting and drawing on these more effectively, and to provide guidance toward more specific expertise and documentation.

The major models and data sources that are examined in this report are listed in Table 1, for the residential sector, and Table 2 for the commercial sector. These tables also summarize many of the outputs and analytical features and serve as a reference to the separate discussion of each model and data source given in the body of the report.

The selection of these models and data sources was determined by Hittman Associates, Inc., in consultation with the Conservation Policy Office. The choice focuses on models and data sources that were most relevant to aggregate end use and fuels demand analysis within the residential and commercial sectors. Generally excluded are models and data sources that stress engineering/structural energy load characteristics of individual buildings and appliances. While such building design approaches are extremely important for developing and implementing specific buildings energy conservation programs and policies, many have been covered in Department of Energy (DOE) studies of building energy performance standards, residential conservation programs, and retrofit and weatherization programs. Further, the macro emphasis of this report reflects the importance at the national and regional levels of understanding and planning for the overall impacts of energy use and fuels demand.

The models and data sources of this report were, in general, chosen so that they were complementary rather than competitive with one another in their detail and policy relevance. Thus, for example, the Oak Ridge National Laboratory (ORNL) residential and commercial models offer the detailed end-use and fuels demands from engineering/economic simulations; Brookhaven Buildings Energy Conservation Opti-

TABLE 1. OUTPUTS AND DETAILS OF RESIDENTIAL SECTOR MODELS AND DATA SOURCES[1]

Residential Sector Models and Data Bases	Energy Use (Demand)[2] Year	Residential Housing Types	Region	Fuel Type	End Use
MODELS					
ORNL Residential	1970, 1977 initial; Annual projections	5: new and existing; single-family, multifamily, mobile homes	U.S. 9 Census, 10 DOE, states (in process)	4: elect., oil, gas, other	8 end uses, Version V 10 end uses, Version VII
BECOM	1975 initial; Annual projections	3: new and existing "typical" buildings - single-family, low-density, high-rise, mobile homes	U.S. 4 Census, 9 Census, some states and utilities	5: elect., oil, gas, solar, coal/fossil	6 end uses
NEPOOL	1970, 1975 initial; Annual projections	4: single-family, multifamily, mobile home, second home	New England Power Pool and utility service areas; states	2: electricity, other	10 basic appliance types
MATH/CERDS	1970, 1974, 1975 initial; Annual projections	3: housing by household characteristics	U.S. 10 DOE, Urban/Rural, SMSA/non SMSA	5: elect., gas, LPG, oil, coal	6 appliances; space heating and cooling, hot water
DATA SOURCES					
NIECS National Interim Energy Consumption Survey	Winter 1978-1979	5: single attached, detached; 2-4 units; 5 or more; by household characteristics	U.S. 4 Census Urban/Rural	6 identified; 3 measured: elect., oil, gas	7 principal uses identified
End Use Consumption Data Base ECDB Household	1967, 1971, 1974	5: single attached, detached; multifamily attached, detached; mobile home	U.S. 9 Census	7: elect., oil, gas, LPG, coal, kerosene	9 end uses
MRI Appliance Survey	1976, 1977	2: single, multifamily	U.S. 4 regions, urban	All identified; 2 measured: elect., gas	13 electrical appliances measured; 4 major end uses identified
Annual Housing Surveys	1973-1979	5: single attached, detached; 2-4 units; 5+; mobile home	U.S. 4 Census SMSA Central cities outside SMSAs	6 identified: elect., gas, LPG, oil, coal, wood	3 identified
Census of Housing	1970	2: single, multi-units	U.S. 4 Census 9 Census SMSA Central cities outside SMSAs	6 identified: elect., gas, LPG, oil, coal, wood	3 identified, not measured
AIA/Research Corp. (Phase I data for BEPS)	1973-1976	5: single attached, detached; multi-family low-rise, high-rise apartments, mobile homes	7 climate regions	5 fuel types identified in equipment; Btu/sq ft measured	5 end uses, not measured

[1]Given the variety of detail and purpose of the models, data bases, and survey results, the titles of the categories are aggregated to capture the general attributes. These are qualified within the table and in the relevant sections of the report.

[2]Measured in Btu except for NIECS and MRI (physical units); some sources such as ECDB also provide physical units (bbl, kWh, etc.).

TABLE 1. (CONTINUED)

Residential Sector Models and Data Bases	Structural Conversion Technologies, Materials, and Equipment	Market Shares by Fuel Type	Demand and Demand Measures	Changes and Investments in Energy-Related Devices	Explicit and Implied Prices	Behavioral Measures and Responses
MODELS						
ORNL Residential	Efficiency/capital cost trade-offs for 16+ equipment-fuels; heat, gain, and loss by structures and materials	4 fuel types by end use and housing	Final energy demand by fuels, housing, end use	Capital cost for each change in efficiency and structure; units installed	Implicit discount rates; capital-to-operating cost trade-offs for equipment, structures	Efficiency, market share, usage elastisticities calculated by end use, fuel
BECOM	25 (approx.) conversion, 8 structural for each housing type	5 fuel types by end use and housing	Assumes final demand given; calculates intermediate, primary flows by use, fuel, housing	25 devices, 8 structural investments by number, cost	Shadow prices for all resource and technology constraints. Discount rate given	Final demands are input to the model. Discount rate is proxy for behavior
NEPOOL	19 appliances 4 structural	Electricity share by end use and housing type	Final electric demands, hourly electric levels by end use and housing type	Relates loads to generation	----	Appliance specific price elasticities by family size, income determinants
MATH/CHRDS	Efficiencies by 6 appliances; heating, cooling ratios, general structural	5 fuel types by end use, housing, household characteristics	Final demands for fuels, energy by housing, household, end use	Changes by number of reward retrofit and their distributions	Fuel prices are inputs	Home fuel expenditure econometrically determined by socioeconomic equipment, and structure variables; short-run price and income elasticities of fuel demand as inputs
DATA SOURCES						
NIECS National Interim Energy Consumption Survey	25 (approx.) appliances; 4 structural, Fuel Oil Survey: 8 conversion, 8 structural	6 fuel types by end use and housing	Oil, gas, electricity consumption per household	8 changes queried in Fuel Oil Survey	Oil, gas, electricity prices	----
	----	7 fuel types by end use and housing	Final demand for energy, fuels, end use	----	----	----
End Use Consumption Data Base ECDB Houshold	6 structural	----	Electric demand monthly, hourly by appliance, by household; gas demand monthly	Insulation rates	Electric, gas	Implicit demand curves for electric appliances from monthly data
Annual Housing Surveys	10 appliances/equipment; 3 structural	----	----	Storm doors, windows, insulation	----	----
Census of Housing	11 appliances/equipment	----	----	----	----	----
AIA/Research Corp. (Phase I data for BEPS)	Full array of structural/thermal envelope. and of conversion technologies	----	Btu/square foot	Structural and conversion implementation identified	----	Housing design and construction practices

TABLE 2. OUTPUTS AND DETAILS OF COMMERCIAL SECTOR MODELS AND DATA SOURCES[1]

	Energy Use (Demand)[2]						
Commercial Sector Models and Data Bases	Year	Commercial Subsector and Buildings	Region	Fuel Type	End Use	Structural and Conversion Technologies; Materials, and Equipment	Market Shares by Fuel Type
MODELS							
ORNL Commercial	1970, 1977 initial; Annual Projections	10 buildings, typed by commercial activity	U.S. 4 Census regions 10 DOE regions States under development	4: elect., oil, gas, other	5 end uses	Efficiency by building, fuel and end use, structural change; capital cost of each	4 fuel types by end use and building
BECON	1975 initial; Annual Projections	5 typical buildings typed by commercial activity	U.S. 4 Census regions 9 Census regions Some states and utilities	5: elect., oil, gas, solar, coal/fossil	6 end uses	25 conversion, 8 structural for each building type	5 fuel types by end use and building
NEPOOL	1970, 1975 initial; Annual Projections	6 "Industries" by SIC groupings; includes some noncommercial	New England Power Pool, and utility service areas; states	2: electricity, other	3 end uses	2 conversion; structural outside the model	Electricity share by end use and industry
DATA SOURCES							
End Use Consumption Data Base (ECDB), Commercial	1974	8 "Industries" by SIC grouping	U.S. 9 Census regions	6: including steam	6 end uses	----	6 fuel types by end use and industry
Dodge[2,3] Construction Potentials	1925-1980; monthly 1964-present	15 commercial groupings, 186 structures	U.S. States, Counties, all aggregations	---	---	----	----
National Federation of Independent Business (NFIB)	1973-1977	8 business types; organizational structure	9 regions	5: elect., oil, gas, coal, other identified, not measured	2, identified, not measured	1 structural 6 conversion	----
Arthur D. Little (ADL)	1970 initial; 1975, 1980, 1985, 1990 projected	5 buildings typed by commercial activity	U.S. 4 Census regions	5: elect., oil, gas, LPG, coal; Total Btu per year per building	5 end uses	6 structural, 24 conversion and appliances implicit	5 fuel types by buildings
AIA/Research Corp. (Phase I data for BEPS)	1973-1976	11 buildings typed by commercial activity	7 Climate regions	5: fuel types identified in equipment, but not measured	5 end uses, building function identified, not measured	Full analysis of structural thermal envelope and conversion technologies	----
Nonresidential Interim Buildings Survey	1979	16 buildings typed by commercial activity	U.S. 4 Census regions	3: elect., oil, gas	3 end uses, identified not measured	6 structural, 16 conversion (approx.)	3 fuel types by buildings

[1] *Given the variety of detail and purpose of the models, data bases, and survey results, the titles of the categories are aggregated to capture the general attributes. These are qualified within the table and in the relevant sections of the report.*

[2] *Given in Btu except for NFIB ($), and Nonresidential Interim Buildings Survey (in physical units, bbl, kWh, etc.). Some sources, such as ECDB and NEPOOL also measure in physical units.*

[3] *F.W. Dodge data do not represent energy use or supply analysis, but are a major input to commercial sector energy projections through floorspace additions.*

TABLE 2. (CONTINUED)

Commercial Sector Models and Data Bases	Total Demand and Demand Measures	Changes and Investments in Energy-Related Devices	Explicit and Implied Prices	Measure of Commercial Activity by Commercial Subsector	Behavioral Measures and Responses
MODELS					
ORNL Commercial	Final energy demand; fuel, building, end use	Capital cost for each change in efficiency and structure; saturation levels	Implicit discount rates, capital/operating tradeoffs	Output and floorspace related to population and per capita income	Efficiency, market share, and usage elasticities by end use/fuel
BECOM	Assumes final demand given; calcs. intermediate, primary flows by use, fuel, tech., building	25 devices 8 structural investments by number, cost	Shadow prices for all demand, resource, and technology constraints. Discount rates in objective function	Building floorspace using each technology combination	Final demands are input to the model. Discount rate is proxy for behavior
NEPOOL	Final electric demands, hourly electric loads by end use and industry	Relates loads to generation; saturation levels	----	Trends in output per employee; employees	kWh/employee changes, with linear price response
DATA SOURCES					
End Use Consumption Data Base (ECDB), Commercial	Final demand for energy, fuels, subsector, end use	----	----	By space-use factors (e.g., per employee, per pupil); by functional activities	----
Dodge[2,3] Construction Potentials	----	Shifts in structure construction levels	----	Building value, number, floorspace, for 15 commercial groupings, 186 structures	----
National Federation of Independent Business (NFIB)	Yearly, hourly energy expenditures	Changes in 1 structural 6 conversion technologies	----	Sales, employers	Lighting, fuel cutback responses
Arthur D. Little (ADL)	Final energy demand, fuel, subsector (building) and end use	14 appliance saturations	Capital/operating tradeoffs	Trend growth of subsectors by income, population	Own and cross-price elasticity for fuels for entire sector
AIA/Research Corp. (Phase I data for BEPS)	----	----	----	Btu/square feet	Building design and construction parameters
Nonresidential Interim Buildings Survey	Fuels consumption data at household levels	Windows, shades, insulation, caulking, temp. controls, heat and cooling changes	Monthly fuel prices	Building activities, occupants' employment	Temperature setback response; conservation activities and implicit response to monthly prices are implicit in the data

[1] *Given the variety of detail and purpose of the models, data bases, and survey results, the titles of the categories are aggregated to capture the general attributes. These are qualified within the table and in the relevant sections of the report.*

[2] *Given in Btu except for NFIB ($), and Nonresidential Interim Buildings Survey (in physical units, bbl, kWh, etc.). Some sources, such as ECDB and NEPOOL also measure in physical units.*

[3] *F.W. Dodge data do not represent energy use or supply analysis, but are a major input to commercial sector energy projections through floorspace additions.*

mization Model (BECOM) takes the end-use demands as inputs and chooses energy-using technologies that achieve those demands at least cost; the Mathematica Policy Research, Inc., Micro Analysis of Transfers to Households/Comprehensive Human Resources Data System (MATH/ CHRDS) model provides distributional expenditure and fuels detail at the micro household level for aggregate conservation policies; and the New England Power Pool (NEPOOL) residential and commercial sector submodels analyze and break out electricity consumption into hourly loads by end use.

Similarly, the data sources selected for discussion emphasize differing inputs into residential and commercial energy demand analysis. These include, for example: appliance ownership, use and efficiency from the Midwest Research Institute MRI data; housing stock from the Census of Housing and the Annual Survey of Housing; commercial buildings floor space from F.W. Dodge; commercial building energy use by activity groupings from Jack Faucett Associates; structural configuration and residential and commercial buildings energy use from AIA/Research Corporation building energy performance standards (BEPS) data; aspects of business energy use behavior from National Federation of Independent Business surveys; and data on fuels and end use behavior in the residential and commercial sector from the Energy Consumption Data Base and the input files to the ORNL models.

Broadly scoped data files for residential and commercial energy consumption analysis are available from several of the sources discussed in this report, but it should be noted that in the near future, there will be available from EIA detailed commercial and residential energy demand survey data on a much more regular basis. Surveys currently planned or being compiled at EIA include: the National Interim Energy Consumption Survey (NIECS) for the residential sector (whose newly released results are discussed in this report); the annual Residential Energy Consumption Survey (RECS) planned to begin in the fall of 1980; the National Nonresidential Buildings Interim Survey of Energy Consumption which was taken in November 1979 and is to be repeated every two years; and various subsample follow-ups for specific fuels and end uses for each of these national samples. Because these survey results are not complete, not all are fully treated in this report. They may be candidates for additional discussions as more information on them becomes available.

The outline for the materials in this report presents the residential and commercial sectors separately. Several items are common to both sectors, namely, the BECOM model, the NEPOOL model, and the AIA/RC data base. No section distinctions are made between models and data sources. The structure and use of the two run together in many cases, particularly where a data source is constructed from numerous parametric extrapolations such as in the A.D. Little or Jack Faucett Associates commercial data, or the MATH/CHRDS model whose base data and projections could be considered as the results of a series of synthetic surveys. However, because it is necessary to deal with more structural detail in discussing the models, the outlined topics for each do differ.

For models, the general outline topics are as follows:

- Purpose
- Basis for model structure
- Policy variables and parameters
- Level of regional, sectoral, and fuels detail
- Outputs
- Input requirements
- Sources of data
- Other
- Computer accessibility and requirements
- Bibliography.

For data sources, the general outline topics are as follows:

- Purpose
- Structure and level of detail
- Source of data (or sampling method)
- Access to data
- Computer requirements
- Bibliography.

Additional topics have been added to the discussion of four of the data sources: the MRI residential sector appliance data; the National Interim Energy Consumption Survey, the F.W. Dodge data on construction potential, and the

Nonresidential Buildings Interim Energy Consumption Survey. For each, the discussion is extended to include further analysis of the application and extensions of the data sources for energy planning. Similar analyses for four of the major models, ORNL Residential and Commercial Energy Models, BECOM, and MATH/CHRDS, are presented in a separate report.*

The analysis and data given in the present document are limited to the information and reports available at the time of its compilation. This is particularly true of the details and timing indicated for future reports and surveys, and, of course, for specific names and telephone numbers of persons to contact for technical questions or for access to the models and data files.

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*Hittman Associates, Inc. *Models for Residential and Commercial Sector Energy Conservation Analysis: Applications, Limitations, and Future Potential*, HC1011-002-80-948. September 1980.

I. RESIDENTIAL SECTOR

MODELS AND DATA SOURCES

A. Oak Ridge National Laboratory Residential Energy Model

A. Oak Ridge National Laboratory Residential Energy Model

[Structural Residential Energy Use Model of the Energy Information Administration (EIA)]

1. Purpose

The Oak Ridge National Laboratory (ORNL) Residential Model was developed as a long-run simulation model to predict annual, national, and regional residential fuel demand from 1970 to 2000. The purpose of the model is to assist public and private sector decision-makers in planning and evaluating the impacts of energy conservation strategies and policies. The model provides disaggregated residential energy use information on four fuels, eight end uses, three housing types, and two housing states (new and existing) at the national or regional level. Forecasts for each of these housing, fuel, and end-use combinations are determined in response to changes in housing stocks; equipment ownership by end use and fuel type; housing unit thermal integrity; appliance energy requirements; and usage factors that represent household energy-use decision making. The model is thus sensitive to major demographic, economic, and technological determinants of residential energy use.

The ORNL Residential Model regional version provides the basis for the residential energy demand sector of DOE's Midterm Energy Forecasting System (MEFS). The model also is used extensively for inputs to analysis and evaluation of DOE residential energy conservation programs and of proposed conservation policies, including appliance energy efficiencies, insulation costs, energy pricing, and taxes. A state-level version of the model was developed to respond to planning and implementation needs for state conservation programs, but this has not yet been fully integrated into use as a planning tool.

2. Basis for Model Structure

The ORNL Residential Model employs a capital stock approach to energy consumption. This approach recognizes that energy is consumed by capital goods (housing and appliances) to provide the more direct energy-using services desired by the household sector. Energy demand thus varies by changes in the stocks of energy-consuming capital, and by the utilization level of those stocks. To estimate and implement this structure, the model combines demographic, economic, and technological variables specific to the residential sector. The demographic analysis projects household formation and housing stock depreciation to estimate housing stock and new additions. The economic analysis develops fuel price, equipment price, and usage elasticities for appliance ownership and energy use decisions. The technological variables permit analysis of the engineering trade-offs of energy use and efficiency to capital costs for heating and cooling equipment and their efficiencies.

The analysis relies heavily on both economic and engineering relationships to calculate future energy demand. Econometrically estimated equations describe short-run energy utilization responses due to changes in, for example, fuel prices. Similarly, fuel choice or fuel switching is primarily forecast with econometric models. Engineering relationships are a key to purchaser and consumer decisions affecting future equipment efficiencies, as well as technology descriptions and cost analyses.

The model structure may be divided into three major parts: the housing or demographic analysis for housing stock, the technology analysis of equipment or housing structure energy efficiency versus capital costs, and the economic analysis of household responses to changes in fuel prices. These are each discussed briefly below.

a. Housing. The housing model generates forecasts of occupied housing stock and construction of new housing for each year. The analysis rests on population, household formation, housing preference, and on retirement rates of structures. Projection of the number of households is determined by econometric estimates of household headship for each of seven age groups as a function of age, family income, marital status, and previous year households. Housing type is determined from historical and trend data for housing choice by age. Calculation of new housing units constructed is based on additional housing requirements above previous year stocks and the necessary replacements for retirement of existing units. The current versions (Versions 6 and 7) of the model also accept stocks and new construction of occupied housing units as an annual input projection.

b. Technology. The technology model provides analysis of trade-offs between energy use of new equipment or structures (i.e., their efficiencies) and their capital costs. This basically entails minimum life-cycle cost calculations comparing operating costs to initial costs for equipment or building designs. Changes in equipment efficiencies provide fuel savings which are discounted to compare with increased equipment costs. This analysis is provided for improvements in thermal performance of the three housing structure types and for appliance and equipment efficiencies of electric, gas, and oil space heat; electric water heaters; refrigerators; and air conditioners.

c. Economics. The economic model analyzes household energy demand responses to fuel price changes. Changes in the overall consumption of a fuel are presented as the result of short-run adjustments in equipment usage levels and of long-run changes in the type (fuel switching) and in the quality (increased efficiency) of the energy-using equipment or structure. A distinctive and important feature of the model is that analysis of energy demand responses to fuel price changes is represented explicitly in three elements: equipment market share elasticities, equipment usage elasticities, and technical efficiency elasticities. These are discussed briefly below.

(1) Equipment Fuel Choice or Market Share Elasticities With Respect to Fuel Price. These estimate the changes in fuel consumption due to changes in fuel choice for new and replacement units (e.g., from electric to gas hot water heaters). These elasticities are econometrically estimated for five major end uses as a function of fuel prices, equipment prices, per capita income, temperature indices (for space heating and cooling), percentage of all households in single-family units (food freezers), and percentage of households living in urban areas (food freezers).

The responsiveness of the market shares of new equipment with respect to changes in the sales prices of that equipment can also be estimated by converting market share fuel price elasticities and applying appropriate consumer discount rates.

(2) Equipment Usage Elasticities With Respect to Fuel Price. These indicate changes that may occur in the operation of the appliance, equipment, or housing structure, assuming the equipment or housing structure remains unchanged (e.g., changes in house temperature settings, or in clothes washing practices). These elasticities are based on estimated engineering possibilities (as opposed to econometric estimates derived for other energy demand models) of what actions could be undertaken by households. Short-term versus long-term effects are determined by inputs that suggest that one-half of the total usage response occurs during the first year.

(3) Technical Efficiency Elasticities. These elasticities represent changes in purchase decisions by residents concerning the efficiency of their energy-using equipment or thermal performance of new structures as fuel prices change (e.g., shifts from electric resistance heating to electric heat pumps or shifts to better insulated housing). These elasticities are estimated from a combination of: a) the engineering analysis yielding life-cycle trade-offs of efficiency (fuel savings) versus equipment costs (see 2.b. above), and b) the market penetration calculations for new equipment and structures.

d. Simulations. The simulation model combines the outputs from the various demographic, economic, and technology submodels together with the initial and end-value conditions (e.g., market shares, fuel, and equipment prices) to calculate the household demand forecasts by fuel and end use. ORNL describes the basic equation of the simulation model that defines residential use of fuel i for end use k in housing type m during year t as:

$$Q_t^{ikm} = HT_t^m \; HS_t^m \; C_t^{ikm} \; TI_t^{ikm} \; EU_t^{ikm} \; U_t^{ik},$$

"where HT is the stock of occupied housing units, HS is the average size of housing units (for space heating and air conditioning only), C is the fraction (market share) of households with a particular type of equipment, TI is the thermal performance of housing units (for space heating and air conditioning only), EU is the average annual energy use for the type of equipment, and U is a usage factor."*

3. Policy Variables and Parameters

Residential energy conservation policy and program analysis is enhanced by several features of the ORNL model: the level of disaggregation, the engineering economics detail, and the fuel price elasticity components analysis.

a. Level of Disaggregation. The large number of end uses (8), fuel types (4), building structures (3), housing states (2), and regions (10) permit more precise and targeted specification of policy inputs and more detailed evaluation of policy impact than previous residential sector models.

b. Engineering Data, Cost Analyses, and Structural Model Relationships. The engineering representations of equipment efficiencies and energy use characteristics permit simulation with changed efficiencies, technology

**From Hirst and Carney, ORNL/Con. 24, p. 46.*

cost-efficiency curves, or utilization rates for existing or new equipment and structures.

c. <u>Fuel Demand Elasticities of Equipment Fuel Choice, Usage, and Technical Efficiency</u>. These elasticities present an analytical and simulation structure that more accurately represents consumer responses -- that is, that recognizes that energy demand is, in reality, demand for the end-use services provided by the energy (warmth from space heating, dried clothes, etc.), and that consumer decisions are based on the total operating price for providing that service. Total operating price is determined by both the fuel price and the equipment efficiency of the energy-using equipment. Over the longer run where equipment efficiencies may be altered by purchase or replacement, both fuel choice and the levels of fuel utilization are determined by the combinations of the fuel price and efficiency levels. Pricing policies, or proposed programs that affect equipment efficiency levels or building thermal performance, are more amenable to analysis, interpretation, and change through the model's explicit breakout of these interactions.

Policy and program variables that can be analyzed with the model include the following:

(a) Fuel price changes from credits, taxes, subsidies, or regulatory policies -- as affecting absolute fuel price level or the relative prices between fuels. Short-term price effects are generally limited to usage effects. The long term allows the introduction of equipment or structure changes in efficiency and equipment fuel choice for new and replacement units.

(b) Prices of equipment or structures, as these are affected by tax credits and subsidies.

(c) Equipment efficiency or building thermal performances, as these are affected by appliance or building standards or possibly large-scale retrofit programs.

(d) Usage factors such as building temperature controls, hot water usage, and lighting practices.

(e) Technological changes that might be introduced by innovation and research incentives. These would affect the cost-efficiency trade-off.

4. Levels of Regional, Sectoral, and Fuels Detail

The ORNL Residential Model provides energy analysis of the following:

(a) Fuels

(1) Electricity

(2) Natural gas

(3) Oil

(4) Other

(b) End uses

(1) Space heating

(2) Air conditioning

(3) Water heating

(4) Refrigeration

(5) Food freezing

(6) Cooling

(7) Lighting

(8) Other (recent versions have included clothes drying and room heating)

(c) Housing types

(1) Single family

(2) Multifamily

(3) Mobile homes

(d) Housing states

(1) New houses

(2) Existing houses.

Versions of the model provide analysis at the national level and for 9 census regions and 10 DOE regions. State-level versions are available but not fully operational.

5. Outputs

The ORNL Residential Model energy forecast simulations combine housing, economic, and technology sector calculations with 1970 (or for recent versions, 1977) initial condition and 1970-2000 (1980-2000) boundary or policy parameters to provide residential energy use forecasts to 2000.

Outputs of the residential sector simulation include:

(a) Total energy use

(b) Energy use by fuel type

(c) Energy use by housing type

(d) Fuels demand by housing type

(e) Fuels demand by end use

(f) End use equipment and installation

(g) Energy requirements of equipment

(h) Buildings structure thermal performance

(i) Fuel expenditures

(j) Equipment costs

(k) Costs of improving thermal performance of new and existing structures.

These results are available at the national level or at regional levels depending on the version of the model.

6. Input Requirements

Inputs to the ORNL simulation model include:

(a) Initial conditions for 1970 (or 1977)

(1) Equipment ownership

(2) Annual equipment fuel use

(3) Equipment prices

(4) New equipment installations

(5) Fuel prices

(6) Housing stocks

(b) Trajectories and boundary conditions for 1980-2000

(1) Housing stocks, new construction, and housing size (from housing submodel)

(2) Technological possibilities for new equipment and structures

(3) Fuel prices

(4) Per capita income

(5) New equipment prices

(6) New equipment standards

(7) Thermal performance standards for new structures

(8) Thermal performance of retrofit programs.

7. <u>Sources of Data</u>

Data collected for the ORNL Model can provide an important source of information for residential sector energy analysis. Sources for several of the more important analyses are given below. Some elements of these are accessible in the input files for the ORNL model, particularly as they are presented in the EIA versions. Much of the input data for the model is regularly updated by ORNL and EIA, so that the national model is presently running on 1977 base data. Data and the basis for the regionalization of the model are given in Kurish and Hirst (1977). The primary source for description of the model, its estimation, and data sources is Hirst and Carney (1978).

a. <u>Housing</u>. Projections of households, housing stock, new construction, and distribution of housing structures are developed by Hirst and Carney (1978) from historical data of the Bureau of the Census housing and population reports.

b. <u>Technology and Cost Data and Analysis of Efficiency-Capital Cost Trade-offs</u>. These data are developed from the following sources:

(1) Electric, gas, and oil space heating (O'Neal, 1978)

(2) Gas and electric water heaters (Hoskins and Hirst, 1977a)

(3) Refrigerators (Hoskins and Hirst, 1977b)

(4) Air conditioners (Papadopoulos and Berger, 1978)

(5) Housing structures thermal performance (Hittman Associates, 1977; Hutchins and Hirst, 1979; Hutchins and Hirst, 1978).

c. Economics.

(1) Equipment Market Share or Fuel Choice. These are estimated by Lin, Hirst, and Cohn (1976), for four fuels -- oil, gas, electricity, and other -- and for five end uses -- space heating, air conditioning, water heating, food freezing, and cooking. 1970 cross-section data by states were collected and analyzed. Primary sources for these data are given below.

(a) Equipment Prices. Electric, gas, and oil furnaces for 48 states (Delene, 1974). Stoves, freezers, and air conditioners (USDA price summaries).

(b) Fuel Prices. Fuel oil (USDA). Electricity [Edison Electric Institute (EEI)]. Gas [American Gas Association (AGA)].

(c) Market Shares. Saturation rates for fuel by end use and for room and central air conditioners and food freezers (1970 Census of Housing).

(2) Fuel Usage. Data on usage of electricity, gas, and oil were collected at the state level for 1951-1974 to determine changes in fuel usage with respect to income and price. These provided the data base for fuel usage elasticity estimation by Cohn, Hirst, and Jackson (1977). Primary sources for these data include the following:

(a) Fuel Prices and Fuel Consumption. Electricity (EEI). Natural gas (AGA). Fuel oil (USDA for prices, Bureau of Mines for consumption).

(b) Economic-Demographic. Per capita income and prices (Survey of Current Business). Households (Bureau of Census).

8. Other

a. Versions of the Model. The ORNL model exists in its original, national-level structure as regional models by nine census regions and by 10 DOE regions, and as state-level models. The model structure for all geographic levels is essentially the same as that developed for the national level. The major changes are the requirements for different data files.

Both the national and regional models are running at ORNL and EIA. The core national version is Version 5 as described by Hirst and Carney (1978). Data and the basis for regionalization of the model are given in Kurish and Hirst (1977). Both the national and regional models have been updated and expanded by ORNL so that the current national model is Version 7, initialized in 1977 data and adding clothes drying and self-standing resistance heaters as end uses (Version 6 differs little from Version 7 structurally but is initialized in 1970 data). The regionalization of Version 7 is nearing completion.

Except for changes in input and output file structure, the EIA and ORNL versions are the same for both regional and national models. EIA is presently still using Version 5 for most projections, but has full access to Version 6 and will update to Version 7 when all data have been thoroughly reviewed, stand-alone versions of both the regional and national models are run at EIA as the structural Residential Energy Use Model, the identical model for the 10 DOE regions is also integrated into the Regional Demand Forecasting System (RDFOR) model in order to develop residential fuels demands for EIA's Midterm Energy Forecasting System (MEFS).

The State Residential Energy Demand (SRED) version of the ORNL residential model was developed by Tetra Tech in 1978 and 1979 with state-level data and equation coefficients replacing those in the more aggregated ORNL models. The latest version of the SRED model parallels the structure and requirements given in ORNL Version 5 as described in Hirst and Carney (1978). The SRED model is stored at EIA but is not currently operational for current analysis primarily due to budgetary constraints to fully developing the state-level data inputs.

9. Computer Accessibility and Requirements

a. General Description. Copies of both regional and national versions of the ORNL Residential Sector Model are presently being run at at least 15 different installations, one of which is EIA. ORNL's Version 5 and EIA's current version are structurally almost identical. Some differences in the parameters used and data file structure have evolved at EIA to integrate the regional model into EIA's Midterm Energy Forecasting System (MEFS) or, more specifically, the Regional Demand Forecasting System (RDFOR). Earlier EIA developed a "reduced form" version of the ORNL model for RDFOR; this is still used occasionally. In addition both the national and regional versions exist as stand-alone models outside of the RDFOR system.

The ORNL residential model is run at Oak Ridge on an IBM 360-370. Questions concerning it can be directed to Dennis O'Neal at (615) 574-5199.

The EIA model is run on an IBM 30-33 in the Forrestal Building in Washington, DC. Questions concerning the model can be directed to Mark Rodekohr at (202) 633-9129 or John Holt at (202) 633-8486.

ORNL's model has baseline data from 1970 and simulates energy demand from 1970 to 2000. Just completed is Version 7 with baseline data from 1977. The regionalization of this should be complete in the summer of 1980.

Tetra Tech, Inc., developed a state-level version of the ORNL Residential Sector Model known as SRED - State Residential Energy Demand Model. The SRED model is running on the EIA computer but lacks updating and state-level data to be fully operational. Questions concerning it can be addressed to Alpha Mutardi at Stone and Webster (202) 466-7415.

b. <u>Accessibility</u>. ORNL can make residential sector model runs under contract. Such runs are submitted to Dennis O'Neal and run by ORNL staff. Rather than make runs for users, ORNL prefers to give the user a copy of the model. This is discussed in the following section.

To access the EIA computer versions, a DOE program manager must submit a Data Service Request (DSR) to Marion King in the Office of ADP Services, EIA, (202) 653-3600. After approval she will assign a valid account number and password.

The EIA computer can be accessed by 300 and 1200 baud remote terminals and is hooked up to TYMNET. Questions concerning the computer installation can be addressed to Ike Digman at (202) 252-8959.

The entire ORNL Residential Sector Model and appropriate baseline data base are needed to make a run.

c. Transferability. A user can get a copy of the latest operational version of the ORNL Residential Sector Model and data base at no cost from ORNL. The model is entirely in Fortran, is nicely commented in the program, and is easily transferable. At most, very minor changes might be required to transfer to another system with Fortran. The model has a 250K CPU storage requirement. Along with the model on cards, the user will receive a user's guide.

d. Ease of Modification in System. The ORNL Residential Sector Model is fairly flexible. Depending on the extent of changes and lead time, it is possible that ORNL could be contracted to modify the model. However, because the model is very modular, in Fortran, and very well commented, it is not difficult for the user to modify the code himself.

e. Documentation. "ORNL Engineering-Economic Model of Residential Energy Use" (CON-24) discusses the theoretical model design. The "ORNL Residential Energy Use Simulation Model User's Guide" describes the input cards required. A more extensive user's guide has been put out by MIT and may be obtained from MIT Energy Laboratory as MIT EL-79-042WP.

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B. Brookhaven Buildings Energy Conservation Optimization Model (BECOM)

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See Section B of the Commercial Sector in this report.

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C. New England Power Pool Model for Long Range Forecasting of Electric Energy and Demand (NEPOOL)

C. New England Power Pool Model for Long Range Forecasting of Electric Energy and Demand (NEPOOL)

1. Purpose

The New England Power Pool Model for Long Range Forecasting of Electric Energy and Demand was developed in response to the uncertainty, caused by the events of 1973 and 1974, about electric load forecasts, planning for generation and transmission facilities, maintenance of adequate reserves, dispatching, and joint use of transmission facilities. The model information is used to assist planning by the 72 NEPOOL participants (26 privately owned, 44 municipal, 2 cooperative systems) in their efforts to assure future adequacy, reliability, and economy of electric power supply in the six-state New England Region.

Although the model is specific to the New England region, its methodology and output can provide important contributions to national energy demand analyses. The disaggregation and analysis in the model to hourly demand analysis of electric energy consumption permits analysis of energy conservation policy at levels of technical and behavioral detail within daily consumption activities. For the residential sector the model incorporates daily load profiles for each specific end use (e.g., appliances, commercial buildings) by hour, day, and month. The model additionally incorporates economic and demographic projections at the subregional level where these projections themselves are a function of the economic, demographic, and energy conditions. This differs from most energy demand models where the economic and demographic projections are generally constructed outside the model and thus are not responsive to changes that may occur during the simulation.

The NEPOOL model was developed jointly by NEPOOL staff and Battelle Columbus for use by NEPOOL members. Though the model is well documented and running at Battelle Columbus, access to the model for policy runs and modification is subject to NEPOOL approval and their proprietary requirements. DOE has only recently initiated discussions on its use.

2. Basis for Model Structure

The NEPOOL model provides energy demand forecasts, load profiles, and load duration for approximately 50 end-use categories based on (1) endogenous economic/demographic forecasts of population and economic activities for specific geographic areas; and (2) forecasts of average end-use demand, and hourly load profiles of end use.

The basic model structure divides end-use demand into the product of two components: determination of the number of users in the end-use category; and calculation of the average consumption of each user. The number of users is calculated in the demographic/economic module, while the average use is in the power module. These modules exist for each residential, commercial, industrial, and other sector, although the detail and breakout of end use are obviously different for each. The residential sector covers 19 appliances, the commercial sector six commercial categories.

The economic/demographic module is common to all sectors. The power or end-use modules differ by sector. Each of these is discussed briefly below.

a. Regional Demographic/Economic Module. The demographic/economic inputs to the energy demand analysis are developed on a regional basis. These geographic regions are defined as the areas where the majority of the work force are both employed and reside. That is, the regional areas are defined to minimize commuting across regions, and thus may be either economic regions similar to SMSAs, or states, the standard use in the model. Both the demographic forecasts which provide a detailed view of population and housing in a region and economic forecasts which shape the employment and income structure are important in residential electricity demand analyses of the model. Commercial electricity demand in the model is driven by the employment forecasts. Interplay between labor force and employment acts as the central driver for migration between regions.

(1) Demographic Submodule.

(a) Population and Labor Force. Population is projected for each region by single years for each one-year age grouping using standard cohort projection techniques. Age- and sex-specific migration rates, which are determined by local unemployment rates relative to national unemployment rates, are applied to each regional population. The labor force is then calculated from estimates of age- and sex-specified labor force participation rates, which are themselves functions of labor market conditions.

(b) Households and Housing. Total numbers of households are developed by applying forecasts of head of household factors to the total population.

These are then used to calculate the increase in required housing stock given the previous year's housing stock, estimated demolitions, and vacancy rates. Allocation by owner and renter to single, multiple-unit, and mobile-home categories is based on the 1970 census. Second homes are also calculated as a function of the primary housing stock.

(c) Income. The distribution of households by income level is necessary to estimate appliance saturation levels. For the income calculation the economic/employment submodule develops employment by industry. Together with U.S. growth rates of salary and wages by industry, this provides wage, social security, proprietor's income, and other labor income. Property and transfer income are calculated from population forecasts and trends in per capita ratios. The distribution of income by households is then derived from state-specific 1970 census income distribution curves. Forecasts of this distribution require adjustments in the distribution of new households by income class so that the total of their personal income equals the personal income calculated by other sources.

(2) Regional Economic/Employment Submodule. Employment is the primary indicator of economic activity in the NEPOOL model. Employment levels drive calculations of household income and income distribution and, through unemployment, levels of regional migration. This also is an input to forecasting commercial electric loads as well as, indirectly, industrial loads. The forecast calculates employment by region in three major categories: "household serving" employment as a function of population; "business serving" employment as a function of total employment; and, for employment that produces for "exports" out of the specific region, "export" employment as a function of ratios of regional-to-national costs of doing business.

b. Residential End-Use Submodule. The residential sector of NEPOOL develops forecasts of energy demand and load patterns for each of 19 appliances. These forecasts require calculation of the number of appliances installed by type, average wattage per appliance, the probability of an appliance being in operation at a given time, and trends in wattage and hourly load profiles by appliance.

(1) Stock of Appliances. For air conditioners, ranges, clothes washers and dryers, freezers, and dishwashers, the appliance saturations, or number of appliances used over time, were estimated econometrically as

a function of family income and type of dwelling for each appliance in each state. Saturations for televisions, lighting, and refrigerators were measured at 100 percent. Electric space heating penetration in competition with other fuels was estimated by multiple regression to be a function of first-year cost differentials per system, including fuel cost differential, total sales expense, percentage of housing permits that are single family, and the urban-rural ratio. Penetration of electric water heaters in non-electric heated homes was estimated as a simple growth trend.

(2) Hourly Load Profiles. The appliance hourly load profiles were developed for each month and for four typical days (Monday or day after a holiday, Saturday, Sunday or holiday, and weekdays). For temperature-dependent space heating and cooling, additional analysis was undertaken. The load profile data were collected from studies by NEPOOL members' analysis of metering as well as other sources. These were converted to connected loads by the average wattage per appliance.

Three major factors were included as affecting the forecast of appliance loads: trends in each appliance usage, trends in each appliance efficiency, and responses to prices. Additionally, the effects of changes in a family's demographic composition on its appliance use were estimated. Forecasts of price responsiveness were estimated from averages of various studies, with short-term elasticities approximately one-half of the long term. These elasticities were assumed to represent several responses: behavioral change in use, technological changes in efficiency, appliance purchase decisions, and, for appliances where there was a fuel competing with electricity, fuel switching.

c. Commercial Sector End Use Submodule. The commercial sector of the model forecasts hourly demand levels and electric energy consumption for six commercial categories. The definition of commercial is broader than that often used in commercial sector energy analyses, including essentially the one-digit SIC non-manufacturing categories. Thus for the NEPOOL model, forestry, fishing, construction, transportation and public utilities are considered commercial categories. The hourly loads and consumption are determined primarily on the basis of employment forecasts from the demographic/economic module. NEPOOL analysis found energy used per laborer as good a predictor of commercial consumption as the energy use per floor space measures of many other models. However, NEPOOL does acknowledge that much of the variance in electricity consumption among commercial categories in the model is due to characteristics of the commercial building rather than inherent differences in their economic activities. Additional adjustments in hourly loads are included for temperature-dependent space heating and cooling loads (from metering analysis), and for electricity price effects through price elasticity estimates (from the literature). Separate saturation equations estimated from trends are included also for electric space heating and cooling equipment.

For each commercial category, the baseload electricity consumption in kilowatt-per-employee terms was estimated from NEPOOL surveys. As with many other studies of commercial energy use, the Battelle and NEPOOL analysis was hindered by the relative lack of available data on commercial energy use. Primary kilowatt-per-employee data were collected for the model on the retail sectors in Connecticut and Maine. This established many of the characteristics and trends for overall use in the sector and its categories, and was used to develop state-by-state estimates. From this, total consumption for each commercial category in each state can be calculated using the employment forecasts of the economic/demographic submodule. Then, using parameters from metered observations of NEPOOL-member customers, monthly, daily, and hourly loads can be forecast.

3. Policy Variables and Parameters

The model provides a wide degree of flexibility for analysis of energy conservation policies directed at electrical consumption in the residential sector. Commercial sector analysis is somewhat more limited since the number of commercial categories is restricted. For both residential and commercial sectors of the model, though, a significant instrument for policy analysis is available in the capacity to simulate hourly loads by end use.

a. Residential Sector. Major variables and parameters which may be used for residential sector energy conservation policy analyses include the following:

(1) Fuel cost differentials between electric, gas, and fuel oil: The major effect is seen in penetration of electric space heating and, indirectly, in electric hot water heaters

(2) Electricity price, both in relative terms compared to the rest of the nation, and in absolute terms for each region. Long- and

short-run elasticities reflect primarily changes in each appliance use, but also for the long run, changes in appliance efficiency and, where applicable, fuel switching.

(3) Appliance efficiency levels as may be affected by public parameters or legislated standards.

(4) Load management and conservation policies that affect time and duration of use of appliances. For example, controlled versus uncontrolled water heaters, changes in times for washing and drying, and changes in daily and hourly thermostat settings.

(5) Regional and income-specific efforts to promote conservation that are accessible through the model's regional disaggregation.

b. Commercial Sector Energy Policy Variables.

(1) Electricity price responsiveness. Prices may be changed differentially for each commercial category and each region.

(2) Changes in electric space heating and air conditioning efficiencies for such commercial categories, where changes could be due to either equipment or to buildings design or retrofit.

(3) Load management and conservation policies that affect business operating practices. For example: operating hours, lighting practices and time-of-day thermostat controls.

4. Level of Regional, Sectoral, and Fuels Detail

a. Regional. The model generally runs on the state level, but is programmed to run at county or SMSA levels. The states are:

(1) Connecticut
(2) Maine
(3) Massachusetts
(4) New Hampshire
(5) Rhode Island
(6) Vermont.

Climatic detail for heating and cooling is available by region.

b. Residential.

(1) Housing

(a) Single-family
(b) Multifamily
(c) Mobile home
(d) Second home

(2) Households by Income Class

(a) 10 classes $0 - $10,000
(b) 7 classes $10,000 - $25,000
(c) $24,000 - $25,000
(d) $25,000 - $50,000
(e) $50,000 +

(3) Appliances

(a) Electric range
(b) Microwave oven
(c) Refrigerator, frost-free
(d) Refrigerator, standard
(e) Freezer, frost-free
(f) Freezer, standard
(g) Dishwasher
(h) Clothes washer
(i) Electric clothes dryer
(j) Electric water heater, controlled
(k) Electric water heater, uncontrolled
(l) Television, color
(m) Television, black and white
(n) Lighting
(o) Room air conditioner
(p) Central air conditioning
(q) Electric space heat
(r) Fossil-fuel space-heating auxiliaries
(s) Miscellaneous.

c. Commercial. Electricity use per employee is analyzed for the following categories:

(1) Forestry, fishing, and construction

(2) Transportation and public utilities

(3) Wholesale trade

(4) Retail trade

(5) Finance, insurance, and real estate

(6) Services and government.

d. Electricity. The NEPOOL model focuses on electric consumption and load distribution. Detail for this is provided at the following levels:

(1) Monthly

(2) Daily

(a) Monday or day after holiday
(b) Tuesday through Friday
(c) Saturday
(d) Sunday or holiday

(3) Hourly.

5. Outputs

Residential and commercial sector outputs are available at a wide variety of disaggregations. For each state or region these include:

(a) Annual residential electricity forecasts by total housing type and appliance

(b) Annual commercial electricity forecasts by total and commercial category

(c) Average residential electricity forecasts for monthly and hourly loads by total, sector, housing type, and appliance

(d) Average commercial monthly electricity forecasts for monthly and hourly loads by total and commercial categories

(e) Peak load analysis for commercial and residential sector by hour, day, and month.

6. Input Requirements

NEPOOL simulations at the state level for residential and commercial runs are initialized with 1970 historical economic and demographic data, residential housing and appliance stocks, commercial category employment levels, electricity, gas, and fuel oil prices, appliance efficiency and wattages, commercial category electricity use per employee, and relevant time of day, month, and seasonal load patterns. These have been variously updated, with calculation simulations run to 1975 and more recent dates. The model is programmed so that each of these initial conditions may be changed, but the important policy inputs to residential and commercial runs involve trend values or parameters for future behavioral or technical factors. Major energy use inputs are given below, excluding projections of demographic and economic rates.

(a) <u>Residential Sector</u>.

(1) Appliance saturations as functions of income or housing types (these may be varied by the user)

(2) Electric space heating penetrations as functions of fuel costs and annualized initial costs, sales expense, percentage of single-family dwellings, urban vs. rural (these may be varied by the user)

(3) Air conditioning saturations and electric hot water heating penetrations

(4) Appliance efficiency trends and efficiency goals

(5) Appliance usage trends

(6) Hourly and daily patterns of appliance usage

(7) Electricity price elasticities by appliance

(8) Trends in electricity, natural gas, and fossil fuel prices by region

(9) Changes in temperature-sensitive demand and hourly load profiles for electric space heating and air conditioning.

(b) <u>Commercial Sector</u>.

(1) Change in saturation rates for space heating and air conditioning

(2) Baseload growth in kilowatt hours per employee for each commercial category

(3) Changes in temperature-sensitive demand and hourly load profiles for space heating and air conditioning

(4) Electricity price elasticities for kilowatt hour per employee consumption

(5) Prices of electricity by region.

7. Sources of Data

Data sources too numerous to account for in this discussion were used in the development of the NEPOOL model. There was, however, also development of primary source data and analysis for both the residential and commercial sectors. These are listed below:

(a) Residential Sector

(1) Appliance saturation rates as a function of income and housing type by state were estimated using census public use samples and state income and housing data

(2) Electric space heating penetration and promotion costs were collected for New England and national samples for 1966 to 1973 and penetration calculated

(3) Electric space heating and air conditioning use matrices were derived from hourly demand data in electric homes in Massachusetts and Connecticut

(4) Temperature insensitive load profile data were collected for appliances from studies by NEPOOL companies.

(b) Commercial Sector

(1) A retail trade energy consumption study was undertaken in Connecticut and Maine in 1976 which provided the basis for most of the baseload heating and cooling per employee data for all commercial categories. This included:

(a) Economic/Physical: Type of establishment, number of employees in each year 1970-1975, business schedule, age of building, square feet of floor space, building type, type of space heating system, percent of floor space air conditioned, and type of A/C system.

(b) Behavioral: Electric energy conservation steps taken in past, and electric energy conservation steps anticipated.

(c) Electric Energy Consumption and Related Data: Monthly electric energy consumption, monthly dollar costs, and monthly billing dates.

(2) Hourly demand profiles were developed from metered observations of NEPOOL companies in 1968-1969 for all electric stores and offices.

8. Other

The NEPOOL was programmed in a flexible manner so that it could be applied at various regional levels (e.g., state, SMSA, county) as long as the areas contained the majority of employment and residences of their population. To date the model is primarily applied at the state levels. The model itself is continually upgraded and updated and is run frequently for NEPOOL member needs.

9. Computer Accessibility and Requirements

a. General Description. The NEPOOL model is being run on a CDC CYBER 73-16 and a CDC 6500 under the SCOPE operating system and the INTERCOM time-sharing system at Battelle Columbus Laboratory.

The model was developed by Battelle for NEPOOL, has been turned over to NEPOOL, and is currently being modified and updated by NEPOOL staff. Questions concerning the model or its data bases can be directed to James R. Smith, Director, New England Power Planning, (413) 785-5871.

b. Accessibility. The model and data bases are not presently accessible to anyone but members of NEPOOL. The proprietary requirements placed on its use have limited the public experience with this tool, but NEPOOL staff are supportive of outside or cooperative analysis within the constraints of the proprietary strictures.

c. Transferability. The model and/or data bases are not presently available for transfer. The data bases and program are structured in the NUCLEUS language. (The NUCLEUS system is a computer-based methodology featuring a structured programming language, dynamic simulation modeling, and a DBMS including a report generator.) Because of its size and complexity and because it is written in the NUCLEUS language, the model would not be easily transferable even if it were presently available for transfer.

d. Ease of Modification in System. The model is presently very flexible both in its input and in the reports generated from running it. It is possible to run segments of the model.

e. Documentation. The model is well documented in a two-volume report by NEPOOL and Battelle Columbus Laboratories entitled "Model for Long Range Forecasting of Electric Energy and Demand." An update volume to the original two volumes is also available. Appendix N of the two-volume report is an instruction manual on how to run the system. Although the above report does include a discussion of the model implementation, that subject is dealt with more thoroughly in the publication "Program Listing of the NEPOOL System."

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Report on a Model for Long Range Forecasting of Electric Energy and Demand to the New England Power Pool, NEPOOL Load Forecasting Task Force and Battelle Columbus, West Springfield, Massachusetts, June 30, 1977, Volumes I and II, and extensive updates.

D. Micro Analysis of Transfers to Household/Comprehensive Human Resources Data Systems (MATH/CHRDS)

D. Micro Analysis of Transfers to Household/Comprehensive Human Resources Data System (MATH/CHRDS)

1. Purpose

The MATH/CHRDS model was developed to provide simulated data for distributional analysis of household energy consumption across various socioeconomic subgroups. A synthetic micro data base has been created by augmenting and updating base-year survey information. The micro simulation model then extends this to project results of a household energy consumption survey that might have taken place in a future year. The model thus provides a basis for evaluating the impacts on household energy expenditures of trends and policy changes in energy prices, appliance efficiency levels, energy use patterns, and demographic and socioeconomic variables.

2. Basis for Model Structure

MATH/CHRDS employs microanalytic simulation techniques developed originally for planning and evaluation of public welfare (transfer) policies in the 1960s. The Micro Analysis of Transfers to Households (MATH) model by Mathematica Policy Research, Inc., is basically a modification of the Transfer Income Model (TRIM) that was developed for analysis of tax and transfer payment systems of Income Maintenance Programs. This structure has been extended to include detailed characteristics on household energy use and expenditure in the Comprehensive Human Resources Data System (CHRDS).

a. Overview of Model Structure. The basic structure of the model derives from hierarchical micro data files on households which are assembled from merged base-year survey information on energy use, and on demographic, economic, and energy-related characteristics of individual households. These demographic, economic, and energy-related variables are then projected to provide elements of synthetic household survey records, as if obtained from a new (future) survey. Specific energy-using characteristics of each household are then also updated to reflect exogenously determined aggregate national and regional changes in fuels use, appliance ownership and efficiency, and housing type, age, and location. Each household's energy expenditures for fuels can then be calculated from econometrically estimated parameters applied to such updated "survey" variables as cooling fuels, space- and water-heating fuels, number of rooms, type of structure, household size, appliance ownership, family income, price of fuel, and urban/rural location of the household.

The following outlines the major elements of the model structure.

b. Basic Data File and Data Base. MATH/CHRDS begins with the basic data file, a special subsample of 150,000 households from the 5 percent Public Use Sample of the 1970 Census of Population and Housing. This provides detailed information on demographic, socioeconomic, housing, fuel, and appliance characteristics of the households. These data were adjusted to impute energy expenditure information for renters and owners who did not report energy consumption information (including most importantly renters who did not pay their utilities separately). Imputation was by multiple classification analysis developed for 1/1000 Public Use Sample. Transportation-related data from other surveys were also merged into the MATH/CHRDS file via a statistical matching technique.

The original MATH/CHRDS Data Base was a 1974 synthetic data base created by updating techniques on the basic 1970 MATH/CHRDS base file. Changes to develop this base and subsequent projections from the 1974 base are explained further in the discussions below. More recently an update to a 1975 data base was undertaken. This is discussed in i. below. A 1977 file was completed but is not in use. A 1978 to 1979 file is contemplated for late 1980.

c. Demographic and Economic Aging of Data File. Probabilities for individual household demographic changes by age, race, sex, and location are distributed across the MATH/CHRDS file in a manner that develops the new demographic structure approximately equal to control totals from Bureau of Census population projections.

Similarly, changes in economic characteristics of individuals within the data file are also determined exogenously for 14 sources of income both by economy-wide employment-unemployment changes and by modifications to earnings trends. Taxes and transfers are then calculated based on dependents, parameters of the tax system, eligibility requirements, and, possibly, energy tax policies and credits.

d. Housing Stock and Fuels Use. The structure of the future housing stock is simulated to reflect exogenous macroeconomic housing forecasts of age and type of structure. Within the file, however, the relative position of residents with respect to age of their houses is held the same by varying randomly selected houses.

Changes in space- and water-heating fuels use for new and existing homes are assigned exogenously from Annual

Housing Survey, Census Bureau Surveys of new construction and trends in home-heating fuel conversions. These changes are made for randomly selected households in the sample. Similar changes can be made for fuel efficiencies and insulation.

e. Appliance Ownership. Ownership rates are by income class for six major appliances. These rates are exogenously specified and changes are randomly selected for households to conform to these specified rates.

f. Energy Expenditure. Home fuel expenditures for each MATH/CHRDS household are imputed from the updated demographic, socioeconomic, housing, and appliance characteristics of the households. Estimates are from an econometric analysis of the 1970 Census for each of five home fuels as a function of cooling fuel, space and water heating fuels, number of rooms, type of structure, household size, appliance ownership, family income, fuel source, and location.

g. Income and Price Elasticity of Fuels Use. The model assumes the long-run fuels responses to income and prices are incorporated in the earlier specified changes in housing stocks and appliances and in the intensity with which these are used by households. Short-run income and price elasticities for each of the five fuels, however, can be further specified by income group, location, and other demographic variables.

h. The analytical techniques of the simulation model. These include:

(1) Introduction of stochastic factors to represent the random changes in individual behavior

(2) Systematic adjustment of randomly selected files to represent exogenous changes in demographic or economic conditions, or in housing stocks and appliance ownership

(3) Econometrically estimated procedures for imputing home fuel expenditure

(4) Markov-Chain stochastic processes to represent transitions in household status, e.g., employment and earnings changes.

i. Updated 1975 MATH/CHRDS Data Base. The 1975 update was undertaken in part to assist development of a 1975 End Use Consumption Data Base (ECDB) discussed in another chapter of this report. Although the resulting ECDB was primarily an aggregation from the MATH/CHRDS file, it also required usage and expenditure by fuel and functional end uses that necessitated augmenting of the original Data Base.

The 1975 MATH/CHRDS is essentially the demographically and economically aged 1974 Data Base adjusted for 1975 demographic, income, equipment, and housing stock data and for energy use characteristics. For this purpose, extensive use was made of the 1975 Annual Housing Survey. The data file was augmented with additional energy-related characteristics, using the 1975 Annual Housing Survey and the 1975 Washington Center for Metropolitan Studies Lifestyles and Energy Survey. These included:

(1) Air conditioning

(2) Insulation

(3) Storm windows

(4) Storm doors

(5) Black and white vs. color television.

1975 usage and expenditure were then inputed for each fuel using 1975 gas prices, weather data, and distributional demographic and income information. The resulting data base was then calibrated against industry control data.

The 1975 Data Base is in current use for EIA micro distributional projections and analysis from MATH/CHRDS (e.g., for the 1978 and 1979 Annual Report to Congress of EIA).

An excellent description of the 1975 updated Data Base is given in "Residential Energy Consumption by Functional End Use in 1975" (Jill King, 1979).

3. Policy Variables and Parameters

The MATH/CHRDS model can simulate the distributed impacts of proposed household energy conservation policy and present these as a synthetic sample survey showing the effects on each household of the energy changes. The major impact variables are the distribution of household energy expenditures as these are affected by changes in energy pricing in combination with changes in appliance efficiency levels, energy use patterns, and household demographic and socioeconomic characteristics. The results of the model are limited to the direct effects of energy policy on energy use. Feedbacks from changed energy use back onto housing, appliance, income, and other goods expenditure behavior need to be incorporated outside the model, and are not currently undertaken.

With this caveat, the major conservation policy variables and parameters which can be applied to MATH/CHRDS simulation include the following:

(a) Regional- or state-level prices for the five home fuels: electricity, piped natural gas, bottled or LP gas, fuel oil, and coal. For the transportation sector the price of gasoline is also included. These are the primary policy variables of CHRDS.

(b) Changes in energy efficiencies of new homes and appliances. There is, however, no present mechanism to simulate retrofit behavior, although the model structure, with some modifications, is appropriate for this since individual households are identified by housing structure.

(c) Probabilities of increased space heating fuel efficiencies due to increased use of insulation by type.

(d) Aggregate probability distributions of housing structures, home and water heating equipment, fuel switching, cooking fuels. These would be entered as "net effect" policy variables to the extent that other more direct conservation programs and policies are estimated (through other models) to affect these distributions.

(e) Aggregate distribution by income class of appliance ownership and fuel usage for six major appliances: clothes dryers, automatic washing machines, wringer washing machines, food freezers, dishwashers, and televisions. Air conditioner ownership has also been added. Again, these would be entered as "net effects" policy variables to the extent that other more direct conservation policies are estimated to affect these distributions.

(f) Changes in energy-related taxes, rebates, tax deductions, and in overall tax rates.

4. Level of Regional, Sectoral, and Fuels Detail

The CHRDS data files disaggregate household residential data into categories which include:

(a) Region and location

(1) State (though there is presently insufficient data for statistical validity)

(2) DOE region

(3) Urban/rural

(4) SMSA/non-SMSA

(b) Demographic-socioeconomic characteristics of each household member:

(1) Age

(2) Race

(3) Sex

(4) Income by 14 income sources

(5) Employment status

(6) Market status

(c) Housing characteristics

(1) Housing type by:

(i) 1-family detached

(ii) 1-family attached

(iii) 2-family building

(iv) 3-4 family building

(v) 5-9 family building

(vi) 10-19 family building

(vii) 20-49 family building

(viii) 50+ family building

(ix) mobile home

(2) Number of rooms

(3) Number of stories

(4) Year built

(5) Type of heating equipment

(6) Home heating fuel

(7) Water heating fuel

(8) Cooling fuel

(9) Tenure (rent/own)

(10) Insulation

(11) Storm windows

(12) Storm doors

(13) Appliances

(i) washing machine

(ii) clothes dryer

(iii) dishwasher

(iv) food freezer

(vii) televisions

(viii) air conditioners

(d) Expenditure data on five types of home fuels:

(1) Electricity

(2) Piped natural gas

(3) Bottled or LP gas

(4) Fuel oil

(5) Coal (though present data are inadequate).

Fuels expenditures are determined for each data file household, and these results are aggregated to represent the distributional effects among different demographic and socioeconomic groups of households.

The model also contains transportation variables of automobile ownership and gasoline expenditure and consumption; thus providing a full enumeration of household fuel demands.

5. Outputs

The output of the MATH/CHRDS model provides a simulated survey data file representing the effects on each household of proposed energy and energy-related changes. The output file will contain the same variables as the input file, but updated and adjusted for demographic, socioeconomic, housing, and appliance projections and modified to reflect imputations of energy fuels expenditures. Excluding the transportation variables, these changes for each simulation year include:*

(a) Demographic - Population characteristics are altered to match control totals and to reflect changing demographic structure.

(b) Economic - Work experience variables and 14 basic types of income are adjusted to reflect changed conditions.

(c) Housing Stock Adjustment - Age distribution of housing stock, type of space heating, and water heating fuel are modified.

(d) Appliance Ownership - Ownership of appliances for each household is modified.

(e) Energy Expenditures - Annual household expenditures on electricity, natural gas, bottled gas, fuel oil, and coal are "updated."

(f) Elasticity Adjustment - Elasticity adjustments are made for home fuel expenditures.

Further description of specific output and results can be found in "Residential Energy Consumption by Functional

*Brazzel, M., J. Hewlett, E. Reiser, and A. Silver, "A Distribution Analysis of the 1985 Energy Projections for the Annual Report to Congress of the Energy Information Administration," Analysis Memorandum AM/IA/78-09, (EIAC-DOE/EIA-0102/25), June 1978.

End Use in 1975" (Jill King, 1979) and in EIA's Annual Report to Congress, 1978, Volume Three.

6. Input Requirements

The MATH/CHRDS model has been initialized with a 1975 synthetic benchmark Data Base, which is itself an updated and modified version of the 1974 Data Base developed from the 1970 Census Public Use Sample and other Census Bureau publications. The 1975 updated Data Base rests heavily on adjustments from the 1975 Annual Housing Survey and the 1975 Washington Center for Metropolitan Studies Lifestyles and Energy Survey. Inputs to a model simulation are thus basically the updating and aging parameters for projecting the demographic and socioeconomic characteristics, the energy price scenarios for future years, appliance ownership rates, and housing start forecasts. Specifics of these are indicated below with potential input data sources.*

(a) Demographic - Census Bureau projection of population by age, race, and sex; Census Series B household projections.

(b) Unemployment rate adjustment - Projected unemployment and labor force from appropriate Data Resources, Inc., (DRI) forecast.

(c) Income adjustment - Income growth rates by source of income over simulation period, from DRI.

(d) Tax Payments - Projected tax tables and payroll tax parameters for simulation years.

(e) Transfer Program Income - Eligibility standards and benefit levels by state and by program.

(f) Housing Stock Adjustments - DRI forecasts of housing starts and demolition rates; historical housing stocks by age from the 1975 U.S. Statistical Abstracts; fuel distribution for new and existing homes from the Annual Housing Survey.

*King, Jill. *The Distributional Impact of Energy Policies: Development and Application of the Phase I Comprehensive Human Resource Data System*. Mathematica Policy Research, Inc., June 1977.

(g) Appliance Ownership - Data computed by user.

(h) Energy Expenditures and Prices by Fuel, by State, or Region - For historical price data, American Gas Association, 1970 Gas Facts and other relevant years; Edison Electric Institute. For projected prices, DOE, Mid Term Energy Forecasting System (MEFS) projections, or other projection series.

(i) Elasticity Adjustment - Short-run price and income elasticities of demand supplied by user. Percent price changes over simulation period from MEFS.

Additional inputs are necessary for the transportation submodel.

7. Sources of Data

The 5 percent State Public Use Sample of the 1970 Census on Population and Housing provides the special subsample of over 150,000 households for the basic MATH/CHRDS data file. This is augmented with energy data estimates from the 1/1000 Public Use Sample of the Census; the Consumer Expenditure Survey Series: Interview Survey, 1972, 1973 of the Bureau of Labor Statistics; the Washington Center for Metropolitan Studies (WCMS) Lifestyles and Energy Use Survey (1975); and the Annual Surveys of Housing of 1973, 1974, and 1975. 1975 appliance ownership and fuel characteristics are taken from WCMS and the Annual Survey of Housing. Imputation equations for fuel usage and expenditures were estimated from WCMS and the 1970 Census of Population and Housing data using determinants such as family size, size and type of dwelling, income and employment, appliance ownership, climate, housing characteristics, and energy prices. Data for fuel prices and sales by state are taken from the American Gas Association, the Edison Electric Institute, and the Bureau of Mines. The 1976 Survey of Income and Education provides updated data on employment and income for households in the data file.

8. Other

MATH/CHRDS currently interfaces with EIA's Midterm Energy Forecasting System (MEFS) to provide the detailed distributional impacts analysis of the Annual Report to Congress. Major requests for model outputs at DOE primarily take the form of more detail from existing runs further disaggregated by distribution of income, location, or building structure.

EIA is in the process of incorporating changes in MATH/CHRDS which will correct many of the present model limitations. Principal among these is development of the microsimulation model of household consumption. This will provide a more complete consumer expenditure system to account for indirect effects of energy price changes on other goods and services.

9. Computer Requirements

a. General Description. The MATH/CHRDS system is running on EIA's IBM 30-33 in the Forrestal Building in Washington, DC, its only location. Only one version of the system exists. The baseline data are not being modified.

The system is very large, consisting of modules that update a data tape. The input tape is a set of characteristics for about 200 households. A whole record is read into the computer, parts of it are modified according to the type of run being made, and the whole record, as modified, is written on the output tape.

For questions about the MATH/CHRDS system contact Gerald Peabody, (202) 633-8508, or Eugene Reiser, (202) 633-9397, of the Division of Regional, Socioeconomic and Environmental Analysis, EIA.

b. Accessibility. The MATH/CHRDS system can be accessed in two ways. The first is to contact Gerald Peabody, (202) 633-8508, describing the type of run desired. He will submit and carry out the run if adequate resources and staff time permit. This method is preferred, since it would take about six months to learn the system well enough to run it. Alternatively, if funding is available, Mathematica Policy Research, Inc., could make the analysis (contact Ms. Jill King (202) 933-9510).

The second method of accessing the system requires that the user fully understand the system. A Policy and Evaluation program manager must submit a Data Service Request (DSR) to Marion King in the Office of ADP Services, EIA, (202) 653-3600. After approval she will assign an account number and password for the computer system. Permission to access the appropriate files must then be granted by Eugene Reiser. A user can then run the MATH/CHRDS system.

The EIA computer can be accessed by 300 and 1200 baud remote terminals and is hooked up to TYMNET. Questions concerning the computer installation can be addressed to Ike Digman at (202) 252-8959.

c. Transferability. A copy of the latest version of the MATH/CHRDS system can be obtained by contacting Jerry Peabody or Eugene Reiser. Again, because it is a very large system it would require a considerable investment in personnel resources to learn to transfer and operate it.

The system is written in Fortran IV and, even though overlays of data are used, 400 K to 500 K CPU storage is required.

d. Ease of Modification in the System. The system is fairly flexible at aggregating and disaggregating information. The potential is there for new assumptions for conservation-type changes, but additional programming is often needed. Programming changes can be made in the system under contract.

e. Documentation. Theoretical model design and implementation are addressed in "Distributional Impact of Energy Policies: Development and Application of the Phase I Comprehensive Human Resources Data System" by Jill King and "MATH/CHRDS: Technical Description" by Mathematica Policy Research. The documents, "MATH: User's Guide" and "ENERGY: User's Guide," deal with the running of the system. There is limited staff available for questions. In the past Mathematica has given classes on the MATH part of the model.

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E. National Interim Energy Consumption Survey (NIECS)

E. National Interim Energy Consumption Survey (NIECS)

1. Purpose

The National Interim Energy Consumption Survey (NIECS) is designed to provide current information on energy consumption in households. It is a one-time, national residential survey that was conducted during the winter of 1978-1979. NIECS has three primary purposes:

(a) Provide current information on energy consumption in households, including rental households

(b) Test the procedures and methodology for a larger (more sample points) Residential Energy Consumption Survey (RECS) to be conducted during 1980 and periodically thereafter

(c) Provide current information on household automobile fuel consumption

(d) Provide a comprehensive, detailed assessment of the energy-related characteristics of 50 households.

In addition, a quick-response survey of NIECS respondents who use fuel oil as their main heating source was conducted in August and September 1979, to collect information on fuel oil consumption, expenditures, and conservation activities.

NIECS was conducted and is maintained by EIA.

2. Structure and Level of Detail

NIECS consists of three surveys. A fourth was designed and conducted separately using the NIECS survey sample. It is considered a NIECS-related survey and, therefore, is also described here. The largest of these four surveys, or the "basic" survey, is a sample of 3,843 household units in the 48 contiguous states plus the District of Columbia. A second NIECS survey is a separate two-month survey of a subset (500 to 1,000 households) of the basic sample designed to record automotive fuel usage. A third consists of a detailed assessment of the energy characteristics of another subset (50 households). The fourth survey is a separately ordered survey of 498 NIECS households that use fuel oil and kerosene as their primary source of heating energy.

At the time of this writing (June 1980), information is available only from the basic and the fuel oil surveys. For the fuel oil survey, tabular data in fuel oil inventories and expenditures have been published. For the basic survey, both preliminary and final compilations have been published summarizing the characteristics of housing stocks and households and energy conservation practices and responses during the survey period. The preliminary data lacked information about space and water heating fuels used in rental units. These data were provided from a mail questionnaire. A computer tape providing the basic survey data file has been released so recently that analyses of the NIECS data and incorporation of the results for energy conservation planning are only beginning.

The information now available from the basic survey summarizes energy use on an annual basis. Later in the summer, energy use information will be published by billing period also. The information from the other two NIECS surveys is also expected to become available during 1980. The Residential Energy Consumption Survey (RECS) patterned after NIECS is due to begin in September 1980 and will provide annual information on household energy consumption and conservation.

The characteristics of the data summarized in the following sections are for the basic and the fuel oil surveys only. The information that will become available from the other two surveys is described briefly in Subsection c below.

a. Basic NIECS Survey. Data are collected in the basic survey from a household questionnaire and from monthly fuel billings requested from fuel suppliers. The household questionnaire provides data on housing stock characteristics, appliance stock characteristics, heating fuel characteristics, and selected socioeconomic characteristics. Monthly data on the amount of fuel sold and the price paid by each household are provided from fuel supplier records. Data collected include:

(1) Housing stock characteristics

(a) Regional

(i) Northeast

(ii) North Central

(iii) South

(iv) West

(v) Urban

(vi) Rural

(b) Ownership/rental

(c) Utilities paid

(d) Type of housing structure

(i) Single-family detached

(ii) Single-family attached

(iii) Building with 2 to 4 units

(iv) Building with 5 or more units

(v) Mobile home

(e) Year house built

(f) Size of residence (square feet)

(i) Less than 500

(ii) 500 to 999

(iii) 1,000 to 1,499

(iv) 1,500 to 1,999

(v) 2,000 to 2,999

(vi) 3,000 or more

(g) Number of floors

(i) One

(ii) One and one-half

(iii) Two

(iv) Two and one-half

(v) Three or more

(h) Number of rooms

(i) Number of windows per room

(j) Insulation

- (i) Inches of attic insulation
- (ii) Presence of wall insulation

(k) Major conservation measures undertaken 1977 to 1978

- (i) Window shading
- (ii) Weatherstripping
- (iii) Attic insulation
- (iv) Wall insulation
- (v) Crawl space insulation
- (vi) Thermostat controls
- (vii) Wrap hot water pipes
- (viii) Hot water heater wrap
- (ix) Heat pump purchase
- (x) New hot water heater
- (xi) Furnace charge
- (xii) Caulking

(l) Air conditioning

- (i) Central air conditioning only
- (ii) Individual room units only
- (iii) Central air conditioning and room units
- (iv) No air conditioning

(m) Number of rooms air conditioned

(n) Value of residence

(i) Less than $20,000

(ii) $20,000 to $39,000

(iii) $40,000 to $59,000

(iv) $60,000 to $79,000

(v) $80,000 to $99,000

(vi) $100,000 or more

(o) Monthly rent

(i) Less than $149

(ii) $150 to $299

(iii) $300 or more

(2) Appliance stock characteristics

(a) Number of refrigerators

(b) Refrigerator features

(c) Separate food freezer

(d) Number of electric ovens

(e) Number of gas ovens

(f) Oven features

(i) Electric oven

- Self cleaning
- Continuous cleaning

(ii) Gas oven

- Self cleaning
- Continuous cleaning

(g) Microwave oven

(h) Range or countertop burners: gas, electric

(i) Cooking fuel used most

(i) Electricity

(ii) Natural gas

(iii) LPG

(iv) Other

(j) Washing machine

(i) Automatic

(ii) Wringer

(k) Clothes dryer

(i) Electric

(ii) Gas

(l) Dishwasher

(3) Heating fuel characteristics

(a) Primary heating equipment

(i) Warm air furnace with ducts

(ii) Electric heat pump

(iii) Steam or hot water system

(iv) Hot water pipes (radiant heat)

(v) Floor, wall, or pipeless furnace

(vi) Built-in electric units

(vii) Room heaters with flue

(viii) Room heaters without flue

(ix) Fireplace or stove

(x) Portable space heaters

(xi) Other

(b) Primary heating fuel

(i) Natural gas

(ii) Fuel oil, kerosene

(iii) Electricity

(iv) Liquid petroleum gas

(v) Wood

(vi) Other

(c) Fuel for secondary heating equipment

(i) Wood

(ii) Electricity

(iii) Natural gas

(iv) Fuel oil, kerosene

(v) Liquid petroleum gas

(vi) Other

(d) Water heating fuel

(i) Natural gas

(ii) Electricity

(iii) Fuel oil, kerosene

(iv) Liquid petroleum gas

(v) Other

(e) Most used cooking fuel

(i) Natural gas

(ii) Electricity

(iii) Liquid petroleum gas

(f) Heating and cooling degree days

(i) < 2000 CDD and >7000 HDD

(ii) < 2000 CDD and 5500-7000 HDD

(iii) < 2000 CDD and 4000-5499 HDD

(iv) < 2000 CDD and < 4000 HDD

(v) > 2000 CDD and < 4000 HDD

(4) Socioeconomic characteristics

(a) Number of household members

(b) Number of full-time wage earners

(c) Full-time employment

(i) Respondent married

- Only respondent employed full-time

- Only spouse employed full-time

- Both employed full-time

- Neither employed full-time

(ii) Respondent not married

- Respondent employed full-time

- Respondent not employed full-time

(5) Fuel supplier data for each household

(a) Total amounts of fuel used

(i) Electricity

(ii) Gas

(iii) Fuel oil

(b) Total price paid

(i) Electricity

(ii) Gas

(iii) Fuel oil.

b. <u>NIECS Fuel Oil Survey</u>. The quick-response fuel oil survey contains data for single-family housing units on fuel consumption, changes to the heating system, status of fuel inventories in August 1978 and August 1979, and any conservation changes performed on dwelling units since the fall of 1978. The data cover:

(1) Fuel consumption and price

(a) Heating period

(i) September 1978 through March 1979

(ii) September 1979 through March 1980

(iii) April 1978 through August 1978

(iv) April 1979 through August 1979

(b) Average gallons delivered

(c) Total gallons delivered

(d) Average expenditures

(e) Household income

(i) Under $15,000

(ii) $15,000 and over

(f) Average price

(i) 1978

(ii) 1979

(iii) Month

- April
- May
- June

(g) Heating degree days

(2) Changes to the heating system

(a) Plans for winter of 1979-1980

(i) Will continue to use fuel oil

(ii) Have converted or plan to convert from fuel oil to:

- Utility gas
- Wood
- Other

(b) Plans for supplementary fuel use in the winter of 1979-1980

(c) Furnace cleaning and other heating system changes between September 1978 and August 1979

(i) Furnace cleaned

(ii) Nozzle replaced

(iii) New furnace installed

(iv) Flame-retention heat burner installed

(v) Thermostat recalibrated

(vi) Home heating system zoned

(vii) Automatic flue door added

(3) Status of fuel inventories

(a) Proportion of tank filled

(b) Date

(i) August 1978

(ii) August 1979

(c) Storage tank capacity (August 1979 only)

(4) Energy conservation changes

(a) Period

(i) January 1978 to November 1978

(ii) December 1978 to August 1979

(b) Type of change

(i) Weatherstripping and/or caulking

(ii) Types of insulation

- Roof or attic
- Outside walls
- Hot water pipes or heating ducts
- Basement or crawl space
- Other

(iii) Storm windows and/or insulating glass

(iv) Storm doors and/or insulating glass

(v) Automatic or clock thermostat.

c. Additional Survey Components. Two additional surveys were conducted using subsets of the basic survey sample. A transportation panel comprising between 500 and 1,000 households was initiated in June 1979. Participating households have been asked to keep a log of their fuel purchases and automobile odometer readings for a two-month period. Separate tabulations of gasoline consumption and miles-per-gallon data are planned.

A residential energy assessment study is being performed on 50 NIECS household dwellings. Trained technicians are analyzing exact square footage, temperature distribution in various parts of the house, the presence of insulation, and the features of the major appliances in the house. This study is being used to test the feasibility of collecting technical data during future RECS surveys and to provide technical information that can be used to test the validity of other NIECS survey results.

3. <u>Source of Data or Sampling Method</u>

The NIECS sample is a representative area probability sample consisting of 103 primary sampling units (PSUs). These PSUs were selected from approximately 1,140 PSUs that collectively form a mutually exclusive and exhaustive division of the 48 contiguous United States plus the District of Columbia. Region, metropolitan status, and size classification were the primary considerations in the selection of the PSUs sampled.

Within each PSU, secondary sampling units (SSUs) were defined. Based upon 1970 Census counts, 400 SSUs were selected from the 103 PSUs. An additional 56 SSUs were selected independently. These 56 SSUs comprised a probability selection of areas that had undergone substantial new construction since 1970. This effort to locate areas of new construction was undertaken to control the variation in cluster size.

Within each SSU, a subdivision was made. Census block statistics and rough field counts were used to break up each SSU into segments. These segments were formed so that they ultimately contained about 25 households. From these, a sample of 10 or 11 households was selected to be visited. The resulting national sample contained 4,507 household units.

Of these 4,507 household units, interviews were obtained from 3,843 households, yielding an initial response rate of about 85 percent. Subsequently, mail questionnaires were sent to the 664 households that were not interviewed. Completed mail questionnaires were received from 239 of the households. This additional effort increased the response rate by around 5 percent.

Through waivers obtained from the respondents, suppliers of heating energy were contacted to obtain information on the quantity of energy or fuel supplied by billing period. The fuel used by apartment dwellers was obtained from apartment managers.

4. <u>Access to Data</u>

Preliminary NIECS data are available in printed form as percentages of total households responding in each category. The final data files are now available on magnetic tape. This file contains fuel usage data on an annual basis. Another data file containing fuel usage data by billing period will be available in late 1980 or early 1981. Data from the transportation panel will be available during the last half of 1980. Data from the fuel oil users quick-response survey are available in printed form.

NIECS and its ancillary surveys were conducted and are maintained by the Office of the Consumption Data System, Office of Program Development, Energy Information Division, Department of Energy. Questions concerning NIECS may be addressed to Wendel Thompson (202) 644-5533 or Leslie Whitaker (202) 634-5483, of EIA's Office of Consumption Data Systems.

5. Computer Requirements

The "basic" survey results on computer tape were released in late May 1980 and are available from EIA as the "Preliminary Compilation of the National Interim Energy Consumption Survey Data File." These are on 7-Track 800 BPI BCD character tape. The tape contains a paragraph description, a card image SPSS file, and a card image of the late paper from the household energy use file. Contact Leslie Whitaker (202) 634-5483 in the EIA Office of Consumption Data Systems for further information.

6. Comparison of the NIECS Data With Other Survey Data

The National Interim Energy Consumption Survey provides a great deal of primary data concerning details of residential energy use at national and regional levels. The NIECS disaggregation by types of buildings, fuels used, end use, fuel price, monthly consumption of each fuel, and various socioeconomic and demographic factors offers significant advances in some areas of data collected for energy consumption analysis and forecasting. A comparison to three other surveys of similar scope is given below in Table E-1 to indicate several of these major differences. Two surveys, the Annual Housing Survey and the MRI Appliance Survey, are discussed in more detail in other sections of this report.

TABLE E-1. COMPARISONS OF THE NIECS WITH THREE OTHER SURVEYS

Annual Housing Survey, U.S. Census Bureau

NIECS Advantages	AHS Advantages
Provides energy price and consumption data for all fuels per household	Offers larger sample size which permits state and SMSA disaggregation

TABLE E-1. (CONTINUED)

Annual Housing Survey, U.S. Census Bureau (Continued)

NIECS Advantages	AHS Advantages
Presents data on conservation responses and existing conservation measures, especially insulation. Provides more detail on building thermal characteristics, especially window and floor area	Offers continuing annual survey permitting time series analysis [(though NIECS will be followed by the annual Residential Energy Consumption Survey (RECS)]
Provides data on wider variety of appliances, especially freezers, ovens, refrigerators, dryers, and washers	Gives more detailed financial, demographic, and locational data

Patterns of Energy Use by Electric Appliances by Midwest Research Institute

NIECS Advantages	MRI Advantages
Provides more recent data (1979 vs. 1976)	Provides much more appliance detail, especially size, age, types of electric appliances, and appliance usage by kWh per month
Gives fully national sampling without rural and renters gaps	Notes whether house has gas available for fuel choice
Larger sample size	Presents data more amenable to microeconomic analysis from individual households
Greater disaggregation of housing types, conservation measures, and conservation responses	Provides data on attitudes toward energy consumption
Gives more detailed demographic data	
Collects monthly consumption data on all fuels	
Collects data on renters characteristics and usage	
Estimates age of housing	
Gives rental and homeowner data	
Expects to provide annual data series through RECS	

TABLE E-1. (CONTINUED)

Lifestyles and Household Energy Use, 1972-1975 by Washington Center for Metropolitan Studies

NIECS Advantages	WCMS Advantages
Provides more recent data (1979 vs. 1975)	Gives data on consumer attitudes toward energy consumption
Provides more data on conservation measures undertaken	Shows longitudinal data for some households common to the 1973 and 1975 samples
Gives fully national sampling with better response rates and fewer data gaps	Provides data on changes of residence
Offers larger sample size	Shows stock and behavior changes over a two-year period when energy prices and supplies were changing
Gives energy consumption by all fuels, (WCMS has fuel oil by homeowner response) plus gas and electric suppliers data	
Expects to provide annual data series through RECS	

7. Possible Changes in NIECS for the Future National Residential Energy Consumption Survey

As is the case with most surveys, it is possible to imagine additional questions and details that could have been added to NIECS, or in this case, to the forthcoming annual Residential Energy Consumption Survey (RECS) that is patterned after NIECS. Examples of this can be found in the advantages identified in the other surveys listed in the previous section. A more systematic list and justifications for changes in the NIECS/RECS survey instrument are given in a recent EIA draft report "A Review of Residential Sector Energy Consumption Information Requirements," (McGrady and Oleson). The report reviews specific data items which would assist the modeling, analysis, and evaluation of residential energy consumption. These are matched against the data collected in NIECS, and a prioritized list of additions to NIECS is suggested. A summary of these findings is listed below. A detailed discussion is found in the EIA report.

In general, major areas identified where data are needed for residential energy consumption analysis include:

(a) Thermal characteristics of housing units (especially size, insulation, and air tighteners)

(b) Characteristics of household appliances (especially year of manufacture, capacity, and efficiency)

(c) Appliance purchase behavior by consumers (especially regarding price versus efficiency trade-offs)

(d) Fuel costs and availability by households

(e) Weather

(f) Household characteristics

(g) Appliance utilization.

The data collected in NIECS and in the future RECS, should satisfy many of these requirements, except that of appliance purchase behavior. The study, however, identifies several critical items which, if added to the NIECS/RECS format, would enhance the usefulness of the collected data.

a. Housing Thermal. Major additions to better estimate the thermal envelope include:

(1) Type and amount of insulation in walls and floors

(2) Type of foundation

(3) Materials of exterior walls

(4) Existence of unfinished attic

(5) Number of windows by size and type of frame

(6) Some measure of air tighteners to complement the information on insulation.

b. Appliance Stock. Items that might be added include:

(1) Television

(2) Humidifiers

(3) Dehumidifiers

(4) Swimming pool equipment

(5) Business or farming equipment using the household fuels.

c. Appliance Characteristics. Those that might better assist analysis and predictions of appliance energy consumption, operating cost, and estimates of changes in future appliance stocks include:

(1) Appliance capacity

(2) Year of manufacture

(3) Appliance model and possibly efficiency.

d. Fuel Choice. For fuel choice, the addition of availability of natural gas hookup would indicate the fuller possibilities for changing heating systems.

e. Appliance Utilization. Simple measures of appliance utilization could be added including:

(1) Thermostat settings

(2) Hours or number of times per day estimates of appliance use

(3) Household activity hours.

There is little question that the addition of these details to the future RECS questionnaire would assist the energy conservation research and planning. These gains, however, must be weighed against the added cost of collection. Apparently, the more detailed Energy Assessment Subpanel of RECS has been dropped for these reasons. That Subpanel would have collected physical meaures of the houses and appliances, providing more precision to appliance and housing physical and thermal characteristics and to the resident's behavior.

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U.S. Department of Energy, Energy Information Administration. "Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households 1978," DOE/EIA-6207/2. February 1980.

This is the most current published summary of NIECS. It describes the sample method and provides survey data for all data categories.

U.S. Department of Energy, Energy Information Administration. "Characteristics of the Housing Stock and Households: Preliminary Findings from the National Interim Energy Consumption Survey," DOE/EIA-0199/P. October 1, 1979.

This provides percentage data from the preliminary survey data.

U.S. Department of Energy, Energy Information Administration. "Single-Family Households: Fuel Oil Inventories and Expenditures," National Interim Energy Consumption Survey, DOE/EIA-0207/1, Order No. 306. December 1979.

This document provides data on average fuel oil usage and expenditures by NIECS households as determined by a quick-response survey in August and September 1979.

U.S. Department of Energy, Energy Information Administration. "Residential Energy Consumption Survey: Conservation," DOE/EIA-0207/3. February 1980.

This presents survey results on household conservation practices and responses during the period of the 1978 energy tax credit.

Washington Center for Metropolitan Studies. Lifestyles and Household Energy Use, 1973 and 1975 National Surveys (Tape), September 1977.

F. Energy Consumption Data
Base: Household Sector

F. Energy Consumption Data Base: Household Sector

1. Purpose

The Energy Consumption Data Base (ECDB) was developed by EIA to provide historical estimates of energy consumption and expenditure for eight major sectors of the U.S. economy: agriculture, mining, construction, manufacturing, transportation, commercial, household, and electric utilities. The data are categorized by sector of the economy, end use, and geographic area for 1967, 1971, and 1974. The estimates have been derived from many different sources and do not rely entirely on primary survey data. Though plans call for these to be updated and revised as better and more recent data become available, to date this has not been undertaken systematically across all eight sectors. However, a 1975 file for the household sector has recently been implemented.

The purpose of the ECDB is to assist DOE (and earlier FEA) and other government agencies in the design, development, and collection of energy information in statistical and forecasting activities and in the analysis of the impacts of energy policies and fuel prices on investment decision, various user groups, and geographic areas. For the household sector of the ECDB, this information was strengthened with the inclusion of data on income level and housing structure. Household consumption data, however, are not published at the state level, but only at the national and census division level.

The household data file contains cross-classification of energy usage, energy expenditures, and number of fuel users by fuel type, end use, geographic area, type of structure, and income class. Five fuel types, eight end uses, five housing structures, and five income classes are distinguished. The 1967, 1971, and 1974 data for the household sector of the ECDB were accumulated and derived by Energy and Environmental Analysis, Inc. (EEAI). The 1975 data file was developed by Mathematica Policy Research, Inc., using their MATH/CHRDS model discussed in another chapter of this report. Consistency of data and file elements is, however, maintained across the 1967, 1971, 1974, and 1975 data bases.

2. Structure and Level of Detail

a. Consumption Data File. The primary source of information to create the ECDB household sector was the micro data file produced by Mathematica Policy Research, Inc., from the 5 percent Public Use Sample of the 1970 Census.

This file was also used for the MATH/CHRDS model discussed in an earlier chapter of this report. The file provided detailed information on demographic, socioeconomic, housing, fuel, and appliance characteristics of the households. This was adjusted by Mathematica Policy Research, Inc., and later by EEAI to account for nonresponses on energy consumption information (including, most importantly, renters who did not pay their utilities separately). This adjustment was introduced to the file via multiple classification analysis from the 1/1000 public use sample and corrected by estimates of an average 35 percent underreporting.

More detailed descriptions of the methodology and data to create the ECDB are given in the Energy Consumption Data Base, Volume III, Chapter 7 of the EEAI development and in "Residential Energy Consumption by Functional End Use in 1975" for the Mathematica Policy Research, Inc., development.

b. Update of Consumption Data to 1967, 1971, and 1974. The 1970 consumption data were updated to 1971 and 1974 and backdated to 1967 by EEIA. Changes in fuel prices, income, demographic composition, housing and appliance inventory, and climatological factors were accounted for. Income and price elasticity of demand were not available by income classes, so that Mathematica's average elasticities by fuel type were used with income variations at the state level only. Space heating demands for each year were adjusted for variation in heating degree days. Changes in household demographic composition, and in number and type of structures were used to estimate energy use. The housing stock changes were measured outside the data base and households were apportioned to the changes proportionately by income class.

c. End Use Estimates for 1967, 1971, and 1974. End use estimates were developed by fuel, income, region, and housing structure for each major house appliance. This was accomplished using Census estimates of the distribution of appliances, trade association and engineering standards for average energy consumption values of the appliances, and total consumption estimates by fuel, income, region, and housing structure from the updated household consumption data file.

d. Update to 1975 Data. A variety of new data sources were available for the 1975 ECDB. These include the 1975 Annual Survey of Housing, the 1975 Washington Center for Metropolitan Studies Energy Survey, the 1972-1973 Consumer Expenditure Survey and the Midwest Research Institute Appliance data. The MATH/CHRDS micro simulation model was used to incorporate these new data into the ECDB instead of extrapolating from the EEAI methodology.

The MATH/CHRDS model is designed to project and update a data base of individual households. The basic data of the MATH/CHRDS system is the 1970 Census Public Use Sample discussed above. This is updated and/or projected to subsequent or future years by varying household specific characteristics to conform with aggregate data or projections of those data. Usage and expenditures on individual fuels are imputed to each household on the basis of its new characteristics and the behavioral equations relating those to its resulting energy consumption. The results are then adjusted to be consistent with aggregate data from outside sources.

The ECDB for the household sector in 1975 was extracted from the 1975 MATH/CHRDS file by computing the usage of each fuel by end-use function and calculating the aggregate usage, expenditures, and users by geographic area, fuel type, functional end use, type of structure, and income.

e. Level of Detail. The resulting output is available cross-classified by the following variables:

(1) National and nine census regions

- (a) New England
- (b) Middle Atlantic
- (c) South Atlantic
- (d) East North Central
- (e) East South Central
- (f) West North Central
- (g) West South Central
- (h) Mountain
- (i) Pacific

(2) Fuel types

- (a) Coal
- (b) Kerosene
- (c) Distillate oil
- (d) LPG
- (e) Natural gas
- (f) Electricity
- (g) Other

(3) Functional use

- (a) Space heating
- (b) Space cooling
- (c) Water heating
- (d) Cooling
- (e) Lighting

(f) Clothes drying
(g) Refrigeration
(h) Other appliances

(4) Type of structure

(a) Mobile home
(b) Single-family detached
(c) Single-family attached
(d) Multifamily attached
(e) Multifamily detached

(5) Income of household (for 1974)

(a) Less than $3,000
(b) $3,000-$5,999
(c) $6,000-$9,999
(d) $10,000-$14,999
(e) $15,000-$24,999
(f) More than $25,000

Energy consumption data from ECDB are available in physical units, Btu, and dollars.

3. Sources of Data

The basic household data for the demographic housing stock, income, and regional distribution derive from the 5 percent Public Use Sample discussed earlier and adjusted for gaps in energy data for renters by the 1/1000 Public Use Sample and more recently the Midwest Research Institute study of gang-metered electricity in apartments.

The end use breakdown for appliances for the 1967, 1971, and 1974 data was accomplished using the sources shown in Table F-1. The 1975 update drew off many of the same sources but also drew heavily on 1975 Annual Housing Survey for information on housing stock and their occupants, and the 1975 Washington Center for Metropolitan Studies Energy Survey (WCMS) for characteristics of the housing units, stock of appliances, and exact usage of electricity and piped gas. The 1975 Annual Housing Survey and WCMS were used to augment the MATH/CHRDS file for air conditioning, insulation, storm windows, storm doors, and television use.

TABLE F-1. VARIABLES AND SOURCES FOR END USE BREAKDOWNS

Information	Variables	Sources
Usage		
1. Percentage of households using a particular appliance (e.g., 24% of the poor/mobile homes in Alabama have electric clothes dryers).	Varies by income class - six breakdowns.	1970 Census Population Report.
2. Percentage of households using fuel for space heating, cooking, and water heating.	Varies by state.	1970 Census of Housing.
3. Percent·ge of households using fuel for air conditioning.	Varies by region and income.	1967, 1971 Consumer Buying Indicator, 1974 Survey of Purchases and Ownership.
Average Consumption		
4. Average amount of energy consumed by: clothes dryer, washing machine, TV, dishwasher, and water heating.	Same for all households	Edison Electric Institute, American Gas Association, and engineering standards.
5. Average amount of energy consumed in space heating and air conditioning.	Varies by region and housing type.	A.D. Little.
6. Average amount of energy consumed in lighting and cooking.	Varies by housing type.	Edison Electric Institute, American Gas Association, and engineering standards.
7. Average amount of energy consumed by: refrigerator, stove.	Varies by two breakdowns of housing types: apartments and mobile homes vs. single-family housing.	Edison Electric Institute, American Gas Association, and engineering standards.

Source: Energy and Environmental Analysis, Inc., Energy Consumption Data Base, Household Sector, Final Report, Vol. III, Chapter 7, Arlington, VA, April 1977.

4. <u>Access to Data</u>

The DOE/EIA publication, <u>End Use Energy Consumption Data Base: Series 1 Tables</u>, provides a summary in tabular form of the data in ECDB for 1967, 1971, and 1974. Selected tabulations from the 1975 household sector ECDB are given in Appendix F of "Residential Energy Consumption by Functional End Use in 1975" by Mathematica Policy Research, Inc. The actual data base for 1967, 1971, and 1974 exists in two forms: (1) as a sequential file on tape for each transferability, and (2) as a random access file on EIA's IBM 30-33 in the Forrestal Building in Washington, DC. The advantage of the random access version is that it operates under the ADABAS data base management system, thus making it easy to generate a formatted report of any part of the data base using English-like commands.

The 1967, 1971, and 1974 ECDB version as a sequential file on tape is available with documentation through NTIS--the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161. There are no security restrictions. The random access file version is not available for transfer.

The data tape for the 1975 ECDB is available at the Department of Energy computer facility. The tape and file classifications are consistent with the DOE End Use Consumption Data Bse for all sectors, though it has not been fully integrated into DOE/EIA documentation and use. Description of the tape files and their access is presently given only in Appendix F of "Residential Energy Consumption by Functional End Use in 1975." Questions concerning ECDB can be directed to Bruce Egan of the Energy Use Systems Development Division, (202) 634-5481.

5. <u>Computer Requirements</u>

To access the EIA computer, a DOE project manager must submit a Data Service Request (DSR) to Marion King in the Office of ADP Services, EIA, (202) 653-3600. After approval, she will assign a valid account number and a password will be assigned. After getting access to the computer one must get permission from Bruce Egan to use the appropriate files. The EIA computer can be accessed by 300 and 1200 baud terminals and is connected to TYMNET. Questions concerning the computer installation can be addressed to Ike Digman at (202) 252-8985.

The DOE/EIA publication, "End Use Energy Consumption Data Base Version 110 User's Manual," describes the logical makeup of both forms of the data base and how to use them. For the random access version, this manual describes the ADABAS data base management system; however, the user will also have ADABAS manuals at his disposal.

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G. Patterns of Energy Use by Electrical Appliances Data Base

G. Patterns of Energy Use by Electrical Appliances Data Base

1. Purpose

This data base was compiled by the Midwest Research Institute (MRI) for the Electric Power Research Institute (EPRI). The objectives were to aid:

(a) EPRI efforts to assess energy conservation policies such as appliance efficiency standards and labeling requirements, and changing building practices

(b) Electric utilities in conducting load research and in assessing the impact of changing appliance saturations on total energy use.

Another potential use of this data base is to explore the relationship between regional and household characteristics and appliance energy use patterns.

2. Structure and Level of Detail

The data base contains information on 1,985 households distributed among 16 cities (4 cities per major census division). The following characteristics were collected for each household in this nationwide probability sample:

(a) Type of residential area (urban or suburban)

(b) Type of residence (single or multifamily)

(c) Number of occupants per household

(d) Relationship of occupants

(e) Age of head of household

(f) Gross family income

(g) Employment status

(h) Method of heating home

(i) Availability of gas

(j) Physical characteristics of house (size, areas insulated)

(k) Type of major and minor appliances owned

(l) Monthly household electrical energy usage (kWh) (for April 1976 to July 1977)

(m) Monthly electricity bill (dollars).

Follow-up information was collected for 1,467 of the households on home heating fuels and systems and included:

(a) Major heating fuel

(b) Major and secondary heating systems

(c) Cooking fuel

(d) Clothes drying fuel (if appropriate)

(e) Whether additional insulation had been added to the home recently, quantity and location

(f) Water-heating fuel.

Monthly electrical energy usage by appliance was measured by individually metering the major appliances in 150 homes (a probability sample selected from the primary sample of 1,985 households). A total of 579 major appliances were metered and data collected monthly for one year. The major appliances metered were:

(a) Refrigerator and refrigerator/freezer

(b) Freezer

(c) Electric range (free-standing)

(d) Electric cooktop (built-in)

(e) Electric oven (built-in)

(f) Electric water heater

(g) Dishwasher

(h) Clothes washer

(i) Electric clothes dryer

(j) Room air conditioner

(k) Central air conditioner

(l) Central electric furnace

(m) Swimming pool pump.

For approximately 700 gas-heated households in the primary survey, the following data were compiled:

(a) Quantity of gas consumed monthly

(b) Monthly gas bill.

3. Source of Data and Sampling Method

The 1,985 households in the primary sample were selected by stratified sampling. The subject population (households in urban and suburban areas) was stratified twice - first by region (i.e., Northeast, South, North Central, West) and then by size of city (population greater than or less than 1,000,000). Four cities were selected to represent each of the four regions (see Table G-1). The number of households selected from each city was determined by weighting the city according to regional population, then classification size population, and finally population of the city itself. The survey population did not include rural households.

Apartment dwellings were undersampled because most apartment units were not individually metered. Individual metering was a prerequisite for inclusion in the sample.

Primary household characteristics were ascertained by means of personal interview. A standard questionnaire was used by the interviewer. Home heating data were acquired by telephone survey. Household monthly electric bills were supplied by the electric utilities. The customers signed a release for this information. Electric energy use by individual appliance was measured by means of special kilowatt-hour meters attached to the appliances and read monthly.

The surveys were conducted between April 1976 and July 1977. Though the original data are presently being updated, the data base is still that from the original surveys.

TABLE G-1. SURVEY LOCATIONS*

Region	Size[a]	City	Sample Size
West	Large	Denver, Colorado	120
		San Diego, California	150
	Not Large	Tucson, Arizona	60
		Spokane, Washington	50
South	Large	Miami, Florida	105
		New Orleans, Louisiana	85
	Not Large	Lubbock, Texas	220
		Owensboro, Kentucky	95
North Central	Large	Minneapolis, Minnesota	135
		St. Louis, Missouri	175
	Not Large	Des Moines, Iowa	145
		Topeka, Kansas	80
Northeast	Large	Boston, Massachusetts	135
		Philadelphia, Pennsylvania	240
	Not Large	Trenton, New Jersey	130
		Portland, Maine	60
Total Households			1,985

[a] Large refers to cities with a metropolitan area population of more than 1,000,000 and Not Large refers to those cities with less than 1,000,000.

*Midwest Research Institute: Patterns of Energy Use by Electrical Appliances. EPRI EA-682, January 1979.

4. Access to Data

Tabulations from the surveys are available in EPRI's Patterns of Energy Use by Electrical Appliances. This also gives a good documentation for the data base and how the survey was conducted. The data base is presently at EPRI and is entirely under their control, i.e., MRI is no longer involved in the project. For questions concerning the data base call Steve Braithwait (415) 855-2606 or Charlene Boyce (415) 855-2742.

5. Computer Requirements

For a copy of the data base, a nine-track tape should be mailed to Steve Braithwait or Charlene Boyce at EPRI. They will copy and return the tape at no charge. The tape is written in EBCDIC.

6. Applications and Limitations

Analysis of the residential demand for energy entails in large part an analysis of the stock, investments, and utilization of energy-using capital, where this capital is primarily housing and energy-using appliances. The MRI survey provides a considerable advance in information available to analyze the appliance stock and its use both on the aggregate level and on the level of individual household decision making.

a. Macro Analysis. The MRI data set was developed from a national survey that collected information on appliance stock and metered electric appliance use and on many of the variables relevant to determining the stock. These variables were previously listed in Section G.2. They include: gas and electric rate structures and fuel prices, fuel availability, details on heating systems and building characteristics, and demographic and socioeconomic data. With these, the MRI data base can be used to update and provide additional disaggregation to macromodels of residential demand in terms of individual appliance stocks and use characteristics of those stocks.

As an example of macro analysis, given the variation of income and prices in the national sample, it is possible to estimate price and income elasticity of energy demand by individual major appliances. Some of these estimates might prove useful, for instance, in updating the ORNL residential model price and income elasticities by fuel type. ORNL further disaggregates these elasticities by appliance-specific information which does not appear to be based on the level of detail or the national scope of MRI. Of course, caution should be exercised in making such estimates from cross-sectional data, since other locational factors often affect the responses and thus bias the resulting elasticities.

b. Individual Decision Making. Major gains to be achieved in residential energy analysis of the MRI data probably lie in estimating determinants of individual decisions on choice and use of appliances. Two significant studies have already used the MRI data to help relate individual consumer appliance choice to appliance operation and the relevant energy savings, the appliance capital costs, and other economic and demographic variables. These studies are the Jerry Hausman analysis of room air conditioners, Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables, and the Charles River Associates Analysis of Household Appliance Choice.

Hausman made use of the MRI survey records of metered electricity consumption for room air conditioners and the data collected on brand name, year of purchase, model characteristics, and socioeconomic data for each household. Air conditioner cost and efficiency were added to the data. The utility maximization theory of consumer behavior then provided the structure for logit statistical estimates of the behavioral parameters. The analysis showed that households selected different models of air conditioners by trading off lower operating costs of the higher-efficiency, models with higher fuel expenditures and lower purchase price of less efficient models and by varying actual utilization depending on the chosen efficiency levels. One result of this work suggests that the individual discounting of future energy savings is higher for those in lower income groups than in higher. If this holds true in general, then there are important implications for the policies and planning of energy conservation.

The Charles River Associates study also estimates the parameters of an individual's utility function, but expands the analysis to all space conditioning equipment choices. This, too, draws heavily on the MRI data that differentiate types of heating and cooling systems, fuels used, housing characteristics, and socioeconomic data and augments these by fuel prices and system capital costs. Various procedures are suggested for aggregating the results to provide estimates of market shares for space conditioning appliances and/or for their market penetration. The MRI sampling framework and its national structure facilitate this analysis, though there are shortcomings discussed below.

c. Limitations of the MRI Data Base. A number of limitations have been identified in the MRI data, both by the MRI staff and in the studies using the MRI data. Some of the more important of these are listed below.

(1) Data were not collected on all appliance purchase dates (to determine their ages), but only on electric appliances. This limits identification of the capital and operating cost trade-off, particularly in interfuel variations.

(2) No information on age of building is available to better understand decisions to purchase, replace, and upgrade appliances.

(3) Rural households are excluded from the sample, thus limiting the national sampling characteristics of the survey.

(4) The survey included only households which were metered individually for their electric bills. This excludes many renters and creates an unestimated undersampling of apartment dwellers and apartment buildings.

(5) The sample size for monthly metering of individual electric appliances use was limited to 150 homes. Though this provided valuable information, sample sizes for individual appliance types become rather small for some statistical analysis with nationwide validity. For example, the Hausmann analysis of room air conditioners was limited to 51 units in the sample.

Despite these limitations, the MRI data set provides significant opportunities to expand understanding and statistical estimates of appliance stock and usage and the effects of these on energy demand and response to energy conservation measures.

7. Bibliography

Charles River Associates, Inc. Analysis of Household Appliance Choice, EPRI EA-1100. June 1971.

Hausman, Jerry. "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables." The Bell Journal of Economics, Vol. 10, No. 1, Spring 1979.

Midwest Research Institute. Patterns of Energy Use by Electrical Appliances, EPRI EA-682, Project 576. January 1979.

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H. Annual Housing Survey

H. Annual Housing Survey

1. Purpose

The Annual Housing Survey is designed to provide a current series of information on the size and composition of the housing inventory, the characteristics of its occupants, changes in the housing inventory resulting from new construction and from losses, the indicator of housing and neighborhood quality, and the characteristics of recent movers.*

The Annual Housing Survey has been conducted by the U.S. Bureau of the Census for the U.S. Department of Housing and Urban Development each year from 1973 to 1979. The surveys are a primary source of data for recent residential sector energy models (e.g., MATH/CHRDS, ORNL) as well as analytical and policy studies of housing and energy use behavior.

2. Structure and Level of Detail

The Annual Housing Survey is actually two independent surveys. One is designated "Housing Characteristics for Selected Metropolitan Areas" (Series H-170). This survey contains information on housing units within the 60 largest Standard Metropolitan Statistical Areas. It will be referred to as the SMSA Survey in the following discussions. The other part of the Annual Housing Survey Series H-150 (herein designated the Nationwide Survey) contains data for housing units throughout the nation. In 1973 and 1974, the survey was also supplemented with Survey of Purchases and Ownership for appliances.

a. SMSA Survey. The SMSA Survey is reported in a separate volume for each SMSA. Distributions are reported for the entire SMSA, and also separately for housing units in the central city and not in the central city. The following characteristics tabulated in the SMSA Survey are most relevant to analysis of energy conservation policy and programs.

(1) Number of housing units

(a) Owner occupied

(b) Renter occupied

*U.S. Bureau of the Census, Annual Housing Survey: 1976. Current Housing Reports H 170-76-42, U.S. Government Printing Office, 1978.

(2) Number of units in the structure

(a) 1, detached

(b) 1, attached

(c) 2 to 4

(d) 5 or more

(e) Mobile home

(3) Year built (distribution of housing units by five-year intervals)

(4) Number of rooms

(5) Type of heating equipment

(a) Warm air furnace

(b) Heat pump

(c) Steam or hot water radiator

(d) Built-in electric

(e) Pipeless furnace

(f) Room heater

(g) Fireplace or stove

(6) House heating fuel and cooking fuel

(a) Utility gas

(b) LP gas

(c) Electricity

(d) Fuel oil or kerosene

(e) Coal or coke

(f) Wood

(7) Storm Windows

(a) All windows covered

(b) Some windows covered

(c) No windows covered

(8) Storm doors

(a) All doors

(b) Some doors

(c) No doors

(9) Attic or roof insulation

(a) Yes

(b) No

(c) Don't know

(10) Air conditioned

(a) Room units

(b) Central

(c) None

(11) Principal means of transportation to work

(12) Distance from home to work

(13) Financial information

(a) Income

(b) Mortgage

(c) Payment

(d) Rent

(e) House value

(14) Household characteristics

(a) Number of members in household

(b) Relationship to household head

(c) Marital status

(d) Race

(e) Education of household head.

b. Nationwide Survey. The Nationwide Survey (Series H-150) provides distributions over the same characteristics as the SMSA survey. These data are disaggregated geographically by Census Divisions (Northeast, North Central, South, West). Within each Census Division, characteristics are given for inside SMSAs in central cities, in SMSA - not in central city, and outside SMSAs. The distributions are also separately reported for mobile homes and for new construction (since 1970).

c. Survey of Purchase and Ownership. In 1973 and 1974, the Annual Housing Survey was augmented by a supplement administered to approximately one-third of the Annual Survey Sample. This supplement, Survey of Purchases and Ownership, provided detailed information on appliance ownership so that for example, it would be possible to estimate appliance ownership by income class. Survey of Purchase and Ownership was discontinued after 1974.

3. Source of Data or Sampling Method

Both the SMSA Survey and the Nationwide Survey are based on probability samples, and information is obtained by direct personal interviews with occupants, or, in the case of vacant units, with rental agents or knowledgeable neighbors.

a. SMSA Survey. For the SMSA Survey, the 60 SMSAs covered are divided into three groups. The SMSAs in one group are sampled every three years on a rotating basis (see Table H-1 for years). Interviews are distributed over 12 months. The following sampling procedure is used. For the four largest SMSAs in each group, a sample of 15,000 housing units is drawn, half within the central city, half outside the central city. For the other SMSAs in each group, a sample of 5,000 housing units was selected; the sample was divided in direct proportion to the number of housing units in the central city vs. number outside the central city. The samples for each SMSA were selected from housing units enumerated in the 1970 Census, plus newly constructed units identified through building permits.

b. Nationwide Survey. The Nationwide Survey is conducted every year in the fall (interviews are distributed

TABLE H-1. SMSAs SAMPLED IN THE ANNUAL HOUSING SURVEY

GROUP A

- Albany-Schenectady-Troy, N.Y.
- Anaheim-Santa Ana-Garden Grove, Calif.
- Boston, Mass.*
- Dallas, Tex.
- Detroit, Mich.*
- Fort Worth, Tex.
- Los Angeles-Long Beach, Calif.*
- Madison, Wis.**
- Memphis, Tenn.-Ark.
- Minneapolis-St. Paul, Minn.
- Newark, N.J.
- Orlando, Fla.
- Phoenix, Ariz.
- Pittsburgh, Pa.
- Saginaw, Mich.
- Salt Lake City, Utah
- Spokane, Wash.
- Tacoma, Wash.
- Washington, D.C.-Md.-Va.*
- Wichita, Kans.

GROUP B

- Atlanta, Ga.*
- Chicago, Ill.*
- Cincinnati, Ohio-Ky.-Ind.
- Colorado Springs, Colo.
- Columbus, Ohio
- Hartford, Conn.
- Kansas City, Mo.-Kans.
- Miami, Fla.
- Milwaukee, Wis.
- New Orleans, La.
- Newport News-Hampton, Va.
- Patterson-Clifton-Passaic, N.J.
- Philadelphia, Pa.-N.J.*
- Portland, Ore.-Wash.
- Rochester, N.Y.
- San Antonio, Tex.
- San Bernardino-Riverside-Ontario, Calif.
- San Diego, Calif.
- San Francisco-Oakland, Calif.*
- Springfield, Chicopee-Holyoke, Mass.-Conn.

GROUP C

- Allentown-Bethlehem-Easton, Pa.-N.J.
- Baltimore, Md.
- Birmingham, Ala.
- Buffalo, N.Y.
- Cleveland, Ohio
- Denver, Colo.
- Grand Rapids, Mich.
- Honolulu, Hawaii
- Houston, Tex.*
- Indianapolis, Ind.
- Las Vegas, Nev.
- Louisville, Ky.-Ind.
- New York, N.Y.*
- Oklahoma City, Okla.
- Omaha, Nebr.-Iowa
- Providence-Pawtucket-Warwick, R.I.-Mass.
- Raleigh, N.C.
- Sacramento, Calif.
- St. Louis, Mo.-Ill.*
- Seattle-Everett, Wash.

*Sample size of 15,000 housing units; all others are 5,000 housing units.
**Included with Group B for the first interview.

SOURCE: U.S. Bureau of the Census, Annual Housing Survey: 1976. Current Housing Reports H 170-76-42, U.S. Government Printing Office, 1978.

over three months). The survey is performed by means of multi-stage probability sampling with approximately 75,000 housing units eligible for interview. In the first stage, approximately 900 counties and independent cities are chosen as primary sampling units.

The coefficient of variation (a measure of sampling error) for the Annual Housing Survey ranges from about 0.3 percent for characteristics with large numbers to about 20 percent for characteristics with a very small number of positive responses (e.g., 5,000 units).

4. Access to Data

The Annual Housing Survey is available in published form and on computer tapes. Non-published data are also available from the Census Bureau at the cost of reproduction. The SMSA Survey is published as a separate volume for each SMSA. These are designated Current Housing Reports - Series H-170. The Nationwide Survey is designated Current Housing Reports - Series H-150. These are available for 1973-1977. Results of the 1978 survey will be available in the fall of 1980.

5. Computer Requirements

a. General Description. A copy of the Annual Housing Survey is available on nine-track computer tapes. Questions concerning the Annual Housing Survey and its design should be addressed to Arthur F. Young, (301) 763-2881, Housing Division, Bureau of the Census, Washington, DC 20233.

b. Accessibility. The Annual Housing Survey documentation and tapes are available for borrowing from the Bureau of the Census Library, (301) 763-5042.

c. Transferability. A copy of the tapes can be ordered by contacting the Bureau of the Census, Data Users Services Division, Customer Services Branch, (301) 449-1600. The cost is $80.00 a reel. The entire data base requires two 1600 bpi tapes or four 800 bpi tapes. It is possible to order less than the entire housing survey. Technical documentation on the tapes and the "Annual Housing Survey" is included free when the tapes are ordered. The documentation can be ordered separately for $5.00.

A "data development" writeup describing the tapes and the ordering procedure can be obtained free from the Subscriber Services Branch.

6. Bibliography.

U.S. Department of Commerce, Bureau of the Census. Annual Housing Survey: 1976, Current Housing Reports H 170-76-(1-60), Housing Characteristics for Selected Metropolitan Areas. U.S. Government Printing Office, 1978.

These reports are available from 1973 to 1977 for each metropolitan area selected as indicated by the number after the last hyphen in the report number.

U.S. Department of Commerce, Bureau of the Census. Annual Housing Survey: 1975, Current Housing Reports 150-75(A-E), United States and Regions. U.S. Government Printing Office, 1977.

These reports are available from 1973 to 1977. Volumes A-F of each year 1974-1977 are as follows:

A General Housing Characteristics for the United States and Regions.

B Indicators of Housing and Neighborhood Quality for the United States and Regions.

C Financial Characteristics of the Housing Inventory for the United States and Regions.

D Housing Characteristics of Recent Movers for the United States and Regions.

E Urban and Rural Housing Characteristics for the United States and Regions.

F Financial Characteristics by Indicators of Housing and Neighborhood Quality for the United States and Regions.

U.S. Department of Commerce, Bureau of the Census. "Selected Data from the 1973 and 1974 Surveys of Purchases and Ownership." July 1976 (unpublished).

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I. 1970 Census of Housing

I. 1970 Census of Housing

1. Purpose

The Census of Housing is designed to provide information on the size and composition of the housing inventory, the characteristics of its occupants, changes in the housing inventory resulting from new construction and from losses, the indicator of housing and neighborhood quality, and the characteristics of recent movers.

2. Structure and Level of Detail

The housing characteristics data in the 1970 Census are reported by state, by SMSA (within central city and outside central city), and separately for urban and rural areas within each state. The Census Bureau recognized 247 SMSAs in the 1970 Census.

The following general housing characteristics are available for the 100 percent sample:

(a) Number of housing units

(b) Number with one unit in structure

(c) Number with two or more units in structure

(d) Number that were owner occupied

(e) Number of mobile homes

(f) Number of rooms.

The detailed characteristics (based on the 20 percent probability sample) that may be relevant to energy policy are:

(a) Year built

(b) Presence of basement

(c) Type of heating equipment

(1) Warm air furnace

(2) Heat pump

(3) Steam or hot water radiator

(4) Built-in electric

(5) Pipeless furnace

(6) Room heater

(7) Fireplace or stove

(d) Type of heating and cooking fuel

(1) Utility gas

(2) LP gas

(3) Electricity

(4) Fuel oil or kerosene

(5) Coal or coke

(6) Wood

(e) Air conditioner (window unit, central unit, or none)

(f) Appliances

(1) Clothes washer

(2) Clothes dryer

(3) Food freezer.

3. Source of Data

The Census of Housing is conducted every ten years as part of the decennial Census. All occupied and vacant housing units are included in the survey of general housing characteristics. In addition, 20 percent of the households were selected for a more detailed survey of housing characteristics. A 15 percent probability sample and a 5 percent probability sample were drawn from this 20 percent sample. The surveys were conducted by the method of self-enumeration using a mail out/mail back questionnaire with follow-up for non-respondents and identification of vacant units by visit. The total response rate to the questionnaire was 87 percent. The total undercount in the 1970 Census of Housing is estimated at 1.4 percent. The coefficient of variation for most of these distributions over general housing characteristics is estimated at 0.6 percent.

4. Access to Data

The 1970 Census of Housing is available in published form. Several computer tapes are also available. The "Fourth Count" tape contains data on detailed housing energy use and appliance characteristics tabulated for 35,000 Census tracts.

5. Computer Requirements

a. General Description. A copy of all or part of the 1970 Census of Housing is available on nine-track computer tapes. Questions concerning the 1970 Census of Housing and its design should be directed to Edward Montford, (301) 763-2880.

b. Accessibility. The 1970 Census of Housing documentation and tapes are available for borrowing from the Bureau of the Census Library, (301) 763-5042.

c. Transferability. A copy of all or part of the tapes can be ordered by contacting the Bureau of the Census, Data Users Services Division, Customer Services Branch, (301) 449-1600. The cost depends on the amount of data and thus the number of tapes desired.

A "data development" writeup describing the tapes and the ordering procedure can be obtained free from the Subscriber Service Branch, Bureau of the Census.

6. Bibliography

U.S. Department of Commerce, Bureau of the Census. Census of Housing, 1970, Six Volumes (see below). Government Printing Office, Washington, DC, 1972.

Volume I: Housing Characteristics for States, Cities and Counties, HC(1) in 5 parts by state and territory.

Series HC(1) - A General Housing Characteristics

Series HC(1) - B Detailed Housing Characteristics (including energy measures)

Volume II: Metropolitan Housing Characteristics

Volume III: <u>Block Statistics</u>

Volume IV: <u>Components of Inventory Change</u>

Volume V: <u>Residential Finance</u>

Volume VI: <u>Estimates of Substandard Housing</u>

Volume VII: <u>Subject Reports</u>

J. AIA Research Corporation
Data Base

J. AIA Research Corporation Data Base

[Phase I Data for Buildings Energy Performance Standards (BEPS)]

See Section H of the Commercial Sector of this report.

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K. Additional Models and Data Sources

K. Additional Models and Data Sources

The treatment of the models and data sources in this section is not in the detail or the format of those preceding it. The purpose of this presentation is simply to alert the reader to their existence and possible use. Some of these and other models or data sources might be included in any future version of this report.

1. Residential Energy Consumption Survey (RECS)

The Residential Energy Consumption Survey (RECS) is designed to provide current information on energy consumption in households. This survey is to be conducted for EIA during 1980 and periodically thereafter. The projected survey date is now September 1980. It is presently still in the planning stage; however, the procedures and methodology as well as the majority of sample questions were tested in the National Interim Energy Consumption Survey (NIECS).

RECS is planned as a household interview survey with supplementary data collected from utility billings to develop fuel consumption and cost data for each survey household. The household survey will be similar to that of NIECS described in Section E of this report. The basic household survey categories will include questions on housing and appliance characteristics, transportation and vehicles, demographic and socioeconomic characteristics, and various energy conservation measures. The utility survey will collect data from utilities on the monthly fuel consumption of electricity, gas, and/or fuel oil for each household. These, together with heating and cooling data from regional weather stations, will be merged with the household survey data.

Various subsample studies have been planned in order to collect more detailed and accurate data. The status of these at present is undecided. One earlier plan to have an Energy Assessment Subpanel in RECS to provide a more precise, expert onsite evaluation of housing, appliance, and use characteristics has been dropped.

The initial plans are for a survey sample of 5,000 taken twice a year for each of the 10 DOE regions. The initial fall-winter 1980 survey will be drawn from the four Census regions. The sampling surveys also include households that do not directly pay their bills. Two surveys will be required to obtain a statistically significant sample.

Tabulations and computer accessible data files from the surveys will be available after the data is processed. Complete processing typically takes 1 to 1-1/2 years.

The annual basis of the survey, though not providing longitudinal data on individual households, will complement analyses from the survey's cross-sectional detail with consistently defined time series variables. Together these should permit expanded and refined analyses of household energy consumption and conservation behavior.

2. Solar Market Development Model

The Solar Market Development Model simulates the development and commercialization of solar heating and cooling devices in residential and commercial buildings. The objectives are: (1) to provide an estimate of the extent to which solar equipment could penetrate the residential and commercial market and (2) to measure the impacts of various federal incentive programs in stimulating those applications for hot water heating, space heating, and space cooling of the buildings.

The model considers major factors in the solar energy market at a detailed level which include: 10 market and building types, 10 DOE regions, two applications (retrofit and new construction), three solar devices (hot water, hot water and space heating, and hot water space heating and air conditioning), and seven conventional fuel backup systems. These have been used to simulate the annual solar market demands of the residential and commercial sectors from 1977. Current versions are based on 1980 data.

The basic model structure presents the market penetration of the solar devices by representing both financial and nonfinancial decision variables for each solar option. The undiscounted payback period associated with each solar device, building type, and backup system is chosen to be the financial measure which reflects consumer economic behavior. Estimated percentages of customers who would choose the device for each payback period provide the basic penetration curve, which is then weighted to allow for nonfinancial factors such as aesthetics, attitude toward solar, etc. Each penetration calculation depends on relative fuel and equipment sources for conventional fuels, equipment prices for the solar devices, the amount of previous years' penetration, supplier markets and experience, and various federal incentive programs. The model also rests heavily on descriptions of the solar industry infrastructure production possibilities and technical trends.

The model provides analyses for the following categories:

(a) Residential structures

(1) Single family

(2) Low density

(3) Condominiums

(4) Multifamily

(5) Mobile homes

(b) Commercial structures

(1) High hot water institutional (hospitals)

(2) High hot water other (restaurants, hotels, laundries)

(3) Low hot water institutional (educational, government)

(4) Low hot water owner/lessor (offices, banks, retail, social, religious, warehouses)

(5) Low hot water owner occupied (offices, banks, retail, social, religious, warehouses)

(c) Fuel shares by building type

(1) Electric

(2) Gas

(3) Oil

(d) Solar systems

(1) Water heating

(2) Water heating and space heating

(3) Water heating, space heating, and air conditioning.

The model is designed to estimate the market acceptance and impact of solar heating and cooling in response to a wide variety of federal policy variables or incentive procedures. These include:

(a) Federal economic inventives

(1) Grants

(2) Tax credits

(3) Tax deductions

(4) Investment tax credit

(5) Accelerated depreciation

(6) Low interest loans

(7) Loan guarantees

(8) Government buildings program

(b) Federal non-economic incentives

(1) Consumer education programs

(2) Financial education

(3) Building code/certification programs

(4) Utility programs

(5) Government insurance program

(6) Federal RD&D.

The simulation provides cross-tabulated output on the following:

(a) Solar installations in each region

(b) Residential structure and commercial category

(c) Solar system

(d) Direct energy savings for each fuel

(e) Results of the incentive programs.

The model and computer programs were developed for DOE by Arthur D. Little, and are subject to regular update of data and program modification. The analytical structure of the present version does not vary significantly from the earlier versions, nor do the descriptions of the technologies. The housing and demographic data have been updated to 1980.

The program is on line on the DOE computer and tapes can be accessed or copied on request. Chuck Allen of EIA's Office of Integrative Analysis may be contacted for access and questions concerning technical detail. Documentation for the model structure, data inputs, sample results, and computer program can be found in Arthur D. Little, Inc.,

Solar Heating and Cooling of Buildings (SHACOB) Commercialization Report. Part B, Analysis of Market Development (3 Vols). Prepared for FEA, May 1978 (NTIS-HCP/M 70066-01/1, 01/2,01/3). (Source document for the Solar Market Development Model).

Other models at DOE which provide analyses similar to elements of the Solar Market Development Model include the Simulation of Solar Systems Performance and Market Penetration Model (SOLARSIM) and the System for Projecting the Utilization of Renewable Resources (SPURR). References to these are given below.

The MITRE Corporation. The SPURR Model: A System for Projecting the Utilization of Renewable Resources.

Orkand Corporation. "SOLARSIM Operations Manual," TR-77W-061 and "SOLARSIM Specification Manual," TR-77W-060. July 1977.

3. ORNL Buildings Energy Use Data Book

See Section J-5 of the Commercial Sector in this report.

II. COMMERCIAL SECTOR

MODELS AND DATA SOURCES

A. ORNL Commercial Sector Model of Energy Demand

A. ORNL Commercial Sector Model of Energy Demand

[Structural Commercial Energy Use Model of EIA]

1. Purpose

A comprehensive economic-engineering model of commercial energy use was developed at ORNL to provide detailed annual forecasts of energy use in the commercial sector to the year 2000. The model provides analytical capabilities for forecasting future commercial energy use, for formulating effective government energy conservation programs in the commercial sector, and for evaluating such programs.

Two versions of the ORNL commercial sector model are available: a national version and a regional version. The national version provides annual forecasts of commercial sector energy use in the aggregate. The regional version provides annual forecasts of energy use for the commercial sector for each of 10 DOE regions and forms the basis for the commercial energy demand of DOE's Regional Demand Forecasting System (RDFOR) of the Midterm Energy Forecasting System (MEFS). The model is available at EIA independent of RDFOR as the "Structural Commercial Energy Use Model." A third version of this model is presently under development and will provide annual forecasts of commercial sector energy use by state.

2. Basis for Model Structure

The ORNL model uses an economic-engineering approach to forecasting commercial energy use. The model employs a capital-stock approach which explicitly recognizes that energy is consumed by capital goods in the commercial sector to provide services. Detailed engineering estimates of energy use by equipment, building structure type, fuel type, and age of capital stock are used to develop a disaggregated model of the commercial demand for energy.

Energy use in the commercial sector for a specific case year is described as the product of five variables:

(a) Utilization rate of equipment of a given year vintage as a function of energy prices in the case year

(b) Potential energy use required per square foot of building by equipment of a given year vintage

(c) Fraction of floor space additions in a given year served by each fuel

(d) Commercial building floor space added in a given year

(e) Fraction of floor space additions in a given year which are still standing in the case year.

The resulting energy use in the commercial sector, given in Btu, is therefore determined by fuel prices, energy use requirements (Btu/ft^2), and net commercial floor space additions (ft^2). An energy use index (EUI) is developed to estimate energy use requirements in commercial buildings by fuel type and end use. The utilization rate (which is a function of fuel prices) and potential energy use requirements (EUIs) for a given year are then measured relative to the utilization rate of the equipment for an arbitrary base year. The net fuel and equipment shares of commercial floor space additions are estimated based on assumed fuel-price elasticities, and the additions are estimated as a function of population and personal income.

Given the floor space additions and their resulting energy use requirements, the model provides analysis of final energy demands in terms of equipment and structure efficiencies and fuel price elasticities. Choice of efficiency levels of new space heating and cooling systems depends on the trade-off between initial (purchase) cost and operating cost (fuel price and efficiency) of the new equipment, weighted by the commercial establishment's discounting of the future energy savings. Engineering descriptions provide the technical/cost possibilities for the space conditioning systems. Efficiencies of other equipment and appliances are determined by econometric estimates of the fuel price/efficiency responses.

The actual equipment utilizations are modeled as a function of both the fuel price changes and the efficiencies with which the equipment can be run. In the short run, the efficiency levels are fixed for existing equipment so that short-run utilization is a function only of energy prices.

Over the longer run, the equipment utilization is actually determined as a function of the cost of the end use service produced by the equipment, and thus as a function of fuel prices weighted by the equipment efficiency level. Choice of equipment efficiency is itself described as a function of fuel price (and technology options, initial price, and discount rate for space conditioning), as described above. The analysis is similar where there is the added possibility of fuel choice. Thus, final energy demands are modeled as a series of interrelated decisions on capital stock choice (efficiency) and utilization (fuel price and efficiency) combined with short-run behavior responses to price.

3. Policy Variables and Parameters

a. Short-run. The primary policy variable which operates in the short run (1 year) for the ORNL commercial model is the price of energy. Thus, short-run fluctuations in the demand for energy as a result of energy price changes are expected to include only behavioral changes, such as resetting thermostats, changing ventilation levels, and removing light bulbs, which reflect a change in the intensity of utilization of the present system.

Fuel prices can be affected through regulation or price decontrol policies and through tax policies, such as utility tax rates or oil import taxes. Policy options which yield short-run changes in demand for energy (i.e., the utilization rate) are limited by the ability to directly or indirectly alter energy prices and the short-run elasticity of energy demand, where the opportunities to respond to price changes are again limited to utilization changes with the existing stocks.

b. Long-run. The primary policy variables which operate in the longer run for the ORNL commercial sector model include the following:

(1) Absolute and relative fuel prices

(2) Levels of equipment and building energy efficiency

(3) Relative price of capital and energy.

Absolute and relative fuel price changes affect commercial sector demand primarily through the fuel price/efficiency trade-offs and elasticities for new equipment purchases and the equipment utilization elasticities of efficiency weighted prices. Changes in absolute fuel prices can be accomplished through regulatory and tax policies, as mentioned above. The model properly reflects that the responses to these policy options are less limited in the long run than in the short run, because the longer time period allows changes in investment to occur, such as investing in more fuel-efficient equipment or conservation devices. Changes in relative fuel prices can be accomplished through similar policies which are fuel-specific and differ by fuel.

The model response in this case would be to alter the fuel mix, or the fraction of floor space served by each fuel. The opportunity for this type of response is also greater in the long run than in the short run, as long-term investments may be undertaken which result in fuel switching.

Changes in the level of equipment energy efficiency can be accomplished through the ORNL model by altering the energy use index (EUI) variables which reflect the specific technological trade-offs. Examples of such changes are buildings energy standards, which alter the energy efficiency of the building envelope, and appliance efficiency standards, which affect the energy use of water heaters, space heating or cooling equipment, and lighting fixtures. The long run affords the opportunity to invest in such conservation measures, and the model can estimate the impact of these conservation policies.

Changes in the relative price of capital and energy can involve the policy variables of fuel price and/or the purchase price for equipment energy efficiency levels. Altering these variables differentially can demonstrate the effects on conservation of substituting more energy-efficient capital stock for energy use in the long run. Thus, the model can represent the process of market penetration of new or modified technologies and analyze their effects on energy conservation.

4. Level of Regional, Sectoral, and Fuels Detail

The ORNL commercial model disaggregates the commercial sector into 10 subsector categories. These are:

(a) Finance and other office-related activities

(b) Retail/wholesale

(c) Auto repair and garage

(d) Warehouse activities

(e) Educational services

(f) Public administration

(g) Health care services

(h) Religious services

(i) Hotel/motel services

(j) Miscellaneous commercial activities.

Each of these commercial subsector categories is further disaggregated by fuel type and end use. The four fuel types included in the analysis are:

(a) Electricity

(b) Natural gas

(c) Oil

(d) Other.

The five end uses included in the model are:

(a) Space heating

(b) Cooling

(c) Water heating

(d) Lighting

(e) Other.

Analysis is available for each of the 10 DOE regions from the Regional Model.

5. Outputs

The outputs of the ORNL commercial model include forecasts to the year 2000 of the following:

(a) Total energy use in the commercial sector (in 10^{15} Btu)

(b) Commercial sector energy use by fuel type (percent of total Btu)

(c) Trends in fuel choice within the commercial sector (i.e., fuel type market shares as percent of total Btus)

(d) Commercial sector energy use by end use (percent of total Btu).

These forecasts are obtained for a baseline scenario and alternative policy scenarios. The model thus determines energy savings in the commercial sector by calculating the difference between the forecasts obtained for a specific policy scenario and the baseline. These results can be obtained for each commercial subsector as well as for the total commercial sector.

The results of commercial sector or subsector energy use are determined on a national level and for the 10 DOE regions. Results by state are not presently available, but such a version of the ORNL commercial sector model is under development.

6. Input Requirements

Input variables required for the ORNL commercial sector model include the following:

(a) Fuel prices (in dollars)

(b) Commercial floor space estimates (in square feet)

(c) Fraction of floor space served by each fuel (percent)

(d) Energy use index numbers for buildings/equipment.

Commercial floor space is estimated through the use of historical data on per capita disposable personal income and population, and school enrollments for educational buildings.

Energy use forecasts require input data on annual growth rates of fuel prices and commercial floor space, and the energy use index numbers for each year of the forecast. Determination of the annual growth of commercial floor space requires the use of annual growth rates of per capita disposable personal income and population. To determine the annual growth of floor space in educational buildings, the annual rate of growth of school enrollments is substituted for the population annual growth rate.

7. Sources of Data

A variety of data sources were used in the development and operation of the ORNL commercial sector model. These are presented here by category of use within the model. A number of these are discussed elsewhere in this report.

a. Primary commercial fuel use data sources include, by category of fuel:

(1) Electricity

(a) Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry (annual).

(b) Jack Faucett Associates, Inc., National Energy Accounts: Energy Flows in the U.S., 1947-1972, JACKFAU-75-122-8, November 1975.

(2) Gas

(a) American Gas Association, Gas Facts (annual).

(3) Oil

(a) U.S. Bureau of Mines, Sales of Fuel Oil and Kerosene (annual), U.S. Department of the Interior.

(b) American Petrolcum Institute, Petroleum Facts and Figures (annual).

(c) Federal Energy Administration, National Energy Outlook, February 1976.

b. Primary commercial floor space data sources include, by category of building:

(1) General

(a) F.W. Dodge Division of McGraw-Hill Information Systems Company.

(b) U.S. Department of Commerce, Historical Statistics of the United States, Colonial Times to 1970.

(c) U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States (annual).

(d) A.D. Little, Project Independence Blueprint, Final Task Force Report, Residentidential and Commercial Energy Use Patterns, 1970-1990, prepared for the Federal Energy Administration, November 1974.

(2) Retail - wholesale buildings

(a) Department of the Treasury, Office of Industrial Economics, Business Building Statistics, GPO Stock No. 048-000-00279-0, August 1975.

(3) Schools

(a) Pulscak, M.W., and P.A. Abramson, "A Report to Survey Participants," Federal Energy Administration Memorandum, November 2, 1976.

(b) U.S. Department of Health, Education and Welfare, Inventory of Physical Facilities in Institutions of Higher Education, Fall, 1970, 1974.

(4) Public Buildings

(a) Ide, E.A., et al., Estimating Land and Floor Area Implicit in Employment Projections. How Land and Floor Area Usage Rates Vary by Industry and Site Factors, NTIS No. PB-200-069, July 1970.

(b) Jack Faucett Associates, Inc., Energy Consumption in Commercial Industries by Census Division - 1974, prepared for the Federal Energy Administration, Consumption Studies Division, March 1977.

(5) Hotel-Motel

(a) Brener, S.W., and A.C. Gamoran, "The Economic View," Hotel and Motel Management, May 1972.

c. The energy use index is a new data base for use in the ORNL commercial sector model developed from the following data sources by fuel and end-use category:

(1) Space and water heating

(a) Westinghouse Research Laboratories, "Assessing the Potential for Optimal Utilization of Off-Peak Power," prepared for the Federal Energy Administration, December 1975.

(b) Hittman Associates, Inc., "Physical Characteristics, Energy Consumption, and Related Institutional Factors in the Commercial Sector," Report HIT-630, October 1975.

(c) A.D. Little, Project Independence Blueprint, Final Task Force Report, Residential and Commercial Energy Use Patterns, 1970-1990, prepared for the Federal Energy Administration, November 1974.

(2) Lighting

(a) Dugas, D., S. Dole, H. Peterson, and K. Riegel, "A Preliminary Assessment of Energy Conservation in Lighting," Rand Corporation, Report WN-8666-FEO, May 1974.

(b) Illuminating Engineering Society, IES Handbook, 9th ed., New York, 1966.

(3) Climate

(a) "Monthly Heating Degree Days by State and Season," National Climatic Center, North Carolina, 1973.

8. Other

The ORNL commercial sector model was originally developed with 1970 as its base year. A detailed regional version has been developed which relies on the model structure and accomplishes the same analysis as the basic (national) version just described, but does so for each of 10 federal regions. A draft report on this regional version has been completed at ORNL. An updated version of both the regional and national model is currently available from ORNL using 1977 as the base year. These changes are also integrated into the commercial model of EIA's Regional Energy Demand Forecasting models (RDFOR) and EIA's stand-alone version of RDFOR, the Structural Commercial Energy Model.

A state-level version is currently under development by Charles River Associates and is nearing completion.

9. Computer Accessibility and Requirements

a. General Description. Copies of both versions of the ORNL Commercial Sector Model are presently being run at at least 30 different installations, one of which is EIA. ORNL's version and EIA's version are structurally almost identical. In addition to the national versions at ORNL and EIA, regional versions for the 10 DOE regions also exist at both installations. They are run for one DOE region at a time with no interaction between regions. The regional versions are essentially identical to the national versions except that they operate on regional data bases. Some differences in the parameters used and data file structure have evolved at EIA to integrate the regional model into EIA's Midterm Energy Forecasting System (MEFS) or, more specifically, the Regional Demand Forecasting System (RDFOR). Earlier, EIA displayed a "reduced form" version of the ORNL model; this is still used occasionally. Charles River Associates is presently developing a state-level version.

The ORNL model is run on an IBM 360-370. Questions concerning it can be directed to Ken Corum at (615) 574-5226 or Steve Cohen at (615) 574-5225.

The EIA model is run on an IBM 30-33 in the Forrestal Building in Washington, DC. Questions concerning the model can be directed to Mark Rodekohr at (202) 633-9129 or John Holte at (202) 633-8486.

ORNL's model has baseline data from 1971 and simulates energy demand from 1971 to 2000. Just completed is a version with baseline data from 1977. The regional version of this should be complete in the summer of 1980.

b. Accessibility. ORNL can make commercial sector model runs under contract. Such runs are submitted to Ken Corum and run by ORNL staff. Rather than make runs for users, ORNL prefers to give the user a copy of the model. This is discussed in the following section.

To access the EIA computer versions, a DOE program manager must submit a Data Service Request (DSR) to Marion King in the Office of ADP Services, EIA, (202) 653-3603. After approval she will assign a valid account number and password.

The EIA computer can be accessed by 300 and 1200 baud remote terminals and is hooked up to TYMNET. Questions concerning the computer installation can be addressed to Ike Digman at (202) 252-8959.

The entire Commercial Sector Model and appropriate baseline data base are needed to make a run.

c. Transferability. A user can get a copy of the Commercial Sector Model and data base at no cost from ORNL. The model is entirely in Fortran, is nicely commented in the program, and is easily transferable. At most, very minor changes might be required to transfer to another system with Fortran. The model has a 270K CPU storage requirement. Along with the model on cards, the user will receive a user's guide.

d. Ease of Modification in System. The Commercial Sector Model is fairly flexible. Depending on the extent of changes and lead time, ORNL could be contracted to modify the model. Because the model is in Fortran and well commented, if the user has a good understanding of what the model is doing, he could modify the model himself.

e. Documentation. ORNL's CON/14, CON/15, and CON/40 discuss the theoretical model design. CON/14 describes the process of disaggregating total fuel use in 1970 into fuel use by fuel (4 types), end use (5 types), and building (10 types). CON/15 is the most complete documentation on the model structure. Appendix H of the Economic Analysis of Buildings Energy Performance Standards (BEPS) offers a condensed version of CON/15. CON/40 discusses the regional model.

An ORNL user's guide to the model describes how to run the model. A soon-to-be-released CON/44 includes the information in the user's guide in addition to a listing of the model and input requirements, flowcharts, and complete information on the model implementation.

Both ORNL and EIA staff are available to answer any questions.

10. Bibliography

Jackson, J.R., and W.S. Johnson. Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use, ORNL/CON-14. Oak Ridge National Laboratory, February 1978.

Jackson, J.R., et al. The Commercial Demand for Energy: A Disaggregated Approach, ORNL/CON-15. Oak Ridge National Laboratory, April 1978.

Cohn, S., et al. A Commercial Energy Use Model for the Ten U.S. Federal Regions, ORNL/CON-40. Oak Ridge National Laboratory, April 1979 (Draft).

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B. Brookhaven Buildings Energy Conservation Optimization Model (BECOM)

B. Brookhaven Buildings Energy Conservation Optimization Model (BECOM)

1. Purpose

BECOM is designed as an extension of the Brookhaven Energy System Optimization Model (BESOM) to provide detailed disaggregation of end use energy demands. The technology choices and energy requirements resulting from BECOM optimizations are used to project, analyze, and evaluate the effects on energy use of conventional and proposed energy-related technologies in residential and commercial buildings. For any combination of building stocks, fuel prices and availabilities, and other constraints on technological availability, BECOM calculates the optimal technological configuration of the buildings sector. This is expressed in terms of levels of market penetration of specific technologies.

2. Basis for Model Structure

BECOM is designed as a linear programming optimization model. Mathematically, the model is formulated as a modified transportation/transsshipment problem concerned with distributing energy from specific supply centers to points of demand. The objective is to meet energy demands at all destinations at minimum cost. The model accomplishes this by determining the lowest-cost technology that can be used to the fullest extent possible to meet these energy demands.

The energy demands described by BECOM are energy requirements of each specific market. For example, in the residential sector the space heating requirement for single-family homes in the Northeast is one specific point of energy demand. The extent to which any given technology can be utilized to meet the energy demands, that is, its market penetration, is determined by the existing constraints on its use. These constraints are equations which describe the limitations of resource availability that affect the production or implementation of a technology. These are described more fully below.

BECOM may be run simultaneously with BESOM which optimizes technology choice and energy flows for a detailed representation of the energy supply system; or may be run independently of BESOM. In the latter case, assumptions concerning the availability of fuels must be made, which serve as the information on energy supply for the residential and commercial buildings. When this approach is not taken, and BESOM is used to provide fuels supply data to BECOM, the constraints of both models are included in the analysis.

The analysis uses nine prototypical or reference buildings for which heat losses or service demands are calculated from accepted industry procedures. These are placed in prototypical cities with appropriate degree days and cooling hours. Fuel demands are then calculated using average utilization efficiencies in the building. Costs and efficiency changes postulated for representative (policy determined) technological measures then permit the model to calculate and compare optimal (usually optimal for the least cost objective) configurations of investments and utilization of all technologies to meet the given final end-use demands for energy.

The BESOM constraints are classified as follows:

(a) Supply constraints, which limit the amount of a given energy source (by fuel type) that may be used in the planning year

(b) Demand constraints, which specify the basic energy requirements that must be met to satisfy the demands for each demand category

(c) Electricity supply and peaking constraints, which limit the electrical generating capacity of plant types

(d) Environmental constraints, which limit emissions of various types

(e) Market penetration constraints for specific technologies under consideration.

BECOM constraints include the following:

(a) Demand constraints for each type of demand and building type: for example, the energy flow for air conditioning of offices must equal the theoretical air-conditioning load for the total stock of office buildings

(b) Constraints on the minimum residual stock of buildings, such as for mobile homes, so that the number of mobile homes heated by electricity in any given year equals the number that actually existed in the base year minus the number of removals from the base year to the year for which the analysis is performed

(c) Constraints which require seasonal load balance for buildings, so that heating, air-conditioning, thermal, and appliance loads for each shell, such as hospital building envelopes, are balanced

(d) Constraints on the fuel mix (market shares of fuels) in new construction, which are set to reflect current construction trends in either residential or commercial buildings, or to reflect housing models

(e) Seasonal operation constraints on heat pumps, so that the heat pumps have a ratio of heating and cooling equal to the ratio of heating/cooling loads for the specific shell, building type, and region, such as multi-family building envelopes in the North-Central region

(f) Constraints which reflect backup requirements for solar energy uses when insolation is insufficient

(g) Constraints which require that solar space heating must also be employed in any building which has solar air conditioning, which recognize that solar air conditioning is never used by itself

(h) Solar hot water heating constraints, which ensure that buildings that employ solar space-heating systems derive their hot water from the same system.

3. Policy Variables and Parameters

Policy variables and parameters within BECOM include the following:

(a) Input prices, which can be altered to assess the impacts of alternative tax and pricing policies

(b) Capital charges for building types, which can be altered to determine the effects of various tax incentive programs and policies

(c) Limits on the constraints, which allow the effects of regulatory policies to be assessed, such as for energy demand or supply limitations, or environmental controls

(d) Equipment costs and/or efficiencies, which can be modified to assess the market penetration levels of different types of energy equipment in buildings.

4. Level of Regional, Sectoral, and Fuels Detail

BECOM has been developed to extend BESOM, which has a detailed representation of the energy supply system but a highly aggregated representation of the demand portion of the system. BECOM provides end-use detail for residential and commercial buildings. It explicitly models 25 energy conversion technologies, such as burners, heat pumps, electric motors, condensers, blower fans, and light bulbs and other lighting equipment, and eight structural technologies such as the building envelope, pipe and heater insulation, and appliance performance levels.

These conversion and structural technologies can be used by nine residential and commercial building types. The residential building types include:

(a) Single-family homes

(b) Low-density dwellings

(c) Multifamily high-rise buildings

(d) Mobile homes.

Commercial building types include:

(a) Hospitals, including all health care facilities, private and public

(b) Schools, including classrooms, laboratories, and libraries

(c) Offices, including general office space; state, local, and federal administration buildings; and banks

(d) Retail, including malls and general mercantile buildings

(e) Miscellaneous, including hotels, motels, churches, service stations, recreational facilities, and other commercial buildings not included in the above four categories.

Each of these residential and commercial building categories includes both retrofitted (existing) buildings and new construction.

In the basic version of BECOM, each of these residential and commercial building types is analyzed for each of four regions and each of six energy end uses. The four regions are:

(a) Northeast

(b) North Central

(c) South

(d) West.

The six energy end uses include:

(a) Space heating

(b) Air conditioning

(c) Water heating

(d) Cooking

(e) Appliance loads

(f) Illumination loads.

In addition to the regional and end-use detail in the residential and commercial sectors described above, the BECOM energy demand analysis considers a number of fuel types. Data concerning the availability of these fuel types are obtained either by assumption or through the use of the BESOM energy supply analysis. These fuel types include:

(a) Natural gas

(b) Oil

(c) Coal/fossil fuels

(d) Electricity

(e) Solar.

The analysis of the energy flow is accomplished through a detailed flow network that represents technologies in buildings in one of the four regions, and an aggregated demand representing the energy requirement in the other three regions. This is done for each region so that a national energy flow projection is developed.

5. Outputs

Output of BECOM for each region is given at three levels of aggregation. These are:

(a) Energy demand by building type, including both retrofitted and new buildings, by fuel conversion technology

(b) Summation of energy flows, done separately for residential buildings and commercial buildings, by fuel conversion technology

(c) Net energy demand for each sector and region, by fuel and end use.

In addition to these outputs, the investment (in 1975 dollars) in energy-related devices and structures is summarized during the period from 1976 through the base year. These data are given by new and retrofit markets and buildings.

The model also yields the implied "shadow" prices associated with each of the constraints. These prices indicate the tradeoff between a given constraint and the objective (meeting energy demands at minimum cost). They can also be a useful tool in analyzing differences between existing pricing practices and prices that would more accurately reflect equilibrium of demand and the availability of energy resources.

6. Input Requirements

The main categories of data input required by BECOM are the following:

(a) Building stocks, including inventory data for the year 1975, removals and new construction for years 1976 to 2000, and total building stocks. Residential building stock is given in number of units; commercial building stock is given in number of square feet.

(b) Theoretical building loads for different building types and different climatic conditions in various regions, in the following categories: space heating, air conditioning, hot water, lighting plus power, and auxiliaries for commercial buildings.

(c) Shell efficiencies, which are the percentage improvement in structural integrity over a nominal 1975 value that can be expected from implementing certain technologies in building envelopes.

(d) Conversion-device efficiencies, which are the percentage of delivered energy which can actually be applied to the theoretical building loads.

(e) Technology costs, including the cost of conversion devices and structural technologies, both for new buildings and retrofit applications.

7. Sources of Data

BECOM relies on performance and cost data taken from a wide variety of sources, including the Arthur D. Little data base for buildings for the year 1975, Oak Ridge National Laboratory (ORNL) data bases, and various reports such as those done for the American Gas Association and the Electric Power Research Institute. The data used in BECOM have been updated once, and efforts are currently underway to coordinate with ORNL to obtain 1978 data on the building stock and other technological parameters for the residential and commercial sector.

8. Other

Two other versions of BECOM have been developed. One is a detailed regional version which accomplishes the same analysis as the basic version just described, but does so for each of the nine census regions. The second version was developed for use by New York State. This version uses data specific to New York State and is referred to as the New York Brookhaven Energy Model (NYBEM).

9. Computer Requirements and Accessibility

a. General Description. BECOM is run on a CDC 7600 at Brookhaven National Laboratory in Upton, New York. Questions concerning BECOM can be directed to Peter Kleeman, principal investigator of the BECOM program, (516) 345-2116.

There are two versions of BECOM. One is a developmental version and the other is operational. The baseline data base which BECOM uses is rarely modified. A BECOM run produces an output data file. Both this data file and the original baseline data base are accessible by a report writer, a machine which allows for flexible reporting.

b. Accessibility. BNL can be contracted to make BECOM runs. Such runs are usually submitted to Peter Kleeman and run by BNL staff; however, arrangements can be made for remote access to the BNL computer and BECOM. BECOM is not presently available at any other computer installation.

The entire BECOM program and data base are needed to make a BECOM run. Subsets of the model, such as commercial buildings, can be specified at run time.

c. Transferability. A user can get a copy of the latest production version of BECOM. It is currently implemented using CDC's APEX III linear programming code and PDS/MaGen which puts the data in the correct form for APEX III. The model is programmed in the language of the APEX-MaGen system. Therefore the model could most easily be transferred to another CDC installation. There is, however, a certain amount of compatibility with IBM equipment. The input to APEX III is the same as that to IBM's MPS-X package, thus allowing the output of MaGen to be run on IBM equipment with MPS-X.

The amount of CPU space required by BECOM is dependent on the number of constraints used.

d. Ease of Modification in System. BECOM is a flexible model with multiple options built in. If further options or changes are needed, BNL staff can, under contract, make them.

e. Documentation. The BNL January 1978 document, "The Brookhaven Buildings Energy Conservation Optimization Model," by Steven Carhart, Shirish Mulherkar, and Yasuko Sanborn, discusses the theoretical model design. BNL staff are available to answer questions on this and the structure of the computer model.

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Brookhaven National Laboratory. Regional Reference Energy Systems, Topical Report EPRI EA-462. Prepared for the Electric Power Research Institute, June 1977.

Carhart, Steven C., Shirish S. Mulherkar, and Yasuko Sanborn. The Brookhaven Buildings Energy Conservation Optimization Model. Prepared for the Division of Buildings and Community Systems, U.S. Department of Energy, by the Economic Analysis Division, Department of Energy and Environment, Brookhaven National Laboratory, January 1978.

Carhart, Steven C., et al. The Least-Cost Energy Strategy -- Technical Appendix. Pittsburgh, Pennsylvania: Carnegie-Mellon University Press, 1979.

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C. New England Power Pool Model for Long Range Forecasting of Electric Energy and Demand (NEPOOL)

C. New England Power Pool Model for Long Range Forecasting of Electric Energy and Demand (NEPOOL)

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D. Energy Consumption Data
Base: Commercial Sector

D. Energy Consumption Data Base: Commercial Sector

[Jack Faucett Associates: Energy Consumption in Commercial Industries by Census Division - 1974]

1. Purpose

The Jack Faucett Associates (JFA) data base was developed for use as part of the FEA Energy Consumption Data Base (ECDB). Its purpose was to assist the FEA and other government agencies in the design, development, and collection of energy information for use in statistical and forecasting activities and in analyzing the impacts of energy policies, as required by the Energy Conservation and Production Act of 1976.

The JFA data base provides data on measures of activity in the commercial sector, such as space inventory or number of hospital beds, and measures of energy consumption per unit of commercial activity which are presented in physical units, such as barrels of petroleum products or per Btu. These data were estimated only for the year 1974 although the ECDB was to contain data for the years 1967 and 1971 as well.

2. Structure and Level of Detail

Most of the data are derived through the use of secondary sources and various estimated parameters. The commercial sector is examined as a set of specific industries or activities. The estimation techniques vary by the specific commercial activity analyzed. In general, for each industry, energy use per unit of the activity (termed energy coefficient) is determined. Estimates of energy consumption for each commercial activity are obtained by applying the values of the energy coefficients to the measures of the activity, such as inventory of floor space.

The energy coefficients are variable, so that for some activities they are fuel-specific within a region,and for other cases they measure total Btu per activity of an entire industry. The energy consumed by a specific commercial activity may be affected by several types of energy coefficients. This presents difficulties in establishing the quality of data developed for a specific commercial industry.

Functional use (end use) patterns of energy consumption were estimated in several commercial industries by applying "functional use matrices" derived from a study of ASHRAE Standard 90-75 to the estimated energy consumption data. These "functional use matrices" were adjusted to be fuel specific and to fit the functional use categories specified for each commercial industry.

For purposes of developing the Energy Consumption Data Base, the commercial sector is defined to include the following industries:

(a) Retail trade

(b) Wholesale trade

(c) Communications

(d) Utilities (excluding material inputs to electric generation process)

(e) Finance, insurance, real estate, and services

(f) Schools

(g) Hospitals and nursing homes

(h) Public administration (local, state, and federal, including the military).

In addition to the U.S. total, the nine census regions included in the data base are:

(a) New England

(b) Middle Atlantic

(c) South Atlantic

(d) East North Central

(e) East South Central

(f) West North Central

(g) West South Central

(h) Mountain

(i) Pacific.

The commercial sector portion of the ECDB includes six fuel types. The types of fuel and the physical unit associated with each are as follows:

(a) Coal (thousands of short tons)

(b) Fuel oil (thousands of barrels)

(c) LPG (thousands of barrels)

(d) Natural gas (millions of cubic feet)

(e) Electricity (millions of kWh)

(f) Steam (millions of pounds).

Within each commercial industry, data concerning energy consumption are presented for each of the following functional or end uses:

(a) Space conditioning

(b) Water heating

(c) Cooling

(d) Lighting

(e) Refrigeration

(f) Other, not elsewhere classified

(g) Total of all functions.

3. <u>Sources of Data</u>

The data base is developed through the use of secondary sources, such as Census Bureau publications. Some of the other major sources are listed below:

(a) Ide, Edward A. et al. Estimating Land and Floor Area Implicit in Employment Projections. How Land and Floor Area Usage Rates Vary by Industry and Site Factors, NTIS #PB-200-069. Ide Associates, Inc., Philadelphia, Pennsylvania, July 1970.

(b) U.S. Department of Labor, Bureau of Labor Statistics. Handbook of Labor Statistics, 1975 Reference Edition. U.S. Government Printing Office, Washington, DC.

(c) Energy Conservation in New Buiding Design: An Impact Assessment of ASHRAE Standard 90-75, Conservation Paper Number 43B, Federal Energy Administration, U.S. Government Printing Office, Washington, DC, 1975.

(d) 1974 Gas Facts, American Gas Association, Arlington, VA.

(e) Statistical Yearbook of the Electric Utility Industry, 1974, Edison Electric Institute, New York, New York.

These data were developed for the commercial sector portion of the 1974 Energy Consumption Data Base. No updating of these data has taken place.

4. Access to Data

The DOE/EIA publication, "End Use Energy Consumption Data Base: Series 1 Tables," provides a summary in tabular form of the data in ECDB. The DOE/EIA publication, "End Use Energy Consumption Data Base Version 110 User's Manual," describes the logical makeup of both forms of the data base and how to use them both at EIA and from purchased tapes.

5. Computer Requirements

a. General Description. The End Use Energy Consumption Data Base (ECDB) exists in two forms: (1) as a sequential file on tape for easy transferability, and (2) as a random access file on EIA's IBM 30-33 in the Forrestal Building in Washington, DC. The advantage of the random access version is that it operates under the ADABAS data base management system, thus making it very easy to generate a formatted report of any part of the data base using English-like commands. Questions concerning ECDB can be directed to Bruce Egan, (202) 634-5481, of the Energy Use Systems Development Division.

b. Accessibility. To access the EIA computer, a DOE project manager must submit a Data Service Request (DSR) to Marion King in the Office of ADP Services, EIA, (202) 653-3600. After approval, she will assign a valid account number and password. After getting access to the computer, one must get permission from Bruce Egan to use the appropriate files. The EIA computer can be accessed by 300 and 1200 baud terminals and is connected to TYMNET. Questions concerning the computer installation can be addressed to Ike Digman at (202) 252-8959.

c. Transferability. The ECDB version as a sequential file on tape is available with documentation either by contacting Bruce Egan or through National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Virginia 22161. There are no security restrictions.

The random access file version is not available for transfer.

d. Documentation. The DOE/EIA publication, "End Use Energy Consumption Data Base Version 110 User's Manual," describes the logical makeup of both forms of the data base and how to use them both at EIA and from purchased tapes. For the random access version, this manual does describe the ADABAS data base management system; however, it would be helpful if the user also had ADABAS manuals at his disposal.

The methodology used in generating the ECDB is documented in the reports listed on page 3 of the User's Manual or on page 191 of "End Use Energy Consumption Data Base: Series 1. Tables" manual.

6. Bibliography

Jack Faucett Associates, Inc. Energy Consumption in Commercial Industries by Census Division - 1974. Chevy Chase, Maryland, March 1977.

U.S. Department of Energy, Energy Information Administration. End Use Consumption Data Base: Series 1 Tables, DOE EIS-0014. June 1978.

U.S. Department of Energy, Energy Information Administration. End Use Consumption Data Base, Version 110 Users Manual, DOE/EIA 0175.

U.S. Federal Energy Administration. Energy Consumption Data Base Volume III, Chapter 6, Energy Consumption and Commercial Industries by Census Division - 1974. (NTIS PB-268851, same as Jack Faucett Associates above.)

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E. F.W. Dodge Data Base

E. F.W. Dodge Data Base

1. Purpose

The Dodge data base provides information on new construction to firms that sell products and services to the new construction market. The data base is developed and maintained by the F.W. Dodge Division of McGraw-Hill Information Systems Company, which gathers, records, stratifies, and analyzes new construction facts and figures.

The Department of Energy's Energy Information Administration (EIA) presently has Dodge data on its system for the years 1931 to 1976. Data are available for 1977 to 1980, but DOE does not currently have the means for procurement of these data. Dodge began automating its data files in 1965. Consequently, EIA's data is in two groups, 1931 to 1964 (purchased as printed data) and 1965 to 1976 (purchased on tape). These data are keypunched by EIA to be compatible with the automated format, but they are less detailed than the more recent data.

2. Structure and Level of Detail

The Dodge data base is structured as a data bank. It includes data on 267 structure types. Data are provided on approximately 106 nonresidential building types and 80 residential building types. There are 15 major commercial categories. Some of the major commercial structure types include:

(a) Store and other mercantile buildings

(b) Warehouses

(c) Office and bank buildings

(d) Schools

(e) Hospitals and other health treatment buildings

(f) Government administration and service buildings

(g) Religious buildings

(h) Amusement, social, and recreational buildings

(i) Housekeeping residential buildings

(j) Non-housekeeping residential buildings.

For various structure types, information on specific characteristics is available. These characteristics include:

(a) Valuation

(b) Floor area

(c) Dwelling units

(d) Number of projects

(e) Number of stories

(f) Framing description

(g) Type of ownership (public or private).

The data are available by county, by state, and in any level of aggregation.

3. Source of Data

The Dodge data base is compiled from results of ongoing surveys by over 1,400 data gatherers across the United States. These individuals contact designers, planners, and builders who initiate new construction projects and record the information. Data are available on a monthly, quarterly, or annual basis, and are updated regularly.

4. Access to Data

Dodge data may be accessible in three ways. First, some data on valuation and floor space are available on an annual basis through the Statistical Abstract of the United States. These data are annual only, and are highly aggregated, given in national figures only.

Second, the Dodge data which are already in place on EIA's system (1931-1976) are accessible to any DOE agency or contractor to DOE. These data may be obtained by filing a Data Service Request (DSR) with Marion King, in the Office of ADP Services, EIA, (202) 653-3600. The use of these data is restricted by Dodge, particularly the form in which it is to be published;* however, there is no restriction on the level of disaggregation for non-published analysis.

The EIA-accessable data (lacking 1976 to the present) are available in the form of one record per county per building type, with information on square feet of space, number of stories, and other specific measures. Aggregation is accomplished by the user. EIA would like to purchase the 1976-1980 data, but to date has lacked sufficient funding ($50,000). Contact Gerald Benis (202) 633-9022, for any questions regarding this.

Third, the Dodge data are accessible through direct purchase from Dodge, including up-to-date data with a one-month lag. The use of these data is also restricted, as stipulated by the specific contract. In general, Dodge sells its data only to firms directly involved in the construction industry. It has been recently reported that the annual Dodge data will be made available through the Data Resources, Inc., data bank. No specific information is available on this at the present date.

5. <u>Computer Requirements</u>

The Dodge data base is in place at EIA on two IBM 30-33 computers. Computer requirements are minimal. Once the Data Service Request is completed, Gerald Benis of EIA, (202) 633-9022, should be contacted for permission to access the appropriate files. The data may be obtained through remote terminals or directly from EIA. EIA also has a report writer through which the approved user may enter his or her own programs to obtain the data in the form required.

6. <u>F.W. Dodge Data in Commercial Sector Energy Analysis</u>

a. <u>Use of Dodge Data in Commercial Energy Estimates.</u> Many energy consumption studies in the commercial sector are developed on the assumption that there is a good empirical relationship between commercial floorspace and energy use. This is based on the use of floorspace inventory

**Generally, Dodge requires sufficient aggregation so that the published data will not satisfy market analysis requirements for any of Dodge's commercial customers. This has resulted in numerous skirmishes between Dodge and researchers, including those involving the General Electric Commercial Sector Energy Consumption Data Base, the ORNL Commercial Sector Model, and the ORNL Data Book, among others.*

as an approximation for energy-using equipment. (Space conditioning and lighting are two obvious examples.) Since there are no periodic surveys of commercial floorspace which encompass all commercial needs, the requirements to generate these inventories by commercial categories have drawn heavily on the F.W. Dodge commercial sector construction data.

Three sources discussed in this present report used the Dodge data for floorspace calculation: General Electric, Energy Use in Commercial Buildings (GE); Arthur D. Little, Residential and Commercial Energy Use Pattern 1970-1990 (ADL); and the Oak Ridge National Laboratories Commercial Sector Model of Energy Demand (ORNL). The use of the Dodge data in all three rests basically on a "stock additions" model in which inventory in any year is equal to the inventory in the previous year, plus construction awards in the previous year, less the retirements or demolitions. Since Dodge data on construction activity are central to these calculations, the major differences occur in deciding how to treat limitations in those data. These limitations and ways they were treated in various studies are discussed below.

b. Limitations in Applying the Dodge Data.* Dodge data are available from 1925 to the present. However, over that time there have been a number of changes in the data coverage and categories, as well as lack of complementary data with which to make the inventory calculations. The effects of these on floorspace calculations are listed below and then discussed in more detail with the alternative approaches taken to this solution.

(1) Incomplete geographic coverage

(2) Changes in the building categories

(3) Lag time between the building permit collected by Dodge, and actual building completion

(4) Lack of a corresponding series of demolition or removal rates for buildings

(5) Lack of an initial inventory for 1924.

*For a more complete treatment of this topic, see an article by M.G. Strohleim in Energy Use in Commercial Buildings, ORNL, May 1979 Draft, not for official use.

(1) Geographic Coverage. Between 1925 and 1956 Dodge did not collect data on 11 Western states, and between 1956 and 1968 Hawaii and Alaska were left out. Both the GE and ADL approach was to extrapolate from the 1925 data with 37 states to the 1956 data with 48 by using population ratios between the two regions to make the adjustment. The appropriate application of these ratios would be to the construction additions, although Strohleim points out that GE adjusted the inventory totals instead. The ORNL study included population growth comparisons as well as absolute level comparisons in the adjustment, since a growing population would require more construction. Without this the figures are underestimated in the earlier years of rapid Western states development. A more complete analysis would explain the differences by additional variables beyond just population and population growth, but these were not attempted.

(2) Building Categories. Seven building categories were reported in Dodge between 1925 and 1956. After 1956, there were 15 categories. GE estimates use the 15 categories throughout the period by calculating the ratios between the 15 and the 7 as they existed after 1956 and applying these to expand the categories for the earlier years. This makes the strong assumption that the composition of the commercial sector does not vary between 1925 and 1956. ADL's discussion was to use the existing 7 Dodge categories and then make adjustments within categories although the exact methodology for proportioning the adjustments is not clear from the ADL test. The ORNL model's 10 commercial categories were estimated using the Dodge inventories and then estimating the commercial categories by using cross-sectional data from other sources.

(3) Lags Between Permit and Construction-Put in-Place. There may be considerable lag between construction permit collected by Dodge and actual building completion. GE assumed a 12-month lag time between permit issue and completion. This was held for the entire 1925-1976 time period and did not vary by building type. GE's own estimates showed considerable variation in this, so that the accuracy of the annual inventory data may be compared. ADL does not consider the lag issue. Similarly, ORNL did not compensate for the lag period.

(4) Demolition Rates. Little or no annual data are available on the "decay" of commercial buildings over the 1924-1976 period. Estimates for GE, ADL, and

ORNL all assume a decay rate based on an average 45- to 50-year lifetime of commercial buildings. GE assumed a constant decay rate corresponding to 50 years. ADL, on the other hand, appears to have assumed a constant lifetime of 45 years, so that the inventory in 1970 is simply the sum of new construction between those years. The ORNL solution assumes a logistic decay function that allows low decay in the first 20 years of building life and then rapidly increasing over the last 15 years. In none of the studies does the removal rate vary by building type.

(5) 1924 Inventory Estimates. Because the Dodge additions series begins in 1925, there is no estimate of the total commercial floorspace for the preceding year. This could very much influence the 1970 or 1976 inventory estimates and the 1925 inventory apparently does vary by commercial category, as indicated by ORNL (p. 25) where in 1969, 26 percent of office building floorspace was from before 1925, while only 13 percent of retail building floorspace existed before 1925.

ADL's solution to the initial inventory question was the simplest, and also the most inaccurate. ADL assumed that the 45-year building lifetime argued no need for a 1925 inventory in the 1970 study year (45 years later). GE tried a variety of procedures: straight line extrapolation of the stabilized cumulative construction activity for years after 1925, ratios of inventory to GNP, relationships between inventory growth rates and GNP on population, and calculations based on inventory growth and growth in the economy in 1925. These provided a broad range of 1925 inventory estimates from which GE took an average. The composition of the initial 1925 inventory by separate commercial category depended on the 1956-1976 composition, as discussed in (2) above.

The ORNL initial stock estimate varied depending on the building category. Where there were cross-section estimates of inventory proportions at some point in time (as there were surveys for retail buildings and office buildings, age distribution statistics for a period of years) then, assuming the decay rate using Dodge addition, ORNL could work backwards to calculate the initial stock. When these cross-section estimates were not available or uncertain for some building categories, then other independent measures were used. An example of this would be square feet per pupil estimates to derive a given year's school building floorspace and then, using Dodge addition and a decay rate, working backward to the 1924 inventory.

The use of Dodge data to calculate commercial floorspace inventory is central to estimates and projections of commercial energy use. However, analysis of the methods applied to the data by various researchers at GE, ADL, and ORNL indicates that there is considerable variation in methodology and results, and also considerable room for improvement in making best use of the Dodge data source.

7. Bibliography

Arthur D. Little, Inc. Project Independence: Residential and Commercial Energy Use Patterns, 1970-1990. Report to the President's Council on Environmental Quality and to the Federal Energy Administration, November 1974.

F.W. Dodge Division, McGraw-Hill Information Systems Company, 2450 17th Street, San Francisco, California 94110. (Further information may be obtained by contacting Dodge national accounts representative, Mr. Emory, (415) 864-8600.)

General Electric Company. Commercial Sector Energy Consumption Data Base Development Project, Volume I. June 1978.

Jackson, J.R., and W. Johnson. Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use, ORNL/CON-14. February 1978.

Strohleim, M.G. and B.J. Hurlburt. Energy Use in Commercial Buildings, noncirculating ORNL Draft Working Paper. May 1979.

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F. National Federation of Independent Businesses (NFIB) Energy Report for Small Businesses

F. National Federation of Independent Businesses (NFIB) Energy Report for Small Businesses

1. Purpose

The "Energy Report for Small Businesses" is a survey conducted by the NFIB to obtain energy information from member companies for use in advancing the goals of the organization. The objectives of the survey are primarily to provide data and opinion to direct NFIB policy toward various energy issues. The questions asked have varied since the survey's inception in 1974 as different energy issues have become important. NFIB has cooperated with Federal energy agencies in attempting to include energy policy relevant questions.

2. Structure and Level of Detail

The questions asked on the survey have varied since the first survey. Data collected for all of the surveys are:

(a) Type of organization (corporation, partnership, proprietorship)

(b) Type of business

(c) Gross sales

(d) Number of employees

(e) Number of vehicles used by the firm

(f) Average monthly expenditures for fuel and electricity (broken out by fuel type: electric, gas and propane, fuel oil and kerosene, vehicle fuels, and coal and coke).

Other data are also collected. The 1977 survey provides data dealing with the following subjects:

(a) Whether the building is owned or rented

(b) Whether utilities are included in the lease

(c) Type of fuel used for heating

(d) Type of fuel used for cooling

(e) Operating hours per week

(f) Type of natural gas contract (interruptible or non-interruptible)

(g) Whether energy deliveries have been curtailed in the past 12 months

(h) Effect of energy supply curtailments on the operation of the business

(i) The effect that restricting operating hours to 60 hours per week would have on the business

(j) The effect on sales of limits on lighted, outdoor advertising

(k) The effect of a 20¢ per gallon increase in gasoline prices

(l) Any changes in operation or capital investments in the past two years to reduce energy use

(m) The businessman's opinion on future fuel availability

(n) A qualitative estimate of how much fuel consumption could be cut without affecting sales.

3. Source of Data

The survey has been conducted by mail using a sample of approximately 18,000 of the NFIB's 465,000 member firms. A 27 percent response rate was obtained from the 1977 survey. Samples were randomly selected for each mailing. No attempt was made to create a longitudinal survey; the survey is termed "quarterly" because it pertains to the three months preceding the survey. However, only five surveys were conducted at irregular intervals between 1974 and 1977. The last survey was performed in 1977, and there are no current plans to undertake additional surveys.

4. Access to Data

Tabulations from the surveys, including analysis of the information, have been published for the National Federation of Small Businesses by Faculty Associates, Inc., in their Quarterly Energy Report for Small Businesses. At present, five energy data sets exist. The data are also available on computer tape which can be obtained from Faculty Associates. It is possible to have Faculty Associates perform analysis of the data, though they do not directly offer their services for their energy data.

NFIB also collects economic information for small businesses. (The samples are different from those used for the energy surveys.) Presently, 26 economic data sets exist from 1973 through 1979. Faculty Research Associates can create a data tape with any combination of the energy and/or economic data sets. The cost of the tape is dependent on the data sets chosen.

5. Computer Requirements

Data from the NFIB Energy Suvey is available on computer tape which can be obtained by contacting Joseph H. Fee, President, Faculty Associates, Box 2176, Placeville, California 95667, (916) 622-8656. The tapes can be written either at 800 bpi or 1600 bpi and in either ASCII or EBCDIC. Documentation is included with the tape.

6. Bibliography

National Federation of Independent Businesses. Fourth Quarterly Energy Report for Small Businesses. Prepared by Faculty Associates, Inc., San Mateo, California, September 1975.

National Federation of Independent Businesses. Fifth Energy Report for Small Businesses. Prepared by Faculty Associates, Inc., San Mateo, California, May 1977.

National Federation of Independent Businesses. Quarterly Economic Report for Small Businesses. Prepared by Faculty Associates, Inc., San Mateo, California, January 1980.

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G. ADL Commercial Sector Energy Use Data Base

G. ADL Commercial Sector Energy Use Data Base

[Arthur D. Little, Inc.,: Project Independence: Residential and Commercial Energy Use Patterns 1970-1990]

1. Purpose

The Arthur D. Little (ADL) data base, which includes data projections, was designed to provide systematic and well-documented data for developing energy policy in the residential and commercial sectors of the economy. The data base was developed as a part of the Federal Energy Administration's Project Independence. It provides data on the building stock and levels of energy consumption in each sector in 1970 and projects growth of both of these through the year 1990.

An updated version of the ADL commercial data base is a major input to the residential and commercial parameters and final demand constraints for the Brookhaven National Laboratory model BECOM and its optimized conservation technology choices. That ADL version forecasts growth in energy consumption in the residential and commercial sectors from 1975 to 2000. As a part of Project Independence Evaluation System, the ADL data base was also an important input into the U.S. energy forecasting system.

The ADL data base is not a primary input to other presently used energy demand models, but elements of its data and methodology still provide a historical basis for the development of current tools of energy conservation analysis.

2. Structure and Level of Detail

The ADL data base uses a computer simulation to describe energy consumption in the commercial sector. For the year 1970, energy use is described in 500 cells along four dimensions, including five building types, five end uses, four geographic regions, and five fuel types. These are described below. Unit energy demands and the market penetrations of specific fuels are estimated for each of these elements. Aggregate energy demand in 1970 is then determined by multiplying these estimates by market penetration and building inventory size. Total energy demand from 1970 to 1990 is estimated from projections of building inventory, unit demand, and market penetrations based on various assumptions.

The ADL commercial data base includes buildings defined by the following categories:

(a) Office buildings, including general office buildings, banks, and public administration buildings

(b) Retail establishments, including stores and other mercantile buildings and garages and service stations

(c) Schools, including educational classroom buildings, laboratories, libraries, and related institutions

(d) Hospitals, including hospitals, clinics, and other medical care facilities

(e) Other, including hotels, motels, dormitories, amusement, social, and recreational facilities, and religious buildings.

Within each commercial building type, data concerning energy consumption are presented for each of the following end uses:

(a) Space heating

(b) Air conditioning

(c) Lighting

(d) HVAC auxiliary equipment

(e) Appliances and hot water heating, refrigeration, and computers.

The ADL commercial data base presents energy use data for building type and end use for each of four Census regions and U.S. total and each of five fuel types. The four regions are:

(a) Northeast

(b) North Central

(c) South

(d) West.

The five fuel types are:

(1) Gas

(2) Oil

(3) Electricity

(4) LPG

(5) Coal.

3. Source of Data

Sources of data for the ADL commercial data base include the following:

(a) Statistics compiled by the F.W. Dodge Division of McGraw-Hill Information Systems Company as reported in the Statistical Abstract of the United States

(b) Various forecasts and projections of personal income, population, employment, and industrial sector earnings and sales

(c) ASHRAE Guide and Data Book

(d) American Gas Association publications

(e) Edison Electric Institute publications

(f) Illuminating Engineering Society (IES) Handbook.

The data developed for the ADL commercial data base are for the year 1970. Regular updating of the data base does not take place. Updating has occurred, however, on a contract basis, such as that undertaken for use in Brookhaven's BECOM system. The base year for BECOM is 1975 and projections are made to the year 2000.

4. Access to Data

Tables for the ADL data base are available in the appendix to the ADL report: Project Independence, Residential and Commercial Energy Use Patterns 1970-1990. Updated data may be referenced from the Brookhaven input data files to their BECOM model. These are not directly available but can be requested from Peter Kleeman, Principal Investigator of the BECOM project (516) 345-2116. The ADL data base is not currently available at EIA.

5. Computer Requirements

The ADL data base in its updated form for commercial buildings is available as input data to the BECOM model of Brookhaven National Laboratories (BNL). Both the baseline data and output files of BECOM are accessible by a computer report writer, which allows for flexible extraction of data. BNL can be contacted to print these files through Peter Kleeman, or arrangements can be made for remote access to the BNL computer and files. The ADL data base is not currently available on other computer installations.

6. Bibliography

Arthur D. Little, Inc. Project Independence: Residential and Commercial Energy Use Patterns, 1970-1990. Report to the President's Council on Environmental Quality and the Federal Energy Administration, November 1974.

H. AIA Research Corporation Data Base

H. AIA Research Corporation Data Base

1. Purpose

The AIA data base was developed by the AIA Research Corporation for the U.S. Department of Housing and Urban Development (HUD) as the first phase in the development of energy performance standards for new construction in conformance with Title III of Public Law 94-385, "Energy Conservation Standards for New Buildings Act of 1976." The purpose of the AIA data base is to establish a consistent reference or baseline of current practice in building design and construction for the evaluation of alternative energy standards to be used in the design of new buildings.

2. Structure and Level of Detail

The AIA data base estimates the energy consumption of recent (1973 to 1976) residential and nonresidential buildings from buildings design data. Energy consumption is measured in Btu's per gross square foot per year. For purposes of data collection in this effort, classifications of building types and climates are defined. Residential buildings are classified into four groups, as follows:

(a) Single-family detached

(b) Single-family attached

(c) Multifamily low rise

(d) Mobile homes.

Nonresidential buildings are classified into 12 categories. These building types include:

(a) Office

(b) Elementary school

(c) Secondary school

(d) College

(e) Hospital

(f) Clinic

(g) Assembly

(h) Restaurant

(i) Mercantile

(j) Warehouse

(k) Residential non-housekeeping

(l) High-rise apartments.

The last category, high-rise apartments, is included in nonresidential buildings because this type of building operates as a commercial building with a central heating unit, even though the activity housed by the building is residential.

In addition to building type classifications, climate regions of the United States were defined. A climatic classification system was constructed which defined seven climate regions based on combinations of heating degree days and cooling degree days. These climate regions do not coincide with specific geographic areas; rather, they cross geographic regions within the United States. This approach was taken to ensure that climatic variables which affect energy consumption in buildings and building design were adequately considered.

Data analyzed for residential buildings include:

(a) Structural configuration

(b) Envelope description, including walls, windows, doors, floors, roof, etc.

(c) Heating, ventilating, and air-conditioning systems.

Heat loss, heat gain, and heating and cooling utilization factors were calculated, which together yield the estimated energy required to heat and cool the residences for one year.

The data analyzed for nonresidential buildings include:

(a) General information, such as floor area, volume, and number of stores

(b) Building envelope and site-related orientation data

(c) Designed use and building functions

(d) Heating, ventilating, and air-conditioning systems data

(e) Domestic hot water and lighting systems data

(f) Incorporation of renewable energy usage considerations.

These data were analyzed using a proprietary energy analysis computer program, AXCESS, developed by the Edison Electric Institute, which calculated annual design energy consumption levels.

3. Sources of Data

Statistical analysis was conducted on 4,300 questionnaires completed by residential construction members of the National Association of Home Builders (NAHB) and 289 questionnaires completed by manufacturers of mobile homes. For nonresidential buildings, 1,661 completed questionnaires from 37 Standard Metropolitan Statistical Areas (SMSAs) were analyzed.

4. Access to Data

Details concerning the data and output of this effort may be obtained through reports available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161. These reports include detailed discussions of the building and climatic classifications, data collection for residential and nonresidential buildings, and the resulting energy consumption levels for residential and nonresidential buildings.

5. Computer Requirements

The AIA/RC survey data, data tape, and documentation have been transferred to DOE. Specific information on how to access this file was not available for this report.

6. Bibliography

AIA Research Corporation. Phase One/Base Data for the Development of Energy Performance Standards for New Buildings:

(a) Final Report, January 12, 1978 (includes Executive Summary)

(b) Task Report, Building Classification, January 12, 1978

(c) Task Report, Residential Data Collection and Analysis, January 12, 1978

(d) Data Collection, January 12, 1978

(e) Data Analysis, January 30, 1978

(f) Sample Design, January 30, 1978

(g) Climatic Classification, January 30, 1978.

I. Nonresidential Buildings Surveys of Energy Consumption

I. Nonresidential Buildings Surveys of Energy Consumption

1. Purpose

This project is a national survey conducted by the Energy Information Administration (EIA) as part of a major effort by the Department of Energy to develop a comprehensive energy consumption data base. The Nonresidential Buildings Survey is to collect basic benchmarking information on energy capacities and inventories in the nonresidential sector. Specific authority for the survey is vested in Section 52 of the Federal Energy Administration Act of 1974, as amended, which charges the EIA with the responsibility for creating and maintaining a National Energy Information System.

Four stages of survey development have been undertaken or are contemplated:

(a) Pilot Survey - Nonresidential Buildings Pilot Survey to test a preliminary version of the questionnaire and the survey design for an interim survey

(b) Interim Survey - Nonresidential Buildings Interim Survey to provide users with timely but limited information for planning an analysis or building conservation

(c) Feasibility Survey - Nonresidential Buildings Feasibility Survey to develop information for a full-scale national survey as well as timely information for key areas of the country

(d) National Survey - National Nonresidential Building Survey to provide on a recurring basis information that will have validity at the national level on energy capacities and inventories on the nonresidential sector.

The specific discussion that follows will provide details only for the most recent and complete of these, the Interim Survey.

2. Structure and Level of Detail for Interim Survey

The Nonresidential Buildings Interim Survey was undertaken by Westat, Inc., for EIA using two survey instruments. The first collected data on building structure operating characteristics and management conservation responses from owner or manager interviews. The second is collecting data on monthly fuels use and billings from utilities and fuel suppliers. The owner/manager phase was completed in October through December 1979; the fuels data phase is nearing completion.

The survey includes information for approximately 7,000 nonresidential buildings in the United States. The buildings included in the survey are classified into 16 categories as follows:

(a) Agricultural buildings

(b) Assembly buildings

(c) Educational buildings

(d) Food-related sales and service

(e) Health -- in-patient care

(f) Health -- out-patient care

(g) Industrial buildings

(h) Laboratories

(i) Mercantile/service

(j) Mixed use

(k) Office buildings

(l) Public order and safety

(m) Residential housekeeping

(n) Residential non-housekeeping

(o) Storage

(p) Other.

Two general categories of information were obtained during this project. General buildings data include:

(a) Number and type(s) of building occupants

(b) Year of building construction

(c) Number of floors

(d) Total square feet

(e) Glass coverage as percent of exterior surface, including type of glass

(f) Use of awnings or shades

(g) Last year additional insulation was installed to roof or walls since construction, if any

(h) Last year caulking or weatherstripping was applied

(i) General categories of heating, ventilating, and air-conditioning (HVAC) equipment

(j) Primary and secondary activity(ies) in the building (by share of square footage)

(k) Number of persons who work in the building.

Data on energy consumption in the buildings covering a period from December 1978 to January 1980 include:

(a) Percent of building square footage heated and cooled

(b) Building operating hours per day

(c) Type of energy conversion (to heat) system

(d) General type of heat distribution system

(e) General type of cooling system

(f) Type of temperature controls (individual/central)

(g) Normal winter and summer interior temperature

(h) Types of fuels or energy sources

(i) Number of fuels or energy suppliers used

(j) Billing method (individual tenants/single building)

(k) Billing coverage (individual building/multiple buildings)

(1) Energy information packets received.

The utility company and fuel supplier data will provide for all fuel accounts in each building surveyed (assuming the appropriate owner waivers are signed), monthly energy, volume, and cost data for a period of not less than 12 months and up to a maximum of 36 months.

The categories of data are regionalized by the four major census regions (Northeast, North Central, South, West).

3. Sources of Data

a. Interim Survey. The Nonresidential Buildings Interim Survey is structured as an area probability survey based on a sampling of 1,900 areas from 79 counties or county groups in the United States. The survey was conducted by Westat, Inc., using their proprietary sampling frame categorized by business activities and with samples drawn from segments of the counties calculated to have roughly equivalent numbers of business establishments. Sampling statistics have not yet been released.

The Nonresidential Buildings Interim Survey consists of two survey instruments. One is a building owner or manager interview. Survey interviews were conducted between September 1979 and December 1979 and covered approximately 7,000 nonresidential buildings. The interviews took approximately one-half hour per respondent.

The second Interim Survey instrument is a questionnaire which was mailed to utility companies and fuel suppliers. This mail instrument requires the companies to provide monthly energy volume and cost data for a period of not less than 12 months and up to a maximum of 36 months.

b. Pilot Survey. This survey was conducted to test a preliminary version of the questions and survey design. The sample consisted of 645 buildings drawn from buildings in 29 of the Bureau of the Census Principle Sampling Units in the Washington, DC, Baltimore, Maryland, and Allentown, Pennsylvania, areas. The survey collected data from interviews with building owners and managers, and from mail questionnaires to the buildings' utility and fuel suppliers. The interview survey was conducted by Westat, Inc., in spring 1979 with utility and fuel supplier data completed by September 1979.

c. Feasibility Survey. This survey is to include Boston, Massachusetts, the Portland, Oregon, Standard Metropolitan Statistical Area (SMSA), the service area of Seattle City Light, and the Tri-Cities area (Richland, Pasco, and Kennwick, Washington). The survey is scheduled for late summer 1980 to be taken by Westat, Inc., for EIA. It is planned that 600 buildings will be surveyed in each of the four areas. An important feature of the Feasibility Survey will be the attempts to use participating electric utility customer lists to identify buildings to be included in the survey. This can be important in helping develop the random and representative sample, and may help avoid the slow and labor-intensive "area listing" of all buildings in the later National Survey.

d. National Survey. This survey is planned as a full-scale national survey to take place in the mid-1980s and to be repeated (tentatively) every two years. The sample size is to be approximately 7,000 buildings.

4. Access to Data

A report on the Pilot Survey and its evaluation were to have been published, but is not yet available. This is to summarize the findings, describe the methods used, and provide cross-tabulation and various tables for evaluating responses to the questionnaire and sampling. No release of the survey data is contemplated.

For the Interim Survey, a first report on characteristics of buildings is due to be released in August or September 1980. An imputation file will have been developed by spring 1981 to fill gaps from missing data or interviews, so that the full tabulation and public use file (and tape) for the interview responses and energy consumption should be available in late spring 1980. A major obstacle in developing that file is the confidentiality question of how to handle responses from buildings that are large or unique in their survey area.

5. Computer Requirements

Public use tapes of these data are expected to be available through the EIA in the early part of 1981.

6. Areas of the Nonresidential Interim Energy Consumption Survey that Represent Additions for Commercial Sector Energy Use Analysis

The Interim Survey represents a major effort toward a comprehensive survey of nonresidential buildings energy use characteristics. The following lists characteristics and variables from the survey questionnaire that should provide significant contributions to commercial-sector energy conservation analysis and planning:

a. National Perspective. The sampling plan should permit weighting of the data to give national projections of the numbers, types, and characteristics of the buildings, building occupants, and their energy use. Earlier surveys either do not provide national coverage or, as is the case with the Census Bureau's Annual Housing Survey or EIA's Interim Energy Consumption Survey, they do not provide the depth of individual appliance classifications and usage.

b. Random Sample. The Westat sampling frame may not provide the same strength of sampling base that is under consideration in the Feasibility Survey and later the National Survey, but it does provide the random sample of representative data for the commercial sector that will permit good cross-sectional econometric analysis across building characteristics, owner/occupant responses, fuels, and prices.

c. Utility and Fuel Supplier Data. Other surveys have collected monthly utility or supplier data (e.g., the NEPOOL data discussed in another chapter of this report), but not in terms of all fuels consumed for a building or as the fuel proportions vary over time. Further, the Interim Survey is careful to collect information on all the accounts and customers within a building and relate these to their specific application. This permits certain further disaggregated analysis. The 14-month longitudinal data also permit seasonal and behavioral analysis across the broad sample of buildings and use characteristics, particularly with respect to outside factors such as the status of imported fuel.

d. Building Activities and Occupants. The Interim Survey provides more information than other similar surveys on the various commercial activities within buildings. Data on the primary and secondary user floorspace in combination with the other survey data should prove very useful in estimating and projecting potential energy conservation responses as they differ across buildings and occupants or activities.

e. Building Categories. The Interim Survey considers a large number (16) and gradation of buildings by use or activity categories. The survey is, however, by building not by establishment (SIC) category nor by physical building type. To date use of SIC category has not proved very useful for commercial energy use analysis. By choosing the activity category, some information is lost in terms of physical structure and perhaps location. (The survey does, however, cover some major structural categories.) To the extent that these physical attributes are major determinants of energy use, conservation analysis may be weakened. On the other hand, the generic use categories may provide additional insights into occupant behavior and consumption and how they may be influenced by conservation measures. These categories also are used in simulation and forecasting since their growth may be linked to economic and demographic determinants.

f. Agricultural and Industrial Buildings. These are included as building categories 2(a) and 2(g) above. They are not typically included in commercial-sector analyses, but are entirely relevant for analysis of energy use and conservation in buildings. However, it does not appear that the interview questionnaire fully addresses the special characteristics of energy use in those buildings (e.g., the survey does not include miscellaneous items of equipment such as machinery).

g. Timing of Conservation Investments or Actions. This is an important item surveyed in the Interim Survey but not covered in most other commercial-sector data bases. It can be extremely important in estimating conservation responses. Examples in the Interim Survey include such items as the last year of insulation installation and the last year of caulking and weatherstripping.

h. Building Operating Hours. By surveying the number of operating hours each day of the week, the Interim Survey provides variables which can assist in estimating and planning the effects of work hour restrictions for increased energy conservation during, for example, crisis periods. The survey, however, does not look at the daily work schedule by time of day.

i. Temperature Setback Program. By specifically inquiring on receipt of materials and actions toward the temperature setback program and asking questions on temperature settings, the program evaluation, and future incentives and regulations can be studied and planned.

7. Additional Data Not Collected by the Interim Survey

It should be noted that the Interim Survey does not provide the depth about building structure that would have been included in a building energy audit. The interview with the building manager is designed to take approximately one hour. The Interim Survey is intended to provide baseline data on energy consumption and must necessarily lack certain details that would be desirable for conservation analysis. Some of the data not covered in the Interim Survey are listed below.

(a) Building thermal integrity

(b) Hourly operation schedule of buildings and loads

(c) HVAC and distribution systems by specific type

(d) Monthly electric billing demand (i.e., kW)

(e) Lighting types and loads by specific types

(f) Computer equipment

(g) Miscellaneous loads

(h) Outside air intake

(i) Number of control zones

(j) Hot water load data

(k) Refrigerator/freezer data.

8. Bibliography

"Nonresidential Buildings Energy Consumption Study," Questionnaire for the Department of Energy by Westat, Inc., OMB No. 038-578042.

"Justification" for nonresidential building survey and waiver collection from nonresidential buildings, mimeograph transmittal, DOE.

"Nonresidential Building Feasibility Study," (Draft) Version 5, November 26, 1979. Draft questionnaire for the Feasibility Survey.

"How the Survey was Conducted," EIA Mimeo on Nonresidential Buildings Energy Consumption Survey, 1980.

In a soon to be released draft report for EIA, BDM, Inc., reviews commercial sector surveys and evaluates elements of the Nonresidential Buildings Interim Survey. Work in the present report has not drawn on this.

Additional information on the Nonresidential Buildings Interim Survey of Energy Consumption may be obtained by contacting Wilbert Laird, Energy Information Administration, U.S. Department of Energy, (202) 634-5615.

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J. Additional Models and Data Sources

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The treatment of the models and data sources in this section is not in the detail or the format of those preceding it. The purpose of this presentation is simply to alert the reader to their existence and possible use. Some of these and other models or data sources might be included in any future version of this report.

1. General Electric Co. Commercial Sector Data Base

General Electric Center for Advanced Energy Systems: Commercial Sector Energy Consumption Data Base Development Project, CF-ES-R-78-1, Volume 1. March 1978.

The General Electric commercial sector data base has been developed as a part of an effort to construct floorspace inventory data for the commercial sector, to identify and analyze energy consumption data sources, and to initiate a data base describing commercial sector energy use. This data base is central to the floorspace calculations used in the Oak Ridge commercial sector energy/demand model. Only the General Electric floorspace inventory is presented in the following discussion.

The approach taken by General Electric in developing its commercial sector data base is based on a relationship between historic construction and demolition activity and present building inventories as a way to estimate commercial floorspace. Annual estimates of commercial buildings and floorspace inventory are developed for 15 building types from 1925 to 1976. These building types include:

(a) Store and other mercantile buildings

(b) Warehouses (excluding manufacturer-owned)

(c) Office and bank buildings

(d) Commercial garages and auto service stations

(e) Schools and college classroom buildings

(f) Laboratories (excluding manufacturer-owned)

(g) Libraries and museums

(h) Hospitals and other health treatment buildings

(i) Government administration buildings

(j) Other government service buildings

(k) Houses of worship

(l) Other religious buildings

(m) Amusement, social, and recreational buildings

(n) Miscellaneous nonresidential buildings

(o) Non-housekeeping residential buildings.

To establish the initial (1925) commercial buildings inventory, General Electric uses six different methods to develop inventory estimates. The two methods which yield extreme results are eliminated and the results of the remaining four methods are averaged to yield the initial buildings inventory. In developing the estimates of commercial floorspace for 1975 from the initial commercial buildings inventory, General Electric applied various methodologies to allow consideration of the following:

(a) Extrapolation of geographical coverage to include the total United States where data were not available

(b) Variations in the definition of the commercial sector and categorical breakdowns of commercial buildings

(c) Lag times between the issuance of a commercial building constrution award and actual project completion

(d) Estimation of commercial building removal rates due to demolition, fire, or other causes

(e) Estimation of regional floorspace inventory and building counts over 173 Business Economic Areas (BEAs) as defined by the U.S. Department of Commerce.

The General Electric commercial sector base is developed from in-house calculations and data from various previous studies and simulation models. Two key sources of data include "Construction Put in Place," published by the U.S. Department of Commerce, and "Dodge Construction Potentials," published by F.W. Dodge Division of McGraw-Hill Information Systems Company.

2. The BOMA Commercial Sector Data Base

Building Owners and Managers Association International (BOMA): Downtown and Suburban Office Building Experience Exchange Report (annually since 1922)

The purpose of the BOMA data base is to provide members with comparative data on expenses, by type of expenditure, per square foot of rentable space. The BOMA data base is unique in that it has been collected annually and thus displays trends in energy use per square foot.

The report, based on a survey of BOMA members, summarizes data on 963 buildings in 1975, representing 8 percent of commercial office space in the United States. Only aggregate data are reported; data on individual buildings are not generally released. General data collected include:

(a) Building city/location in city

(b) Floor space

(c) Age

(d) Height (in stories)

(e) Occupancy type and rate

(f) Number of persons in building

(g) Electrical billing policy

(h) Energy type for air conditioning

(i) Central air conditioning tonnage.

Energy data collected include cost and volume information for the following:

(a) Electricity

(b) Gas

(c) Oil

(d) Coal

(e) Steam

(f) Chilled water.

3. The Tishman-Syska and Hennessy Data Base

Tishman Research Corporation and Syska and Hennessy, Inc.: Energy Conservation in Existing Office Buildings (June 1977)

Tishman-Syska and Hennessy developed a detailed data base on 44 New York City office buildings. The purpose of this effort was to examine how energy use is affected by building characteristics. Data collected include fuel consumption by fuel, building and month for the period 1971 to 1975, as well as information on building characteristics, such as floorspace and lighting systems. Normalization factors for weather and for utilization were developed. Statistical analysis identified correlations between building characteristics and energy. For example, Btu per square foot generally was higher for buildings constructed after 1960 than for older buildings. The data were used to estimate savings in energy from changes in operational practices and equipment.

4. The NEMA Commercial Sector Data Base

National Electrical Manufacturers Association and the National Electrical Contractors Association: Energy Consumption in Commercial Buildings in Philadephia

The NEMA study was based on a random sample of 50 office buildings in downtown Philadelphia, representing approximately 25 percent of the city's commercial office building stock. The buildings examined were classified into three groups as follows:

(a) Class A: modernized, kept up-to-date, and well maintained. About 40 percent of the sample was in this category.

(b) Class B: well maintained, but not completely modernized. About 58 percent of the sample was in this category.

(c) Class C: older, not well maintained. Only 2 percent (one building) was in this category.

The study related building characteristics to energy consumption. Characteristics studied included extent of maintenance, building age, number of stories, occupancy, HVAC system type, owner-operator or rented, and data processing systems. NEMA found that the major factors affecting energy consumption were the extent and type of building use and the presence or absence of computer and data processing systems.

5. ORNL Buildings Energy Use Data Book

Oak Ridge National Laboratory: Buildings Energy Use Data Book, Edition 1, ORNL-5352 (April 1978)

Oak Ridge National Laboratory: Buildings Energy Use Data Book, Edition 2, ORNL-5552 (December 1979, released June 1980)

The ORNL Buildings Energy Use Data Book is a compilation of residential and commercial energy use data. The basic purposes of this effort are:

(a) To make selected existing data available

(b) To identify areas where data are lacking

(c) To identify data inconsistencies and to resolve these where possible.

The data included in the Data Book are from secondary sources only; none are the results of primary data-gathering efforts by ORNL.

a. Buildings Energy Use Data Book, Edition 1. The Data Book, Edition 1 is organized into eight chapters.

Chapter 1 presents historical and definitional data. Included here are municipal, commercial, and residential buildings inventories and historical consumption trends for various fuels.

Chapter 2 discusses appliances by energy source, including a comprehensive inventory of household appliances and equipment for heating and cooling for the residential sector. Similar appliance and equipment data are not available for the commercial sector.

A detailed analysis of the efficiency rating is presented in Chapter 3 for several of the major appliances. Where possible, an attempt is made to give a sales-weighted efficiency rating for the population of appliances.

Chapter 4 presents data on demographic trends and indicators. These data include the number and types of housing units, the number of households, and population variables.

Chapter 5 examines factors which contribute to the determination of a building's energy use, such as floorspace and the number of stories. Data on certain specific structural characteristics such as window area, are found to be particularly scarce.

Data on economic indicators are presented in Chapter 6. These data include economic determinants of energy use, such as disposable income and personal consumption expenditures.

Best available aggregate data on energy by sector and fuel type are presented in Chapter 7. Included here are data on fuel consumption and prices.

Chapter 8 contains a review of various existing energy-related studies. The studies were chosen on the basis of availability, current applicability, and comprehensiveness. This chapter differs from the previous chapters in that it contains discussions and results of modeling efforts and various estimation procedures.

In addition to these chapters, the Data Book includes a user's guide and a glossary. The user's guide provides technical explanatory remarks and supportive data. The glossary provides definitions of technical terms and in some cases addresses definitional discrepancies by indicating reporting organizations.

b. Buildings Energy Use Data Book, Edition 2. The Data Book, Edition 2 was recently released to the public (June 1980). Edition 2 provides an update of Edition 1, with the addition of new data sources as well as organization and evaluation of the data along the lines of research and policy analysis. This reference book is divided into two parts: Part I (Chapters 1 through 5) "Determinants of Residential and Commercial Energy Consumption" focuses on subject areas affecting energy consumption; Part II (Chapters 6 through 9) offers "Special Topics in Residential and Commercial Energy Consumption" composed of three short studies on solar energy, community systems and schools and hospitals, and reviews of selected energy studies.

Chapter 1 discusses building stock characteristics, including inventories, structural characteristics, and thermal characteristics of building envelopes and construction materials.

Chapter 2 provides data on appliance shipments, inventories, efficiencies, and prices. Additional detailed data are given on water heaters, room air conditioners, refrigerators and freezers, cooling equipment, clothes dryers, clothes washers, dishwashers, lighting systems, heating systems, and fuel use efficiencies for warm air furnaces, boilers, heat pumps, and wood stoves.

Fuel production, consumption, and prices are presented in Chapter 3 to provide information on fuel prices and energy sales by geographic region and economic sector. The chapter also addresses data deficiencies as they might be applied to indicators of natural demand, and inputs to models and forecasts.

Chapter 4 provides data on demographic and climatic variables that affect residential and commercial energy demand. Included are total population, household, and locational demographic data, and indoor and solar climatic data.

National economic determinants of residential and commercial energy consumption are given in Chapter 5. GNP status, personal consumption expenditures, employment, and labor force statistics, are among the variables displayed.

Aspects of solar energy are discussed in the Special Topics Chapter 6. This provides an overview of solar technology, equipment, materials programs, and progress. Emphasis is placed on technologies most appropriate for buildings, space conditioning, and water heating. The analysis also looks at cost-benefit and applications studies, barriers, incentives, and government interventions.

Chapter 7 presents discussion and data on community systems approaches to energy conservation. The chapter is organized toward several major subsystems of a community system based on an integrated utility system concept. The focus is on prime movers, solid and liquid waste disposal, and district heating and cooling. Sections on wind power and geothermal resources are also included.

Energy consumption in schools and hospitals is the major topic of Chapter 8. Improved heating system efficiency, reduced full-temperature operating hours, reduced outside air intake, minimizing lighting, and trained operating personnel are topics and data presented on elementary, secondary, and higher education facilities. Health care facilities are discussed in terms of their unique problems: restrictions on air movement, ventilation requirements, temperature and humidity requirements, and other environmental controls.

Chapter 9 reviews selective aspects of several energy studies. Included are:

(1) Methods for Computing Residential Energy Use

(2) Saving Energy - The Home: Princeton's Experiments at Twin Rivers, by R.H. Scolow

(3) Energy Consumption Data Base: the Household Sector, by the EIA

(4) Washington Center for Metropolitan Studies Life Styles and Household Energy Use national survey

(5) Fuel Choice and Aggregate Demand in the Commercial Sector, by S. Cohn of ORNL

(6) ORNL Engineering Economic Model of Residential Energy Use, by Eric Hirst and Janet Larney of ORNL

(7) Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use, by Jerry Jackson and William Johnson of ORNL

(8) The Commercial Demand for Energy: A Disaggregated Approach, by Jerry Jackson et al., ORNL

(9) National Energy Accounts: Energy Flows in the U.S.

6. Solar Market Development Model

See Section K-2 of the Residential Sector of this report.