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Energy and Environmental Systems Division

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DISTRICT HEATING STRATEGY MODEL:
COMMUNITY MANUAL

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by

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Energy and Environmental Systems Division

October 1981

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DISTRICT HEATING STRATEGY MODEL: COMMUNITY MANUAL

ABSTRACT

The U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Energy (DOE) cosponsor a program aimed at increasing the number of district heating and cooling systems. Because buildings in a district can be heated and cooled more efficiently as a group than individually, a group approach can cut the amount and cost of fuels used for these purposes -- reducing national dependence on fuel imports. HUD and DOE expect construction of such systems to create jobs and spur redevelopment at the local level. Twenty-eight communities have received HUD cooperative agreements to aid in a national feasibility assessment of district heating and cooling systems. The HUD/DOE program includes technical assistance provided by Argonne National Laboratory and Oak Ridge National Laboratory. Part of this assistance is a computer program, called the district heating strategy model, that performs preliminary calculations to analyze potential district heating and cooling systems. The model uses information about a community's physical characteristics, current electricity-supply systems, and local economic conditions to calculate heat demands, heat supplies from existing power plants and a new boiler, system construction costs, basic financial forecasts, and changes in air-pollutant emissions resulting from installation of a district heating and cooling system. This report explains the operation of the district heating strategy model, provides simplified forms for organizing the input data required, and describes and illustrates the model's output data. The report is written for three groups of people: (1) those in the HUD/DOE-sponsored communities who will be collecting input data, and studying output data, to assess the potential for district heating and cooling applications in their communities; (2) those in any other communities who may wish to use the model for the same purpose; and (3) technical-support people assigned by the national laboratories to explain to community personnel how the model is used.

1 DESCRIPTION OF THE MODEL AS A WHOLE

1.1 INTRODUCTION

The district heating strategy model (DHSM) is a computer-based analytical tool. It provides technical support for community-level assessments of systems that can supply heat and cooling from a central source to a group of buildings. The purpose of this report is to help community planners determine how the computer model can assist in their own evaluations and those of their consultants. To this end, the model and its four modules (demand,

supply, cost, emissions) are described in the body of the report and amplified with practical and theoretical detail in a series of appendixes -- the information being sequenced as follows.

- An overview of DHSM purposes and functions
- Various scenarios -- i.e., assumptions regarding heating and cooling loads, thermal sources, and financial parameters -- that can be analyzed by the model
- Assumptions and limitations contained in DHSM computational procedures
- Instructions for providing required input data
- Suggestions for decision-making applications of the model's output data
- Definitions of terms (Appendix A); DHSM abbreviations and computer acronyms (Appendix B); metric-English conversions (Appendix C); default data, economic-analysis techniques, and piping cost equations used in the DHSM (Appendix D); blank worksheets (Appendix E); sample completed worksheets, illustrating how DHSM input data are prepared (Appendix F); instructions for developing the needed study-area map (Appendix G); a sampling of DHSM computer output (Appendix H); and a listing of standard industrial and commercial/institutional classification codes (Appendix I).

The report concentrates on how to supply the model with necessary information in order to obtain useful results from it. A description of a test run of the model has been published.*

1.1.1 Specific Purposes of the Model

As an assessment and planning tool, the district heating strategy model can serve several purposes; examples include the following:

- It imposes structure on an analysis of local alternatives for district heating and cooling; i.e., the DHSM enables community planners to focus quickly on the types of data to be collected and the types of subordinate analyses to be performed.
- The DHSM prompts a user to study all possible district heating and cooling options. In the process of providing the data necessary to run the DHSM, community planners must specify several district heating and cooling alternatives that are to be evaluated. Alternatives may differ from community to community according to market area, thermal sources, and construction schedule.

*Davis, H., et al., National District Heating Program: Generic City District Heating and Cooling from Cogeneration Retrofit, Argonne National Laboratory report ANL/CNSV-TM-65 (Feb. 1981).

- The model enables a user to compare all competing options. Assembling data for the first district heating and cooling option to be assessed requires the greatest effort; other options can then be assessed with a minimum of additional effort.
- Because its economic assumptions are variable, the model enables a user to maximize the benefits of district heating and cooling. For example, the general inflation rate,[†] as well as escalation rates[†] for capital, fuel, and operating and maintenance costs,[†] can be varied -- and their impacts on the cash flow of a district system can be evaluated.
- The DHSM permits evaluating the effects of district heating and cooling on airborne emissions. District heating and cooling systems can significantly decrease air pollution in a community.

1.1.2 Role of the Technical Support Representative[†]

A technical support representative (TSR) has been assigned to communities where feasibility studies of district heating and cooling systems are being sponsored by the Department of Housing and Urban Development and the Department of Energy. Each community receives feasibility-study assistance from its TSR. If the community decides to use the DHSM, the representative continues, as necessary, to acquaint community planners and other technical staff with its use. The TSR functions as the first point of contact for community planners needing questions answered and also as the communication conduit through which input data are received from a community and output data are transmitted to the community. The development of input data for the initial district heating and cooling option to be assessed will be the most difficult and costly task. Once those input data for the model have been collected, the community and its technical support representative can quickly analyze many other options with minimal difficulty and at very low cost.

1.2 OVERVIEW OF THE MODEL

The district heating strategy model is designed to provide information about the respective costs, fuel use, and emissions to air of alternative systems that may be used by a community for district heating and cooling. The DHSM is actually a collection of four separate modules whose computer operations are integrated to perform the required calculations. The modules and their basic functions are as follows.

1. Demand module, which calculates thermal demands to be met by a district heating and cooling system.

[†]Throughout this report, terms not formally defined in the text are marked with a dagger signifying that they are defined in Appendix A. Because of the report's large number of possibly unfamiliar technical terms, this appendix includes other basic definitions as well.

2. Supply module, which calculates least-cost combination of power plants needing retrofit[†] and boilers required to meet demands.
3. Cost module, which calculates fuel requirement and costs of meeting thermal demand with and without a district heating and cooling system, and performs cash-flow analysis.
4. Emissions module, which calculates total emissions of various airborne pollutants before and after a district system would be employed.

Each module uses data created in the preceding module or modules. Subsets of the total model can therefore be run only if these subsets begin with the demand module and follow the rest of the order listed above.

1.3 DESCRIPTIONS OF THE FOUR MODULES

The principal inputs and outputs of each module are shown in Fig. 1.1. Inputs are described in greater detail in Sec. 2 of this report, outputs in Sec. 3. The inputs and outputs shown in Fig. 1.1 are limited to the major data types required and provided by the program. A brief description of how the input data are used within each module follows.

1.3.1 Demand Module

The principal function of the demand module is to estimate the thermal loads required for the conceptual design of a district heating and cooling system. To calculate estimated transmission[†] and distribution[†] costs, for example, the cost module of a DHSM must "know" the geographical location of community thermal demands. The user provides the model with this geographically detailed information by tying the information to a system of grid squares, each cell having an area of one square kilometer (km²). For every such unit included in the study area, the user must specify the square feet of floor space for each of several building types, e.g., residential low-density,[†] residential high-density,[†] commercial/institutional,[†] and industrial.[†] As a rule, floor-space data in this much detail are not readily available; they can often be estimated, however, from aerial photographs, assessor's files, construction and demolition permit files, and field surveys.

The demand module uses the floor-space estimates to calculate annual and peak-daily thermal demands in each grid square. Peak demands[†] can be displayed by the program in both tabular and map form; annual demands are displayed in tabular form only.

Other input data that a user needs to provide for the demand module are energy-demand factors and the community's fuel mix.[†] Energy-demand factors for each end use in each building type represent the maximum expected thermal load in Btu per square foot of floor space. Fuel-mix values represent the proportion of the total load currently being met by each fuel type for each end use in each building type. Default values[†] for thermal-load factors are built into the computer program. Appendix D lists these default values.

PRINCIPAL INPUTS

- Floor space for each building type within each grid square†
- Annual energy demand factors† for each end use† in each type of building
- Fuel mix† for each end use in each type of building
- Boundaries of proposed service area
- Escalation rates† for fuel, O&M, and capital
- Utility pre-tax rate of return†
- Minimum reserve margin† for the district heating and cooling system
- Information on potential thermal-supply units (e.g., location, fuel, fuel price, efficiency, emissions data)
- Fuel prices for each end use in each type of building
- Efficiencies of end-use equipment
- Fuel characteristics (e.g., heat content, percent sulfur, percent ash)

Note: † signifies that term is defined in Glossary (Appendix A).

PRINCIPAL OUTPUTS

- Summer† peak daily thermal demand for each grid square
- Winter peak daily thermal demand for each grid square
- Annual thermal-energy demand†
- Electricity generating capacity displaced by district heating and cooling due to decreased electrical space conditioning and water heating
- Competing thermal sources ranked and selected on basis of providing thermal capacity needed at least cost
- Fuel use and fuel costs, before and after installation of a district heating and cooling system, for each end use in each type of building
- Capital and O&M costs†
- Cash flow, net benefits,† savings-to-investment ratio,† and payback period† of a district heating and cooling system
- Annual airborne emissions (particulates, SO_x, and NO_x) at central thermal-supply units, before and after district heating and cooling is installed
- Annual airborne emissions from fuel combustion at individual sites in district, for each end use in each type of building -- before and after installation of district heating and cooling

Fig. 1.1 Principal Inputs and Outputs of the District Heating Strategy Model

1.3.2 Supply Module

To meet the loads computed by the demand module, the supply module compares and selects the most appropriate thermal sources. The user decides which grid squares, building types, and end uses specified in the demand module are to be serviced by district heating and cooling. Based on input data related to economic parameters and candidate thermal sources, the program ranks and selects the sources that provide the necessary total thermal capacity at the lowest cost. Sources the model can consider include cogenerating utility plants, thermal-only boilers, and geothermal[†] facilities.*

The supply module ranks competing thermal sources on the basis of the present value of their costs to deliver energy to the boundary of the service area. The computed costs include retrofit of existing generating plants, replacement of electrical capacity (electrical replacement costs[†]) lost because of cogeneration[†] retrofit, plant operation and maintenance (O&M),[†] and transmission-pipe construction and O&M. Transmission-pipe costs computed in the supply module are for the straightline distance between the thermal source and the nearest boundary of the service area. Transmission and distribution costs within the service area itself are computed in the cost module.

1.3.3 Cost Module

To compute total costs for energy used in a district heating and cooling system, the cost module draws primarily from data generated in the demand and supply modules. These costs are compared with those for the same services without a district system. "Before" and "after" fuel costs are expressed in dollars per million Btu of delivered energy. As part of computing energy costs for a district system, the cost module calculates estimated costs of transmission and distribution within the service area and the costs of retrofitting end-use equipment (plant retrofit costs) in customer buildings. Other economic outputs provided by the cost module are a cash-flow analysis, a savings-to-investment ratio[†] of the district heating and cooling system, and the system's discounted payback period.

1.3.4 Emissions Module

The emissions module analyzes the annual effects of a district heating and cooling system on the community's airborne emissions. Included in the analysis is a determination of such emissions before and after changing over to a district system. The emissions examined include the principal combustion-related pollutants: particulates, sulfur oxides, and nitrogen oxides. Annual emissions of these airborne pollutants are based on the types, quantity, and quality of fuel consumed; and also on the type of pollution-control equipment used, if any. Emissions are calculated for each thermal source in a district system, as well as for end-use fuel combustion by consumers.

*If a community currently lacks capacity from candidate supply sources at or below a use-specified maximum cost per million Btu, the supply module assumes a boiler is constructed to meet peak demands.

Input data that need to be provided to the emissions module are the average seasonal-efficiency values for end-use equipment and such fuel characteristics as heat content and pollutant concentration. Default values, listed in Appendix D, are included in the computer program.

1.4 MAJOR DHSM OPTIONS AVAILABLE, BY MODULE

Computer models such as DHSM allow the user to easily assess changes in the results caused by changing assumptions and conditions. Major options are available for each DHSM module, enabling a user to specify different district heating and cooling scenarios and the types of analyses to be performed. A user should be aware of these options in order to obtain the model's full benefits.

1.4.1 General

A district heating and cooling system would normally be put in place over a period of time, in phases. The DHSM can be used to study phased expansion of both the district service area and its thermal-supply capacity. Each major phase requires a separate run of the DHSM computer model. Costs computed by the DHSM may need to be adjusted to ensure that transmission and distribution costs are not overestimated.

1.4.2 Demand Module

Demand data can be altered in a number of respects, as indicated by the following possibilities.

- Geographic boundaries of the district heating and cooling service area can be varied.
- Building types and end uses to be serviced can be varied.
- Scaling factors[†] can be used to adjust original floor-space estimates. Such adjustments may be appropriate if significant construction or demolition is expected before completion of the district system.
- Scaling factors can be used to adjust energy-intensity factors. Adjustments of this sort can be used to analyze the effects of consumer conservation measures, or to calibrate demands calculated by the model should they vary from demands estimated using other data sources.

1.4.3 Supply Module

The supply module is very versatile, allowing the user opportunities to readily change thermal-source locations and characteristics. Several opportunities illustrate this versatility.

- Thermal-reserve[†] requirements can be varied.
- A user can eliminate specified thermal-source candidates from individual runs.

- Thermal-supply units in existing district steam systems can be analyzed in the process of selecting thermal sources for district heating and cooling.
- Five separate types of thermal-supply units can be evaluated and ranked for use in district systems: 1) single-case turbines,[†] 2) multicase turbines,[†] 3) combustion turbines, 4) conventional boilers, and 5) geothermal sources. Existing steam cogenerators are treated by the model as two units, one a single-case turbine and the other a conventional boiler.
- Fuels used by thermal-supply sources can be varied to examine effects (e.g., economic and fuel consumption) of such modifications. Cost of equipment modification for fuel switching are not computed by the model, however.
- A user can determine the cost of replacing electrical generating capacity (replacement capacity[†]) lost due to cogeneration retrofit -- that is, the percentage of lost capacity actually charged to the district heating and cooling system.
- Thermal-supply units[†] at the same station[†] that use the same fuel can be analyzed and ranked as a group or individually.*
- Thermal-supply units are selected until the annual thermal-energy supply meets or exceeds a service area's annual thermal requirements. It is unlikely that the requirements and the supply will match exactly. In the case of an inexact match, operating and maintenance, fuel, and capital costs of the last selected group of identically fueled supply units are decreased to correspond to the percent of the unit's annual thermal-energy production actually used for district heating and cooling.**

*Each user-specified group of units is referred to as a "station fuel group." The advantage of combining several units in the same group is that the units are assumed to share the same transmission line to the service area. The disadvantage of some such groupings, however, is that an efficient, low-cost thermal-supply unit may be dropped from competition if it is included in a group containing several inefficient and expensive thermal sources.

**This approximation may be insufficient in some cases, particularly if only a small percentage of a group of supply units is required for district heating and cooling. Methods of dealing with this problem are as follows.

1. If a station's last selected group of identically fueled supply units comprises several units, the units can be considered as smaller groups or even individually.
2. A service area can be extended or contracted to provide a better match between thermal requirements and available supply.
3. The group of identically fueled units selected last at a station can be removed from consideration and replaced with a boiler of the appropriate capacity.

- A user can specify whether "high-cost" or "low-cost" estimates are to be prepared. These form the upper and lower bounds, respectively, for expected costs. All costs for an individual run must correspond either to high- or low-cost assumptions, exclusively.

1.4.4 Cost Module

Economic and cost parameters that can be altered by a user include:

- Cost-escalation rates for each fuel;
- Startup and completion dates for construction period;
- Expected lifetime of a district heating and cooling system;
- Utility pre-tax[†] rate of return;[†]
- Discount rate;[†]
- General inflation rate;
- Allowance for funds used during construction (AFC rate[†]); and
- Capital-recovery period[†] for the district system.

1.4.5 Emissions Module

The average sulfur and ash content of fuels can be varied.

1.5 ASSUMPTIONS AND LIMITATIONS OF THE DHSM

The major assumptions inherent in a DHSM analysis, as well as their implications and accompanying limitations, should be familiar to a user for two reasons: 1) so that proper input data are provided and 2) so that the model's results are properly interpreted.

1.5.1 General

The DHSM is not an optimization model. That is, the model analyzes user-specified district heating and cooling scenarios but does not itself determine the "best" district-heating market area, construction build-out plan, etc. Community planners are expected to use the model's results for several scenarios so that they can determine the heating and cooling system most desirable for a district.

The medium used to distribute heat to the buildings in a district is hot water, at approximately 250°F. Hot water, rather than steam, would constitute the most economical heat-distribution medium for most district heating applications. A district system is also assumed to require no significant modifications to match the dispatching requirements of electricity-generating stations.

1.5.2 Demand Module

The model assumes that the principal thermal demands of a district heating and cooling system are for space heating and domestic water heating. Promising district heating systems can be subsequently extended to meet cooling demands from large buildings and some low-temperature demands from industrial processes.

1.5.3 Supply Module

An electric utility's generating plants, retrofitted for cogeneration, represent the major potential source of thermal energy within a district heating and cooling system. Where necessary, thermal-only boilers can also be used. With proper modifications, such other thermal sources as solar collectors, and incinerators that recover heat, can also be analyzed. To the model, these other thermal sources are represented as "boilers" with atypical costs for capital, operation and maintenance, and fuel.

The electricity-generating capacity of single-case turbine units is assumed to be permanently decreased as a result of retrofitting them for cogeneration. However, each generating unit is assumed to produce as much electricity both during the winter and annually as it did normally before retrofit for cogeneration operation.

Groups of identically fueled thermal-supply units at a station are ranked on the basis of average annual (discounted) cost per million Btu thermal energy delivered to the boundary of the service area. Such fuel groups are selected until the total annual thermal-energy production meets or exceeds the annual thermal-energy requirements of the service area. Once this condition is met, the total thermal capacity of all station fuel groups is compared with total peak demands -- and if additional capacity is required, existing thermal-only boilers are selected or a new boiler of sufficient capacity is assumed to be constructed.

Thermal-supply units that burn different fuels but are being considered for use at the same station cannot be combined in the same "station fuel group." Costs might therefore be exaggerated, since each station fuel group is assumed to have its own thermal transmission pipe to the service area.

The model does not currently have the ability to analyze thermal-storage facilities for a district heating and cooling system.

Operating and maintenance costs and plant-retrofit costs are assumed to be proportional to the thermal capacity of a supply unit. Also, the costs of replacing electricity-generating capacity lost due to cogeneration retrofit are based on the costs of installing new combustion turbines of an appropriate size to replace the lost capacity. The user can decide, based on local circumstances,* the fraction of these replacement costs that should actually be charged to the district heating and cooling system.

*For example, if the electric utility has surplus capacity during the winter months (i.e., at the time of peak demands on the district heating and cooling system), none or only a small portion of the charge may be applicable.

1.5.4 Cost Module

All costs are estimated using factors derived from 1980 costs. These should be adjusted with escalation rates for capital and operating and maintenance costs. Individual components of O&M or capital costs cannot be adjusted separately.

The investment costs of a district heating and cooling system can include capitalized interest during construction. All cash flow begins with the first year of system operation. Tax effects and insurance are not included in capital carrying charges.

1.5.5 Emissions Module

All emission impacts are computed on an annual basis. (However, current Environmental Protection Agency regulations include 3-h and 24-h standards; these can occasionally be violated even though annual emissions remain at acceptable levels.)

All specified thermal sources in a district system are treated as point sources.[†] All other pollutant sources in the district are aggregated by grid square and are treated as area sources.[†]

The program considers whether individual point sources are subject to the federal government's New Source Performance Standards. For those that are, the applicable pollution-control equipment is assumed.

2 DESCRIPTION OF INPUT DATA

The district heating strategy model requires a precisely formatted input. Community planners desiring to use the model must complete a series of data forms. The forms describe community characteristics in such a way that DHSM calculations can be performed. At a minimum, planners must define the spatial distribution of those community land uses that may be served by a district heating and cooling system. Such a defining process identifies economic, cost, and fuel characteristics associated with each potential service area. In many instances, the specific data required for a community may be obtainable only with considerable effort. The DHSM stores many default values, or rules of thumb for adjusting a specific program to a community's climate. Default values are listed in Appendix D.

Because a Phase 1 study of district heating is intended only as an estimate of system feasibility, some inaccuracy of input data may be acceptable, especially if expensive data-gathering would be required to achieve highly precise data. The best available data are sufficient in the early phases of an assessment study of district heating and cooling. Estimates can be refined in later work, when sufficient known potential for a district system warrants more detailed and costlier investigation. The main groups of data needed by the DHSM, and their likely sources, are summarized in Table 2.1.

2.1 GENERAL STRUCTURE OF INPUT DATA

Each DHSM module -- demand, supply, cost, and emissions -- requires input data from the community. The four data "files" are:

- Demand data file (DDF),
- Supply data file (SDF),
- Cost data file (CDF), and
- Emissions data file (EDF).

Blank worksheets used to assemble data for these files are shown in Appendix E. Samples of completed worksheets, with detailed explanations, are provided in Appendix F. The forms are marked in the upper right hand corner with D, S, C, or E, respectively, to distinguish them at a glance. Nine different kinds of forms are used in the four data files.

2.2 DEMAND DATA FILE

The demand data file consists of three parts:

1. A community map with a grid system[†] made up of 1-km² cells superimposed on it (see Appendix G);
2. A copy of the "Community Demand Data Sheet;" and
3. As many copies of the "Grid-Square Demand Data Sheet" as there are grid squares on the map, up to a maximum of 450. For grid squares without significant thermal demand

Table 2.1 DHSM Input-Data Groups and Their Likely Sources

Data Group/Selected Examples	Likely Source or Sources
Community physical characteristics <ul style="list-style-type: none"> • area map • area grid system • square footage by structure type, each grid square • fuel efficiencies[†] of end-use[†] equipment, by fuel and building type 	Planning departments, zoning departments, assessor's files, regional planning agencies, housing or industrial development agencies
Community energy-demand characteristics <ul style="list-style-type: none"> • heat and fuel demands by building type and end use 	Energy office, utilities, planning departments
Grid-square energy-demand characteristics <ul style="list-style-type: none"> • fuel mix[†] by building type and end use 	Energy office, utilities, planning Departments
Community financial assumptions (for scenarios [†]) <ul style="list-style-type: none"> • general inflation rate[†] for x years in future • price-escalation rates for individual fuels and other recurring system needs 	Utilities, banks, and other financial institutions, public utilities commission
Utility financial data	Utilities, public utilities commission
Air-pollution information	Utilities, air pollution control officials
Electricity-generating plant data <ul style="list-style-type: none"> • locations of plants • data on individual generating units: seasonal capacity factors, fuel costs, peak capacities, airborne emissions, fuel pollutant contents 	Utility engineers, air pollution control officials
Scenario Assumptions <ul style="list-style-type: none"> • cost escalation rates, to be applied by grid square 	Decision of assessment work group

-- e.g, undeveloped open space and agricultural areas --
no data sheets are necessary because the squares need not
be serviced by a district system.

Most of the information in the file describes the end-use demands for energy in the community and the mix of land uses in the grid squares. Creation of this file requires detailed local knowledge and judgment, both of which are only available within the community itself.

2.3 SUPPLY DATA FILE

The supply data file provides the DHSM with the data required to determine a minimum-cost system for supplying heat to selected buildings in a district. For each model run, the user specifies a service area, a group of thermal-supply candidates, and a financial scenario.[†] The user provides information about existing electric power plants and possible future units. Any existing district steam systems are also described here. The user-specified service-area scenario consists of a geographic area with good district heating potential -- i.e., a subset of the grid squares and a subset of the building/end-use sectors within that area.

The four data sheets (five forms) used for placing input in the supply data file are:

- "Scenario Definition Sheet,"
- "Boundary Identification Sheet" (optional),
- "Station Data Sheet," and
- "Unit Definition Data Sheet" (two pages).

For clarity, these may be considered as two packages. The first package describes the overall scenario and the boundary of the area to be serviced if it is smaller than the entire community. The second package describes all existing and any planned electric power plants and equipment. For each station, an "Electric Generating Station Data Sheet" must be completed along with a set of "Unit Definition Data Sheets" for each unit at the station.

2.4 COST DATA FILE

This data file is simple compared to the previous ones. The "Fuel Cost Data Sheet" requires that each of five major fuel types be specified in terms of its cost in dollars per million Btu for each of the six possible end uses.

2.5 EMISSIONS DATA FILE

The "Emissions Input Data Sheet" requires a list of typical heating equipment efficiencies for each fuel type in each end-use sector. This table may be left blank if the user chooses to use the model's default values (see Appendix D). Various data relating to oil and coal characteristics and use sector are necessary to estimate emissions. The heat content of input fuels must also be specified.

3 DESCRIPTION OF OUTPUT DATA

3.1 INTRODUCTION

The DHSM provides two types of output data:

1. Data that describe the inputs by simply printing out items the computer programmer put into the machine, and
2. Data that represent calculations performed by the computer. A separate output exists for each scenario being studied.

Type 1 outputs, or "data echoes," are useful to community planners because they show the input used to describe the community characteristics and assumptions made for the scenario being run. Data echoes provide the information needed to check the validity of the input data.

Type 2 outputs, or "calculation results," present the following items.

- Calculated heat demands for each grid square in the community.
- Summary of heat demands for the entire community.
- Map of thermal densities, depicting quantity of peak heat demand for each of the community's grid squares.
- Total heat demands for the grid squares included in the scenario; the stations that should be used to supply heat, in rank order based on cost of supply; the new boiler capacity that may be needed; and the stations that are less desirable to convert to district heating because of probable high costs.
- Fuel use and airborne emissions at each community station and in each grid square, before and after implementation of the scenario's district heating systems; plus a summary of fuel use and emissions for the entire community.
- Simulated capital and annual costs of each scenario's district heating system, the changes in fuel use caused by conversion to district heating, and financial ratios useful in determining the value of district heating as an investment opportunity.

In testing the DHSM, Argonne National Laboratory made several computer runs using data from real communities. To illustrate the output format, a portion of the detailed outputs from one scenario in Piqua, Ohio, is presented in Appendix H. Explanatory comments accompany each important category of output in the Piqua example.

3.2 OUTPUTS AND HOW THEY MIGHT BE REVIEWED

All portions of DHSM output should be of interest to all members of an assessment work group (AWG). Considering the large volume of output data, however, it may be desirable to divide the task of reviewing them among the AWG members. One possible division of labor is shown in Table 3.1.

With tasks apportioned in this manner, the engineering staff could use the demand and supply outputs to verify its own figures or to discover where scaling factors and other data inputs to the model might be made more realistic. Utility people interested in assessing demands in their service areas should also verify that the data match local experience and projections.

Utility representatives should probably also check the data on stations recommended for cogeneration conversion to verify (1) whether deratings are critical to the electricity supply system's performance and (2) whether costs of replacing lost capacity agree with local experience.

Portions of the supply and cost modules contain data relating to the financial needs and viability of the proposed system. The AWG bankers, municipal finance people, and utility financing specialists can examine the figures to determine how the needed capital can be raised and whether the return on investment is high enough to attract necessary private and public financing.

Prospective consumers of district energy service should probably examine the parts of the cost module that show alternate fuel prices and decide if the costs for district heating are enough lower than current (and projected) fuel prices to justify their continuing interest.

AWG members involved in air-pollution control should review the emissions output data and determine whether the air quality effects of the district heating system are acceptable. The emissions output per grid square can help in locating potential "hot spots," where high emission concentrations may create problems.

Each member of an assessment work group should have a reasonably good grasp of each scenario being considered. A scenario provides the basis for computer outputs; it can be changed by replacing its assumptions with ones judged to reflect community conditions more realistically.

Table 3.1 A Possible Division of Output-Review Tasks for the Several Members of a Community's DHSM Assessment Work Group

AWG Member (Illustrative Representation)	Likely Focus of Interest	Appropriate Task or Tasks
Project manager	Entire output	Gain overall conceptual familiarity with output to improve delegation of review responsibilities and to understand the whole project
Utility representative (especially electric utility)	Demand data	Compare against the utility's own figures, to improve scenario assumptions
	Supply data	Check feasibility of proposed power plant conversions, especially to determine if capacity losses can be accepted and if costs for capacity replacement match local experience; verify fuel-cost assumptions
	Cost data	Compare capital and ongoing costs against those of similar local ventures
Elected official	Demand data	Check scenario against development patterns for correctness; determine political feasibility of replacing present system with district heating and cooling system
	Cost- of- supply data	Check available public financing strategies for a project of this magnitude; discuss with public works departments whether piping-cost estimates match local experience; determine availability of outside funding; check local and state regulatory structure for possible barriers to the project
Banker or other finance specialist	Cost and supply data	Analyze reasonableness of returns on investment to determine if capital, either private or public, can be attracted; check interest of businesses to be supplied and availability of money for them to convert to district heating; check inflation and interest rates
Environmental specialist	Emissions data	Check for hot spots and sensitive areas nearly or actually violating standards; consider whether additional emissions may be offset by district reductions in use of onsite [†] fuel
Consumer representative	Cost and demand data	Compare costs of individual and district heating systems; check if demand calculations appear correct, given local experience; verify financial assumptions

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APPENDIX A

Glossary of DHSM Terms

absorption cooling space cooling (air conditioning) that uses heat to drive a special refrigeration machine, producing cold water for cooling

adjusted efficiency the fuel efficiency of heating equipment for various building types and fuels

AFC rate (allowance for funds used during construction) the percentage rate charged for borrowing money during the period of constructing a district heating and cooling system

annual costs all costs incurred during the course of a corporation's fiscal year

area source (of air pollution) an aggregation of small, ill defined pollution sources distributed throughout an area (see also *point source*)

arithmetic average the sum of all values in a group of numbers divided by the number of elements in the group

avoided costs in the district heating and cooling model, fuel and hardware costs not incurred because a district heating and cooling system has been installed (but which would otherwise have been incurred)

base fuel fuel required at a station under normal operation, before retrofit for district heating

baseload boiler a hot water boiler that services continuous thermal demands

building end-use sector a certain energy requirement of a certain type of building; for example, one building end-use sector is low-density residential space heating; another is industrial space heating

building retrofit costs costs incurred in changing individual heating and cooling equipment in a building to the kind needed by a district heating and cooling system

capacity credit the amount of electrical generating capacity (of peaking equipment) rendered unnecessary when energy demands formerly supplied by electricity are supplied by a district heating and cooling system

capacity factor (CF) the ratio of the average power load of an electric power plant to its rated capacity; $CF = \text{MWh/yr generated} / \text{the product of the generating plant's MW rating and 8760 h}$

capacity fraction, district steam-system scenario the amount of peak thermal power, or capacity, of an existing district heating system that services grid squares in a scenario (see also *peak thermal capacity, grid square, scenario*)

capacity loss (see *derating*)

capital costs money spent to purchase and install the district plant and equipment

capitalization of interest the interest costs added, during construction, to a project's capital costs

capital-recovery period the time period over which capital costs of a district system are amortized, or annualized

cogeneration the simultaneous production of electricity and useful heat

combustion turbine (see *turbine*)

commercial/institutional a range of service and other nonindustrial building types; see Appendix I for functional breakdown used by the DHSM

cooling degree-days (see *degree-day*)

cost ceiling in the model, the cost per million Btu above which a unit will not be converted to district heating and cooling

cumulative net benefits lifetime benefits minus costs

current dollars today's dollars; the DHSM, having been written in 1980, assumes a "current" dollar to be one as it was valued in 1980; inflation since that time may be taken into account by the user

data file in the model, a package of information, the items of which may be transferred from one part of the model to another (see also *record*)

decimal fraction a fractional part of the number one; for example, 25% may be expressed as the decimal fraction 0.25

default an estimate used by a computer model if no other estimate is provided by the DHSM user

degree-day the product of one day and the number of degrees Fahrenheit below 65°F of the mean temperature on that day; thus, on a day when the mean temperature is 40°F, there are 25 degree-days; the degree-day unit is used to eliminate the weather variable in determining heating-load efficiency and in predicting fuel consumption

demand factor the energy demands for a type of building expressed in thousands of British thermal units per square foot (Btu/ft²); the factor is for service demand, or the quantity of energy actually needed, rather than for fuel demand -- fuel demand being higher than service demand because of equipment inefficiencies

derating the loss in peak electrical generating power (capacity) caused by conversion of electric generating equipment to cogeneration

design temperature for cooling at a given location, design temperature is the outdoor air temperature equaled or exceeded only 1% of the time; for heating, the design temperature is the temperature below which outdoor air drops only 2.5% of the time

discount rate interest rate used to reflect the time value of money

discounted payback period the time period required for cumulative project savings to equal initial investment in the project; future savings are discounted at a specified rate during this period, whereas savings or cash flows are not discounted during a single payback period

dispatching (of power plants) the schedule by which a group of power plants operates -- the scheduling is mainly concerned with the quantity of energy to be delivered and the timing of delivery, both factors being based on functional and economic considerations

distillate oil light oil such as diesel fuel and home heating oil, classed by a number of 1, 2, 3, or 4 (see also *residual oil*)

distribution costs capital costs incurred in constructing thermal pipes from the transmission or loop piping to individual buildings

diversity (in demand) in computer modeling of power and energy demands, the models often assume all similar structures have the same hourly demand pattern; however, because experience has shown that not all occupants behave identically, the DHSM multiplies a diversity factor by the calculated demand peaks to account for such individual differences; the diversity factor lowers calculations for power and energy

electrical credits the annual amount of electricity previously used (for space heating and cooling and water heating) that is no longer required after district heating and cooling services are substituted for it

electricity-replacement costs capital costs incurred to build new electrical generating units to replace the capacity lost by derating of existing power plants

end use the purpose for which energy is consumed by consumers; "end user" refers to the consumer who operates energy-consuming equipment

energy fraction, district steam system scenario amount of the annual thermal output of an existing district steam system that services grid squares in a scenario

escalation rate annual percentage increase in the price of a product (see also *real escalation rate* and *general inflation rate*)

final demand (also *final end-use demand*) requirements for energy services within a building; final demand in the model consists of an actual Btu value based on space-heating, space-cooling, or process-heat needs -- unlike fuel demand (the Btu value of fuel input to a furnace, for example), final demand is the amount of heat needed from the furnace to maintain residential comfort or industrial process requirements

fixed charge rate the rate used to convert the present value of all annual capital charges to a stream of uniform annual charges; see Appendix D for more detailed explanation

fraction electrical credits electrical credits assigned to each cogenerating station in a district system; the fraction is computed by dividing total electrical credits by the total annual amount of electricity generated at all stations assumed to be retrofitted for cogeneration (see also *electrical credits*)

fuel efficiency ratio of the heat being consumed in a system to provide service and the heat content of the fuel used

fuel mix the division of fuels used within a building type, presented as the fraction of floor space of each building type using each fuel (for the scaling of a fuel mix, see *scaling factor*)

general inflation rate general annual increase in the price of goods and services; the annual change in the price deflator of the gross national product and the annual change in the consumer price index are two widely accepted measures of the general inflation rate

geothermal pertaining to heat within the earth

grid square a single 1-km² cell in a community grid system (see *grid system*)

grid system the matrix of grid squares into which a community is spatially divided for purposes of locating such features as power plants, calculating spatial distribution of energy demands, and estimating spatial distribution of airborne emissions (see also *grid square*)

heating degree-day (see *degree-day*)

heat rate (see *thermal heat rate*)

inflation rate (see *general inflation rate*)

industrial buildings used for construction or manufacturing purposes; see Appendix I for functional breakdown used by the DIISM

in-service year the first operating year of a district heating and cooling system

large building (in terms of cooling demand) a high-rise office, residential, or industrial building with a cooling demand of 100 ton or more

lifetime costs in the model, the total costs of all fuels, operation and maintenance, and capital incurred after the first in-service year of a district heating and cooling system

mean coincident wet-bulb temperature the average temperature recorded on a wet-bulb thermometer at the same time as the design temperature is recorded (see also *design temperature*)

multicase steam turbine (see *turbine*)

national energy-demand region one of four areas in a gross division of the 48 contiguous American states (see map, Fig. D.1)

New Source Performance Standards, status relative to the relationship of a source of airborne emissions to the federal air-quality regulations in effect at the time the emitting facility is constructed

nonwinter final demand requirements for heat during all spring, summer, and fall hours -- including industrial process heat and heat needed for the absorption cooling of large building (see also *absorption cooling, large building, and final demand*)

onsite fuel fuels consumed at the point where services are needed; for example, natural gas burned in a homeowner's furnace constitutes an on-site fuel, but natural gas burned in an electrical generating plant to provide electricity to the homeowner does not

onsite fuel prices the price of onsite fuel delivered to a consumer (see also *onsite fuel*)

operation and maintenance costs annually recurring costs of labor and repair to keep mechanical equipment working and to provide for proper administration

peak demand (or instantaneous peak demand) the maximum quantity of energy (electricity or heat) required at any one time

peak thermal capacity total maximum heat supply available within a district heating system

Piqua a small city in Ohio (just north of Dayton); used as an example in the worksheets and sample computer outputs in this report

plant retrofit costs total capital costs incurred in retrofitting an electrical generating plant to serve a district heating network

point source (of pollution) a pollution source that is large, well defined, and stationary (see also *area source*)

present value value of a future amount of money after it is discounted to "the present" at a specified discount rate

present-worth dollars same as *present value* in the DHSM

pre-tax rate of return rate of return before taxes (see also *rate of return*)

process heat thermal requirements for manufacturing goods; in the model, includes only those demands that may be met by hot water (250°F) or steam (up to 400 psi)

- rate of return* an input to the model reflecting the cost of capital to construct a district heating and cooling system; for investor-owned utilities, this is the maximum allowable pre-tax rate of return permitted by a regulatory agency; for municipal utilities, it is the cost of new debt (see also *pre-tax rate of return*)
- real discount rate (simplified)* the positive or negative difference between a discount rate and an actual inflation rate
- real escalation rate* annual percentage of increase in the price of a product, computed by using constant dollars; the real escalation rate does not consider the effects of inflation
- record* one logical grouping of data inputs placed in the DHSM computer model (see also *data file*)
- replacement capacity (power)* the amount of electrical generating capacity that must be built to compensate for the derating caused by conversion of electrical generating plants to district heating and cooling
- reserve margin* in the model, the quantity of electric or thermal power not being used but available for use during peak-demand conditions
- residential high density* residential buildings characterized by 20 or more dwelling units per structure
- residential low density* residential buildings characterized by 19 or fewer dwelling units per structure
- residual oil* heavy or thick oil, classed by a number of 5 or 6 (see also *distillate oil*)
- retrofit* in the model, modification of an existing electrical generating plant or related individual piece of equipment -- for the purpose of changing the previous application or improving the previous performance of that plant or piece of equipment
- savings-to-investment ratio* in the DHSM, the relationship of total lifetime avoided fuel expenditures to capital costs of the district heating and cooling system that made the savings possible (see also *avoided costs*, *lifetime costs*, *capital costs*)
- scaling factor* a multiplier that may be put into the model to change a default value, for the purpose of matching local conditions better or of altering data in a scenario
- scenario* a hypothetical situation created to test assumptions; in the model, it includes the financial, supply, and service-area assumptions determined by a user
- schedule NSPS (New Source Performance Standards)* for an emissions source, a document describing the relationship of source emissions to federal air-quality standards

single-case steam turbine (see *turbine*)

space heating delivery of heat to the interior of a building to raise the inside temperature of the spatial volume

station an electrical or thermal generating plant

summer all hours not included in the total heating hours indicated on the "community demand data sheet"

technical support representative (TSR) staff person at a national laboratory (Argonne or Oak Ridge) who directly provides communities with technical help in applying national district heating and cooling program

thermal density quantity of heat demanded by or supplied to a given geographic area (expressed in Btu/h · km² or in MW/km²).

thermal heat rate quantity of heat that may be extracted from a unit over a specified time period

thermal peaking rate quantity of heat that may be extracted from a unit at peak load

thermal peaker a boiler designed only to serve peak heat demands

thermal reserve quantity of heat stored -- or that can be generated using existing equipment -- above what is normally needed at peak demand or over a period of time

ton (of cooling machine) heat-removal power of 12,000 Btu/h or 3.52 kW

transmission costs in the hot-water transmission loop assumed by the model, the costs of pipe -- sized for maximum thermal output of a station and laid in a straight line from the station to a service-area boundary -- constitute the transmission costs

turbine in this report, a machine that takes in combustion gases or steam in order to create mechanical power for an electric generator; principal types of turbines include:

- *single-case steam*, where steam is passed through the turbine once and then expended;
- *multicase steam*, where steam is passed through a turbine, expended from it into another turbine, and possibly from the second turbine expended for use in others until the steam loses so much heat that it can no longer economically run a new turbine; and
- *combustion*, which uses natural gas, oil, or other fuel to produce combustion gases that turn the turbine

unit one turbine-generator set in a station or one boiler in a heating plant

unit capacity (power) the peak power (electric and/or heat) available from a unit

unit code name in the model, a number and letter combination that identifies a unit

unit heat rate the peak amount of heat that can be produced by a unit

unity equal to 1.00

utility AFC rate (see *AFC rate*)

variable costs operating costs that may be changed from time to time, as opposed to fixed costs that do not change; consist primarily of costs for fuel, operations, and maintenance

year of cash-flow turnaround the first calendar year in which the dollars earned by district heating and cooling system are sufficient to cover all expenses

APPENDIX B

DHSM ABBREVIATIONS
AND COMPUTER ACRONYMS*

AFC	allowance for funds used during construction
ANL	Argonne National Laboratory
AREA	area source of airborne emissions
ASHE	annual space heating energy demand for each building type in each grid square of a community
AWG	assessment work group
B. Btu**	Btu in billions (10^9 Btu)
Btu or BTU**	British thermal unit
CAP	capacity
CDD	cooling degree-days (annual average)
CDF	cost data file
CDFA	input form title (cost data file - Record A)
CDMQC	climatological dispersion model, version QC
CF or cu. ft.	cubic foot or feet (ft^3)
CHDD	community heating degree-days (annual average)
COMM.	commercial
COP	coefficient of performance
CURR \$MIL	current dollars in millions ($\$10^6$)
DDF	demand data file
DDFA	input form title (demand data file - record A)
DDFAM1	input form title (demand data file - record A, map 1)
DDFAM2	input form title (demand data file - record A, map 2)
DDFBC	input form title (demand data file - records B and C)
deg. F or DEG.F	degree Fahrenheit ($^{\circ}\text{F}$)
DH	district heating

*Some of these depart from standard usage of the modern metric system. They have been adopted either for computer purposes or to conform to standard architectural usage.

**The interrelationship between various energy-value multiples used in the DHSM are shown in a table at the end of this appendix.

DH/C	district heating and cooling
DHCS	district heating and cooling system
D.H.S. or DHS	district heating system
DHSM	district heating strategy model
DIST or DISTIL	distillate oil
DSS	district steam system
e	as a subscript, electrical
E	exponent of the tenth power
EDF	emissions data file
EDFA	input form title (emissions data file - record A)
EDFB	input form title (emissions data file - record B)
ELEC.	electricity or electric
EN DEL.	energy delivered
ENER. CR.	energy credit
ESRG	Energy Systems Research Group
F	false or Fahrenheit
FAR	floor area ratio
FS	floor space
FT	foot
FT ²	square foot or feet (ft ²)
gal or GAL	gallon
g/m ³	grams per cubic meter
GWH**	gigawatt hours (10 ⁹ Wh)
HDD	heating degree-day
h.w.	hot water
Ind.	industrial
Inst.	institutional

k	thousand (10^3)
K	a computer term meaning 1024 bytes of memory space
kgal	thousand gallons
km	kilometer
kWh**	kilowatt-hour
MBtu**	Btu in thousands (10^3 Btu)
mil	million
MISC	miscellaneous
MMBtu**	Btu in millions (10^6 Btu)
MIL. CU. FT.	million cubic feet (10^6 ft ³)
MW**	megawatt (10^6 , or million, watts)
NEDS	National Emissions Data System
NEWBLBLR	new baseload boiler
NO _x	nitrogen oxides
N.P.W.	net present worth
NSPS	New Source Performance Standards
NUCL	nuclear
O&M	operation and maintenance
PART.	particulate matter
P.W.	present worth
Res.	residential
RESI	residual oil
RETRO	retrofit
RHDD	regional heating degree-day (annual average) -- model uses the following RHDD values, by U.S. region: Northeast, 5400; North Central, 6200; South, 2800; West, 3800
SDF	supply data file
SDFA	input form title (supply data file - record A)
SDFA.A1	input form title (supply data file - record A, answer A1)
SDFB	input form title (supply data file - record B)
SDFCD	input form title (supply data file - records C and D)

SDFCD.C1	input form title (supply data file - records C and D, Answer C1)
SDFE	input form title (supply data file - record E)
SDFFG	input form title (supply data file - records F and G)
S.F.	square foot or feet (ft ²)
SH&HW	space heating and hot water
SHDF	space heating demand factor
SMSA	standard metropolitan statistical area
SO _x	sulfur oxides
SQFT	square foot or feet (ft ²)
SUMR	summer
T	winter outdoor design temperature
T	true
t	as a subscript, thermal
TRBTU or TBtu**	Btu in trillions (10 ¹² Btu)
THERMAL EN. DEL.	thermal energy delivered
TRANSM.	transmission
TSR	technical support representative
USCS	United States Geological Survey
W/D.H.	with district heating
WNTR	winter
x	(1) any variable or (2) the horizontal axis in a coordinate system
y	(1) any variable or (2) the vertical axis in a coordinate system
YR or Y	year
\$/MMBtu**	dollars per million Btu (\$10 ⁶ Btu)
1980 P.W.\$	1980 "present-worth" dollars

Summary of DHSM Energy-Value Multiples

Number of Units	System of Representation	
	Btu	Watt
1,000 (10^3)	MBtu	kW
1,000,000 (10^6)	MMBtu	MW
1,000,000,000 (10^9)	B.Btu	GW
1,000,000,000,000 (10^{12})	TRBtu (or TBtu)	(none used)

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APPENDIX C

COMMON CONVERSIONS BETWEEN ENGLISH
AND METRIC MEASURING UNITS, AND
HEAT-CONTENT VALUES FOR EIGHT FUELS

THERMAL-POWER CONVERSIONS

- thermal power in British thermal units (Btu/h) to thermal power in megawatts (MWt): multiply Btu value $\cdot 0.2931 \cdot 10^{-6}$
- MWt to Btu: multiply MWt value by $3.414 \cdot 10^6$
- 1 MMBtu/h (or 10^6 Btu/h) = 292.9 kW

TEMPERATURE CONVERSIONS

- Fahrenheit temperature in $^{\circ}\text{F}$ to Celsius temperature in $^{\circ}\text{C}$: subtract 32 from $^{\circ}\text{F}$ value, then multiply by $5/9$
- $^{\circ}\text{C}$ to $^{\circ}\text{F}$: multiply $^{\circ}\text{C}$ value by $9/5$, then add 32
- Celsius temperature in $^{\circ}\text{C}$ to kelvin temperature in K: add 273.16 to $^{\circ}\text{C}$ value
- K to $^{\circ}\text{C}$: subtract 273.16 from K value

LENGTH CONVERSIONS

- 1 foot (ft) = 0.3048 meter (m)
- 1 m = 3.281 ft
- 1 mile (mi) = 1.609 kilometers (km)
- 1 km = 0.6215 mi

AREA CONVERSIONS

- 1 square mile (mi^2) = 2.590 square kilometers (km^2)
- 1 km^2 = 0.3861 mi^2
- 1 acre = 0.004046 km^2
- 1 km^2 = 247.1 acres

HEAT-CONTENT VALUES FOR EIGHT FUELS

● Natural gas	-	1,016 Btu/ft ³ or 100,000 Btu/therm
● Distillate oil†	-	138,690 Btu/gal
● Residual oil†	-	149,690 Btu/gal
● Anthracite coal	-	25.2 MMBtu/ton
● Electricity	-	3,412 Btu/kWh
● Steam	-	1,000 Btu/lb
● 200°F hot water	-	1 Btu/lb per degree of temperature drop
● Average refuse	-	4,500 to 5,000 Btu/lb

APPENDIX D

DHSM DEFAULT DATA, ECONOMIC-ANALYSIS TECHNIQUES,
AND PIPING-COST EQUATIONS

D.1 DEFAULT DATA

Unless modified by the user, the data listed in this appendix are processed by the DHSM in its calculations. They are listed here to familiarize community planners with the demand and cost assumptions, or default values, programmed into the computer model in lieu of more community-specific data -- and also, where appropriate, to encourage replacement of these listed default values.

D.1.1 Annual Energy-Demand Factors

The formula used within the demand module to calculate annual energy demands is:

$$ASHE = SHDF \cdot FS \cdot \frac{CHDD}{RHDD}$$

where:

- ASHE = annual space-heating energy demand for each building type in each grid square,
- SHDF = space-heating demand factor,
- FS = total floor space for each building type in each grid,
- CHDD = annual average of community heating degree-days, and
- RHDD = annual average of regional heating degree-days -- see p. 29 of this report for RHDD values used in model.

Default values for space-heating demands are shown in Table D.1. The user can replace these values either for individual grid squares or for the entire city. The table also lists default values for water-heating factors. Water-heating demands for each building type in each grid square are computed by multiplying the total floor space of the building type in the grid square by the appropriate demand value.

Peak daily space-heating demands are computed by multiplying the annual space-heating demands by $(65-T)/CHDD$, where T is the winter outdoor design temperature in °F. Peak daily water-heating demands are computed by dividing the annual water-heating thermal demands by 365.

D.1.2 Fuel-Efficiency Data

The assumed fuel efficiencies for space heating, space cooling, water heating, and heat for industrial processes are shown in Table D.3. Adjustments to these factors can be made in the input to the emissions module.

Fig. D.1 National Energy-Demand Regions

D.1.3 Cost Factors

Table D.4 lists electricity-replacement costs,[†] and Table D.5 lists the low and high factors used in the district heating strategy model to estimate capital and operating and maintenance costs. Whether the low or the high factors are used is decided by the program user.

The DHSM does not currently have the capability of processing cost factors that may have been adjusted for an individual community. However, because all cost factors are expressed in 1980 dollars -- and because the user must therefore specify escalation-rate[†] inputs to the program for capital, O&M, and fuel costs -- there is a way of indirectly compensating for cost factors that need adjustment. If the DHSM user knows that certain DHSM cost factors are not appropriate to the specific district heating and cooling system under consideration, escalation rates can be used to increase or decrease total capital or total O&M costs to reflect these differences. The ANL staff will make appropriate adjustments in the escalation rates to correspond to other district heating and cooling cost estimates community planners may wish to use.

D.2 INTRODUCTION TO DHSM GENERAL COST-ANALYSIS TECHNIQUES

The economic analysis performed by DHSM is based on estimating a chronological sequence of dollar-value benefits -- in terms of energy saved, avoided costs[†], and district heating and cooling costs (construction, operation, and maintenance), generated over the life of a proposed system. Each

Table D.1 Default Values Used in the DHSM to Calculate Annual Energy Demands -- by Fuel -- for Space and Water Heating

U.S. Region ^a and Building Type	Annual Space Heating (10^3 Btu/ft ²)					Annual Water Heating (10^6 Btu/ft ²)
	Gas	Oil	Coal	Elec- tricity	District Steam	All Fuels
<u>Northeast</u>						
Res. low density	61	81	70	30	63	14
Res. high density	48	64	69	19	63	14
Com./inst.	71	66	75	24	63	3.6
Industrial	49	45	51	16	63	2
<u>North Central</u>						
Res. low density	79	76	78	41	73	14
Res. high density	45	45	45	22	73	14
Com./inst.	66	53	65	19	73	3.6
Industrial	46	37	45	13	73	2
<u>South</u>						
Res. low density	27	49	36	19	32	14
Res. high density	18	32	24	11	32	14
Com./inst.	45	49	47	15	32	3.6
Industrial	27	24	28	11	32	2
<u>West</u>						
Res. low density	32	59	45	27	40	14
Res. high density	24	39	29	16	40	14
Com./inst.	51	46	53	17	40	3.6
Industrial	33	30	34	13	40	2

^aNational energy-demand regions are shown in Fig. D.1

Table D.2 DHSM Default Values for Cooling Large Buildings^a

Region ^b	Annual Cooling Default Values, All Fuels (10^3 Btu/ft ²)
Northeast	33
North Central	36
South	87
West	57

^aExclusive of equipment inefficiencies.

^bNational energy-demand regions shown in Fig. D.1.

Table D.3 Mean Annual Fuel Efficiencies[†] by Building Type and End Use of Energy

Building Type	End Use	Fuel				
		Gas	Oil	Coal	Elec- tricity ^a	District Steam ^b
Res. low density	Space and water heating	0.6	0.5	0.5	0.3	0.64
Res. high density	Space and water heating	0.6	0.5	0.5	0.3	0.64
Com./inst.	Space and water heating	0.6	0.5	0.5	0.3	0.64
Industrial	Space and water heating	0.6	0.5	0.5	0.3	0.64
Large building	Cooling	-	-	-	0.62	0.43
Industrial	Process heat	0.6	0.5	0.5	0.3	0.64

^aAssumes 33% generation efficiency and 90% transmission/distribution efficiency. For cooling, a value of 2.1 is assumed for the coefficient of performance.

^bAssumes 78% thermal generation efficiency and 82% transmission/distribution efficiency. For cooling, a value 0.67 is assumed for the absorption chiller's coefficient of performance.

Table D.4 Costs of Retrofit[†] and Electricity Replacement by Type of Generating Unit

Unit Type	Retrofit Costs (\$/kW)		Replacement Costs (\$/kW)	
	Low	High	Low	High
Single-case steam turbine	41.85	83.70	314	628
Multicase steam turbine	20.95	41.90	314	628
Combustion turbine	13.20	26.40	314	628
Boiler	4.50	9.00	N/A	N/A

Table D.5 Default Factors Used in the DHSM to Calculate
Capital and O&M Costs of System Components

System Component	Cost Factor	
	Low	High
• Boiler (\$/kW _t)		
All fuels but coal	30	60
Coal only	90	135
• Boiler O&M (\$/kW _t)		
All fuels but coal	1.5	3
Coal only	3	6
• Additional O&M when turbine used for cogeneration (\$/kW _e ^a)		
Fuel:		
Nuclear	2.27	4.54
Coal	2.27	4.54
Residual oil	1.54	3.08
Distillate oil	2.5	5
Gas	2.5	5
Other	2	2
• Retrofit for existing in-building equipment		
Res. low density (\$/ft ² floor space)	0.61	0.88
Res. high density (\$/ft ² floor space)	0.32	0.42
Com./inst. (\$/ft ² floor space)	0.54	1
Ind. (SH&HW) (annual \$/10 ⁶ Btu)	0.54	1
Large bldg. cooling (annual \$/10 ⁶ Btu)	0.73	1.35
Ind. process (annual \$/10 ⁶ Btu)	0.34	0.64
• Replacement of existing in-building equipment		
Res. low density (\$/ft ² floor space)	0.75	1.25
Res. high density (\$/ft ² floor space)	0.56	0.94
Com./inst. (\$/ft ² floor space)	0.56	0.94
Ind. (SH&HW) (annual \$/10 ⁶ Btu)	0.45	0.75
Large bldg. cooling (annual \$/10 ⁶ Btu)	0.67	1.23
Ind. process (annual \$/10 ⁶ Btu)	0.1	0.3

$$^a \text{Units in kWh}_e = \frac{(\text{original electric capacity, in MW}) (\text{cogen-} \\ \text{erated annual thermal production, in kWh}_t)}{(\text{cogenerated thermal capacity, in MW})}$$

configuration is then evaluated by calculating its economic benefits over time in terms of present dollars; appropriate user-specified "discount" factors are used, and the system is compared economically to other options and ranked according to its economic merit. This section describes the economic analysis procedure used in DHSM.

D.2.1 Definitions

Elements used in the economic-analysis procedure are symbolized and defined as follows.

- a = allowance for interest on funds used during construction, or $AFC^{\dagger}$ rate (with compounding assumed). Two procedures are common: (1) "normalized" and (2) "flow-through." If the normalized procedure is used, "a" is typically the after-tax embedded (historical or average) cost of capital. If the flow-through procedure is used, the pre-tax embedded cost of capital is usually applied.
- r = allowed rate of return[†] on capital. Typically, this amounts to the pre-tax marginal rate of return plus an allowance for insurance and property taxes.
- d = real discount rate.[†] Typically, this is the rate above inflation used to express the time value of money, or the after-tax marginal rate of return.
- i = inflation rate.
- t = year index.
- e_c = real escalation rate[†] for capital costs.
- e_f = real escalation rate of costs for fuel type f.
- e_{OM} = real escalation rate of operating and maintenance costs.
- C = capital costs.
- F = fuel cost.
- OM = operating and maintenance cost.
- P_C = present value[†] of costs, assuming 1980 as the base year.
- T_C = year construction starts.
- T_S = year service starts.
- T_{LT} = lifetime of system.
- T_{CR} = capital-recovery period.
- FC = annual fixed charge rate on total invested capital. This converts the stream of capital charge stream into a uniform series of costs over the capital-recovery period.[†]

D.2.2 Cost Calculations for a District System

If capital costs are assumed to be incurred at a uniform annual rate (C_0) during the construction period ($T_S - T_C$) of a proposed system, then the total capital cost (C_{T_S}) incurred up to the year service starts (T_S) is expressed:

$$C_{T_S} = \sum_{t=T_C}^{T_S-1} C_0 \cdot (1+i+e_c)^{(t-1980)} \cdot (1+a)^{(T_S-t)} \quad (D.1)$$

where 1980 is the assumed base year for all cost estimates and present value calculations. This expression escalates each year's construction expenditure, C_0 , to T_S at the rate of $(i+e_c)$ -- and compounds interest expenses incurred at rate a .

In each subsequent in-service year, the allowed annual capital charges, C_t , assuming straight-line depreciation, are expressed:

$$C_t = r \cdot C_{T_S} \cdot \frac{1-(t-T_S)}{T_{CR}} + \frac{C_{T_S}}{T_{CR}} \quad (D.2)$$

for $t = T_S, T_S + 1, \dots, T_S + T_{CR} - 1$

The first term in this expression is the allowed rate on undepreciated capital, and the second term is the (straight line) depreciation charge.

The present worth of this stream of costs in 1980 dollars is expressed:

$$P_C = \sum_{t=T_S}^{T_S + T_{CR} - 1} \frac{C_t}{(1+i+d)^t} \quad (D.3)$$

An annual fixed charge rate, FC , on total invested capital, C_{T_S} , makes this stream uniform. This action is expressed:

$$P_C = \sum_{t=T_S}^{T_S + T_{CR} - 1} \frac{FC \cdot C_{T_S}}{(1+i+d)^t} \quad \text{for } FC. \quad (D.4)$$

Therefore, Eqs. D.3 and D.4 can be used to solve for FC :

$$FC = r + \frac{1}{T_{CR}} \cdot \left[1 - r \left(\frac{q}{(1-q)} - \frac{T_{CR} \cdot q^{T_{CR}}}{(1-q^{T_{CR}})} \right) \right] \quad (D.5)$$

$$\text{if } q = \frac{1}{(1+i+d)} \neq 1,$$

or, alternatively,

$$FC = r \cdot \left[1 - \frac{T_{CR} - 1}{2T_{CR}} \right] + \frac{1}{T_{CR}}$$

if $q = 1$.

The average annual present value of capital costs over the system lifetime (TLT) is then expressed:

$$\bar{P}_C = \frac{1}{T_{LT}} \sum_{t=T_S}^{T_S + T_{CR} - 1} \frac{FC \cdot C_{T_S}}{(1 + i + d)^{(t-1980)}} \quad (D.6)$$

Similarly, the average annual present value of fuel costs and operating and maintenance costs are expressed:

$$\bar{P}_f = \frac{1}{T_{LT}} \sum_{t=T_S}^{T_S + T_{LT} - 1} \frac{F_f \times (1 + i + e_f)^{(t-1980)}}{(1 + i + d)^{(t-1980)}}, \quad (D.7)$$

and

$$\bar{P}_{OM} = \frac{1}{T_{LT}} \sum_{t=T_G}^{T_S + T_{LT} - 1} \frac{OM \times (1 + i + e_{OM})^{(t-1980)}}{(1 + i + d)^{(t-1980)}}, \quad (D.8)$$

respectively.

Finally the annual average of present-value costs is expressed:

$$\bar{P}_G = \bar{P}_C + \bar{P}_f + \bar{P}_{OM}. \quad (D.9)$$

D.2.3 Procedure for Configuring a District System

The DHSM uses the above cost analysis to calculate the annual average of present-value costs to deliver energy from each plant to the edge of the user-specified service areas. In selecting and ranking thermal-energy plants, and thus configuring a district heating and cooling system, the DHSM follows the procedure outlined below.

- Calculates various demands for thermal energy, geographically and according to energy end uses by building type, for the scenario being evaluated.

- Calculates operating characteristics of each new or retrofitted turbine and heat-only boiler in a user-specified list of supply options. The options can include cogenerated thermal capacity, electrical capacity derating (if any), base fuel use, system fuel use for district heating and cooling, and thermal energy delivered to the service area.
- Calculates each element of annualized cost for each unit delivering energy to a service area. These include costs for plant construction and/or retrofit, replacement of derated electrical capacity (if any), and plant O&M for either a specified "low-cost" or "high-cost" scenario.
- Aggregates new and retrofitted units, by operating characteristics and annual costs, into groups of units (turbines, boilers) using the same fuel at the same station (station fuel groups); sizes a transmission pipe to the maximum thermal output of each station fuel group; finds the length of that pipe to the nearest point of the service area; and calculates the annualized capital cost of that transmission pipe. It also calculates annual O&M costs for the transmission equipment.
- Calculates escalation and interest during construction, and average annual present-worth factors on the basis of financial assumptions.
- Computes total average of annual costs per 10^6 Btu delivered, discounted to 1980 present-worth dollars over the life of the district heating system for each station fuel group. Also finds the thermal capacity and annual delivered thermal energy from each station fuel group.
- Ranks each station fuel group according to the average annual (discounted) costs per 10^6 Btu thermal energy delivered.
- Chooses the lowest-cost set of these station fuel groups as the thermal supply system -- consistent with providing sufficient thermal energy and peak capacity for the service area, and consistent with a user-specified cost ceiling.
- Assumes that a new baseload heat-only boiler unit is built if sufficient thermal energy supply is otherwise unavailable (at or below ceiling cost). The DHSM then calculates the contribution of the new boiler to the cost of delivering thermal energy within the service area.
- Assigns additional peaking capacity to the system if necessary. This step is taken if the units previously selected to meet an area's thermal demands cannot also provide sufficient thermal capacity to meet peak winter thermal demands (including a user-specified reserve). The capacity thus assigned can come from either of two sources: (1) available capacity from existing thermal-only units that have not been selected to provide thermal energy (in order of their cost per kW); and (2) assumed construction of a heat-only boiler to be used for peaking.

D.2.4 Procedure for Analyzing Savings-to-Investment Ratio[†]

The above procedure allows the model to configure a district heating and cooling system to meet user-specified needs at a minimum annual cost. However, these costs are calculated only for a service area. After the system has been configured, the model performs a savings-to-investment analysis that compares the life-cycle costs of the district system against those of conventional systems -- as follows.

- Calculates the component cost of thermal-loop transmission, distribution, and building end-use retrofit costs in the service areas -- and adds these capital costs to those already calculated to configure the system.
- Calculates building fuel use and fuel costs by sector before and after a district heating system is in operation, and calculates costs avoided by employing the system.
- Analyzes cash flow, net benefits, savings-to-investment-ratio, discounted payback period; determines the year of cash flow turnaround (i.e., community's breakeven year).

D.3 INTRODUCTION TO DHSM TRANSMISSION AND DISTRIBUTION COST-ANALYSIS TECHNIQUES

The transmission and distribution costs of a district system are computed using various engineering conventions as well as the results of district heating and cooling research conducted previously. The parameters and equations used in the DHSM for this specific area of cost analysis follow.

D.3.1 Definitions

Elements used in this cost-analysis procedure are symbolized and defined as follows.

- E - final service area energy demand in 10^9 Btu.
- A - service area in km^2 .
- r_1 - ratio of final energy demand to end-use thermal demand in a district heating system.
- r_2 - ratio of nonwinter to winter thermal demand.
- d - transmission line diameter in inches.
- l - transmission line length in feet.
- C_D - distribution piping costs in millions of 1980 dollars.
- C_L - transmission-loop piping costs in millions of 1980 dollars.
- C_T - transmission-line piping costs in millions of 1980 dollars.
- P - peak thermal power in MW.

c - coefficient plugged into a cost equation (taken from the table following the equations below).

k - variable used to describe the number of transmission pipes required for handling a given peak of thermal power.

D.3.2 DHSM Piping-Cost Calculations

The DHSM calculates separate costs for distribution piping, a transmission loop, and transmission lines.

Distribution Piping Costs

$$C_D = c_{D1} \cdot A + c_{D2} \frac{E}{1000} \frac{1}{r_1(r_2 + 1)} \quad (D.10)$$

$$c_{D1} = \begin{array}{l} 4.0 \text{ for high-cost scenario, or} \\ 1.4 \text{ for a low-cost scenario} \end{array}$$

$$c_{D2} = \begin{array}{l} 20.5 \text{ for a high-cost scenario, or} \\ 7.2 \text{ for a low-cost scenario} \end{array}$$

$$\text{O\&M costs} = 0.01 \cdot C_D$$

Transmission-Loop Piping Costs

$$C_L = c_{L0} \cdot \left(A \cdot c_{L1} + c_{L2} \frac{E}{1000} \frac{1}{r_1(1 + r_2)} \right) \quad (D.11)$$

$$c_{L0} = \begin{array}{l} 1.0 \text{ for a high-cost scenario, or} \\ 0.35 \text{ for a low-cost scenario} \end{array}$$

$$c_{L1} = 1.96$$

$$c_{L2} = 9.21$$

$$\text{O\&M costs} = 0.01 \cdot C_L$$

Transmission-Line Piping Costs

Piping costs depend on peak thermal power.

If $P \leq 581$ MW, then a single-pipe transmission line is used ($k = 1$).

If $581 \text{ MW} < P \leq 1743$ MW, then a dual pipe transmission line is used ($k = 2$).

If $P > 1743$ MW, then a triple-pipe transmission line is used
($k = 3$).

$$d = 2.2 \cdot (P/k)^{1/2}$$

If $d > 24$ ", diameter is rounded to the nearest 6"-diameter size.

$$C_T = k \cdot \frac{1}{10^6} \cdot (c_{T1}(k) + c_{T2}(k) \cdot d) \quad (D.12)$$

$$\text{O\&M cost} = 0.01 \cdot C_T$$

Table D.6 Transmission Cost Coefficients
(Dimensionless)

No. of Pipes Needed	$c_{T1}(k)$ Cost Coefficient		$c_{T2}(k)$ Cost Coefficient	
	Low	High	Low	High
K = 1	121.26	173.23	9.42	13.45
K = 2	22.61	32.3	12.71	18.15
K = 3	-246.5	-352.13	20.18	28.83

APPENDIX E

PREPARATION OF DATA-INPUT WORKSHEETS

E.1 OVERVIEW

This section describes and illustrates the several different worksheet forms used by community analysts for specifying the DHSM input data.

For convenience and orderliness of preparation, each data-input sheet has been designated in one of four ways: demand, supply, cost, or emissions. A large capital letter in the upper right corner (D, S, C, E,) graphically signifies a sheet's designation. Figure E.1 shows the sequence in which the worksheet packages are prepared -- starting with the demand file in the foreground of the illustration and working back to the emissions file. The figure also indicates that the four data files contain a total of nine different types of forms. Some of the demand and supply forms need to be completed in multiple copies; one of the supply forms has two parts; and another supply form is an optional one, which may or may not need to be completed depending upon a community's objectives.

Fig. E.1 Data-Input Packages in Order of Preparation (Front to Back)

The nine data-input forms are individually described and then illustrated below, in the same order as they are prepared: demand, supply, cost, emissions. The next section of this report, Appendix F, then depicts the same nine forms, in the same order, completed with sample inputs. The same sequence will be used to describe each sheet in more detail.

E.2 DEMAND DATA

As shown in Fig. E.2, the demand-data input consists of two types of worksheet: a "Community Demand" cover sheet, and a number of "Grid Square Demand" sheets for the grid-square data.

E.2.1 Community-Demand Worksheet

This sheet establishes the base demand data for the entire community. At a minimum, only the base "X" grid line needs be established for the initial submission. Two other areas of user input, the two tables of scaling factors, should probably be completed with values of 1.0 for the initial computer run -- this causes the model to operate on default values. In later submissions of modified scenarios, the scaling factors may be adjusted to account for the effects of weatherization, conservation, and other community-specific conditions and actions that could reduce demand for space heating or cooling in particular end-use sectors or for particular fuel types.

E.2.2 Grid-Square-Demand Worksheet (Up to 450 copies)

Data for each grid square include the coordinates of its southwest corner, the floor space by building and end-use sector, and the fuel mix.[†] For the large-building-cooling sector, floor space should be provided only for

Fig. E.2 Demand-Data Worksheets in Order of Preparation (Front to Back)

buildings with more than 30,000 ft² (principally in high-density areas) -- the economics of converting smaller buildings to district cooling, with absorption chillers using 250°F hot water, are questionable. Fuel mix for large-building cooling is divided between electricity and district steam from existing systems. For the industrial-process sector, the demand itself (in 10⁹ Btu) is given along with fuel mix. The maximum number of grid squares to which data can be attributed is 450.

The matrix of 1-km² cells should measure no more than 32 km from east to west and 50 km from north to south. The grid-square numbering order must start in the southernmost row at the square nearest to the southwestern corner, then go west to east; the numbering of bottom-row squares ends after the row's easternmost square is numbered, and on the next row up the west-to-east numbering process begins again. (See Figs. G.4 and G.5.) Only squares with demand data need to be numbered.

The sequence in which the grid squares are entered will determine the grid-square identification numbers. Once a square is assigned a number, the number should not be changed. All grid-square coordinates must be entered as integer numbers.

To prepare the data for a given city, it is useful to have a map of the city, broken down into the various zones (e.g., census tracts, transportation planning zones) by which floor-space and fuel-mix data are available and collected. All such data must be put into a grid-square system. (See Appendix G).

For simplicity, grid squares with little or no thermal demand (e.g., lightly developed or undeveloped open space, parks, agricultural areas, and sites containing single-family homes on large lots) need not be encoded.

E.3 SUPPLY DATA

The supply-data input starts with the "Scenario Definition" sheet. If only a part of a community described by the "Grid Square Demand" sheets is being examined for district heating, the "Scenario Definition" sheet is followed by one (or up to two) "Boundary Identification" sheets. Following these two sheets are the station packages consisting of one "Station" sheet and one or more "Unit Definition" sheets for each station each. This sequence is shown in Fig. E.3.

E.3.1 Scenario-Definition Worksheet

One "Scenario Definition" sheet must be supplied for each model run. This sheet displays the basic end-use parameters by sector and basic economic data necessary to establish the performance of a district heating and cooling system.

E.3.2 Boundary-Identification Worksheet (Optional)

If the "Scenario Definition" sheet specifies that only a certain geographical portion of the community will be analyzed, the "Boundary

Fig. E.3 Supply-Data Worksheets in Order of Preparation (Front to Back)

"Identification" sheet must be included. It can be omitted, however, when all the defined grid squares in a community are to be analyzed. A gridded map may be submitted to ANL for coding; otherwise, each data grid square to be included in the scenario must be enumerated on the form. Whenever a geographical limitation is imposed on the model, this of course means that the maximum number of grid squares to be analyzed will be less than the total number of grid squares defined in the community's demand data file.

E.3.3 Station-Data Worksheet

A separate sheet must be provided for each existing or future station located in the community. The X-Y station location, an eight-character name, and the number of generating units in the station are required for input. Immediately after the "Station Data" sheet, each unit[†] within the station must be defined.

Four types of units are candidates for a district heating supply system: (1) a single-case steam turbine; (2) a multicase steam turbine; (3) a thermal unit in an existing district steam system; and (4) an existing steam-driven cogenerator. New units -- i.e., those under construction, anticipated, or that the user wishes to test as a possible thermal-supply system component -- may be included among the potential supply options. Units can be given candidate or noncandidate status and thereby may be forced into or out of consideration for the thermal-supply system. If the unit is not a

candidate, it is assumed to incur no costs that can be ascribed to the district heating system. It is assumed to operate as before, except that electrical generation will be scaled back by an amount representing the fraction of total system generation displaced by the district system in this scenario. Each electrical generating unit, whether retrofit to cogeneration operation or not, is assumed to produce as much electricity during the winter and annually as it does normally before retrofit (minus the fractional scale back caused by electrically serviced demand displaced by the district heating system). Single-case units are assumed to be permanently derated to operate in the cogeneration mode at all times.

E.3.4 Unit-Definition Worksheet (Two Parts)

For each unit in the station, a two-part "Unit Definition Data" sheet must be completed. These two sheets identify each unit, specify the actual unit type and input fuel, and document the emission performance characteristics that must be met. Each unit is also individually designated as to whether it may be considered for retrofit as part of the candidate district heating and cooling system.

E.4 COST AND EMISSIONS DATA

The last two data-input forms are the "Cost" and "Emission" sheets. Because each of these sections consists of only one sheet, all necessary description can be obtained from the sheets themselves (Sec. E.6) and from annotated examples of the completed sheets (Appendix F).

E.5 SUMMARY

The community itself is responsible for characterizing its own energy demands and supplies. The inputs forms can be therefore viewed by community planners as a means of becoming more knowledgeable about the community's energy supply and demand systems rather than as a mechanical task.

E.6 BLANK WORKSHEETS

On each of the following nine pages is a representation of one of the blank forms used to organize input data for the district heating strategy model. Separate quantities of blank forms are available from ANL for planners whose communities are participating in the national feasibility assessment of district heating and cooling systems.

NATIONAL DISTRICT HEATING/COOLING PROGRAM <h1 style="margin: 0;">DHSM</h1>				COMMUNITY TSR DATE		COMMUNITY <h1 style="margin: 0;">D</h1> A	
	COMMUNITY DEMAND DATA SHEET						COMMUNITY CODE (ANL USE)	
	ORIGIN GRID SQUARE COORDINATES: USE WESTERN-MOST GRID LINE FOR X-COORDINATE. REFER TO SAMPLE GRID MAP.						X:	
ANL USE: REGION (1, 2, 3 or 4)								A1
HEATING DATA:		ANL USE:		COOLING DATA:		ANL USE:		
LENGTH OF HEATING SEASON (HRS.)		A3		DESIGN TEMPERATURE (1%)		A6 °F		
HEATING DEGREE DAYS		A4		MEAN COINCIDENT WET BULB		A7 °F		
DESIGN TEMPERATURE (97%)		A5 °F		COOLING DEGREE DAYS		A8		
SCALING FACTORS. THE FOLLOWING FACTORS AFFECT THE ENERGY DEMAND DENSITY TO BE SERVED AT THE DISTRICT HEATING SYSTEM. INITIALLY, ALL VALUES SHOULD BE 1.000 AS A DEFAULT; THIS CAN BE CHANGED LATER. IF YOU WISH TO USE THE DEFAULT VALUES, CHECK THE BOX ON THE RIGHT AND LEAVE THE REMAINDER OF THIS SHEET BLANK.								A9
DEFAULT ☐								
USE SECTOR FUEL TYPE	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL/ INSTITUTIONAL	INDUSTRIAL SPACE HEAT	SPACE COOLING			
NATURAL GAS	•	•	•	•	X			
OIL	•	•	•	•	X			
COAL	•	•	•	•	X			
ELECTRICITY	•	•	•	•	X			
EXISTING DISTRICT STEAM	•	•	•	•	X			
DOMESTIC HOT WATER	•	•	•	•	X			
SPACE COOLING: ELECTRIC					•	•	•	
EXISTING DISTRICT STEAM					•	•	•	
FLOOR SPACE SCALING	•	•	•	•	•	•	•	
INDUSTRIAL PROCESS HEAT DEMAND FACTOR					•	•	•	
FUEL MIX SCALING FACTORS (1.000 RECOMMENDED):					A14			
NATURAL GAS	•	•	•	•				
OIL	•	•	•	•				
COAL	•	•	•	•				
ELECTRICITY	•	•	•	•				
EXISTING DISTRICT STEAM	•	•	•	•

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY _____ TSR _____ DATE _____		GRID SQUARE D B C	
	GRID SQUARE DEMAND DATA SHEET				OF	
	GRID COORDINATES: (SOUTHWEST CORNER OF SQUARE)				X: _____ Y: _____	
FLOOR SPACE INVENTORY: (ENTER THE GROSS FLOOR AREA OF EACH LAND USE TYPE IN MILLIONS OF SQUARE FEET. FOR EXAMPLE, 3,200,000 S.F. WOULD BE: <div style="border: 1px solid black; padding: 2px; display: inline-block;"> | | | 3 | 2 | 0 | 0 </div>				LOW DENSITY RESIDENTIAL HIGH DENSITY RESIDENTIAL COMMERCIAL/INSTITUTIONAL INDUSTRIAL LARGE BUILDING COOLING		
INDICATE THE LOW TEMPERATURE (<200°F) INDUSTRIAL PROCESS HEAT REQUIREMENTS THAT MAY BE MET BY A DISTRICT HEATING SYSTEM. ENTER DATA IN ANNUAL USE REQUIREMENTS (BILLION (10 ⁹) BTU/YR.). FOR EXAMPLE, REQUIREMENTS OF 13,462,000,000 BTU/YR. WOULD BE ENTERED AS: <div style="border: 1px solid black; padding: 2px; display: inline-block;"> | | | 1 | 3 | 4 | 6 | 2 </div>				B1 B2 B3 B4		
ENTER THE DECIMAL FRACTION OF SOURCE FUEL FOR EACH OF THE FOLLOWING (FOR EXAMPLE: 50% = 0.500)						
SOURCE FUEL USE	SPACE HEATING ONLY RESIDENTIAL HIGH AND LOW DENSITY	HOT WATER ONLY RESIDENTIAL HIGH AND LOW DENSITY	HEATING AND HOT WATER COMMERCIAL/INSTITUTIONAL	HEATING AND HOT WATER INDUSTRIAL	LARGE BLDG. COOLING	INDUSTRIAL PROCESS HEAT
NATURAL GAS	• | | |	• | | |	• | | |	• | | |	• | | |	• | | |
OIL	• | | |	• | | |	• | | |	• | | |	• | | |	• | | |
COAL	• | | |	• | | |	• | | |	• | | |	• | | |	• | | |
ELECTRICITY	• | | |	• | | |	• | | |	• | | |	• | | |	• | | |
EXISTING DISTRICT STEAM	• | | |	• | | |	• | | |	• | | |	• | | |	• | | |
CHECK SUM	✓	✓	✓	✓	✓	✓
	1.000 C1.1	1.000 C1.2	1.000 C1.3	1.000 C1.4	1.000 C2	1.000 C3

THIS SPACE FOR ANL USE ONLY

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY _____ TSR _____ DATE _____		SCENARIO <div style="font-size: 2em; text-align: center;">S</div> <div style="text-align: right;">A</div>	
	SCENARIO DEFINITION SHEET				SCENARIO NAME		
	BOUNDARY DEFINITION: MARK "T" (TRUE) IF ALL GRID SQUARES IN THE COMMUNITY WILL BE USED IN THIS SCENARIO. IF NOT, MARK "F" (FALSE) AND INCLUDE THE <i>SCENARIO BOUNDARY SHEET</i> IMMEDIATELY FOLLOWING THIS SHEET. A MAP DELINEATING THE DESIRED GRID SQUARES MAY BE SUBMITTED FOR ANL TO ENCODE.				<div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 2px;">T</div> <div style="border: 1px solid black; padding: 2px;">F</div> </div>		
SECTOR DEFINITION: IN A SIMILIAR MANNER AS ABOVE, INDICATE WHICH OF THE VARIOUS END USES WILL BE INCLUDED IN THE SCENARIO FOR ANALYSIS. ("T" = INCLUDED; "F" = NOT INCLUDED.)			RESIDENTIAL, LOW DENSITY	T	F	A2	
			RESIDENTIAL, HIGH DENSITY	T	F		
			COMMERCIAL/INSTITUTIONAL	T	F		
			INDUSTRIAL SPACE HEAT	T	F		
			LARGE BUILDING COOLING	T	F		
			INDUSTRIAL PROCESS HEAT	T	F		
COSTING: SELECT EITHER LOW (1) OR HIGH (2) COSTS. LOW (1) RECOMMENDED.			1	2	A3		
ELECTRICAL REPLACEMENT COSTS DUE TO DISTRICT HEATING					%	A4	
ESCALATION RATES: REAL ESCALATION RATE FOR ELECTICITY					%	A5	
REAL ESCALATION RATE FOR DISTRICT STEAM					%	A6	
SERVICE: CONSTRUCTION		19	BEGIN SERVICE DATE		19	A7	
DH/C SYSTEM LIFE (YEARS)		YR	CAPITAL RECOVERY PERIOD		YR	A8	
REAL FUEL ESCALATION RATES: (REAL ESCALATION RATES OVER AND ABOVE THE GENERAL RATE OF INFLATION).			NUCLEAR			%	A9
			COAL			%	
			RESIDUAL OIL			%	
			DISTILLATE OIL			%	
			NATURAL GAS			%	
			OTHER (SPECIFY)			%	
OTHER REAL ESCALATION RATES:			O & M COSTS			%	A12
			CAPITAL COSTS			%	A13
			DISCOUNT RATE (PV)			%	A14
			GENERAL INFLATION			%	A15
UTILITY PRE-TAX RATE OF RETURN					%	A16	
UTILITY A.F.C. RATE (FOR INTEREST CAPITALIZATION IN CONSTRUCTION)					%	A17	
COST CEILING ON ENERGY (\$/MMBTU)			\$			A18	
RESERVE MARGIN (FRACTION OF THERMAL PEAK)			0			A19	
(ANL USE ONLY)						1 /

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY <hr/> TSR <hr/> DATE <hr/>		BOUNDARY <div style="font-size: 2em; font-weight: bold; margin: 10px 0;">S</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">B</div>
	BOUNDARY IDENTIFICATION SHEET		OF	SCENARIO NAME <div style="border: 1px solid black; height: 20px; width: 100%;"></div>	
	NUMBER OF GRID SQUARES TO BE INCLUDED IN SCENARIO LIST THE GRID SQUARES BELOW, OR CHECK BOX IF A MAP HAS BEEN INCLUDED FOR ANL TO ENCODE.		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> NUMBER </div> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-left: 10px;"> B1 </div>		
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> MAP </div>		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> B2 </div>			

CHECK BOX IF FORM IS CONTINUED ON A SECOND SHEET.

☐

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM	COMMUNITY <hr/> TSR <hr/> DATE <hr/>	STATION <div style="font-size: 2em; font-weight: bold;">S</div> <div style="font-size: 0.8em;">E</div>
	STATION DATA SHEET	OF	SCENARIO NAME	
	STATION NAME – UP TO 8 CHARACTERS.		<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E1 </div> </div>	
NUMBER OF GENERATING TURBINES AND BOILERS AT THIS STATION (≤14)		<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E2 </div> </div>		
STATION LOCATION IN COORDINATES.		X:	Y:	<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E3 </div> </div>
DESCRIPTION OF STATION				

STOP. THIS DATA SHEET IS COMPLETE. FOR EACH GENERATING TURBINE OR BOILER AT THIS STATION A *UNIT DEFINITION DATA SHEET* MUST BE SUPPLIED. EACH *UNIT DEFINITION DATA SHEET* CONSISTS OF 2 PAGES, BOTH OF WHICH MUST BE COMPLETED AS PER THE INSTRUCTIONS AND ATTACHED IN SEQUENCES BEHIND THIS *STATION DATA SHEET*. ONLY WHEN ALL UNITS HAVE BEEN ENTERED ON THE *UNIT DEFINITION DATA SHEETS* FOR THIS STATION MAY YOU PROCEED TO ENTER THE NEXT *STATION DATA SHEET*.

IF THIS IS THE LAST STATION, PROCEED TO THE *COST DATA SHEET* WHEN ALL UNITS HAVE BEEN ENTERED.

NOTE: THERE MUST BE AT LEAST ONE AND NOT MORE THAN FOURTEEN UNITS AT ANY STATION. IF MORE THAN 14 UNITS EXIST AT ANY STATION, ENTER THE FIRST 14 SUCH UNITS AS USUAL AND THEN STOP. CREATE A SECOND "STATION" BY FILLING OUT ANOTHER *STATION DATA SHEET* FOR THE REMAINING UNITS BY SPECIFYING A "NEW" STATION NAME AND THE SAME UTM GRID COORDINATES. FOR EXAMPLE, THE "MAIN RIVER STATION" FOR AN IMAGINARY COMMUNITY MIGHT BE ENCODED AS BELOW:

NOTE: A TOTAL OF 21 UNITS WERE ASSUMED IN THIS EXAMPLE.

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM	COMMUNITY <hr/> TSR <hr/> DATE <hr/>	STATION <div style="font-size: 2em; font-weight: bold;">S</div> <div style="font-size: 0.8em;">E</div>
	STATION DATA SHEET	OF	SCENARIO NAME	
	STATION NAME – UP TO 8 CHARACTERS.		<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E1 </div> </div>	
NUMBER OF GENERATING TURBINES AND BOILERS AT THIS STATION (≤14)		<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E2 </div> </div>		
STATION LOCATION IN COORDINATES:		X:	Y:	<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E3 </div> </div>
DESCRIPTION OF STATION				

STATION NAME – UP TO 8 CHARACTERS.	<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E1 </div> </div>
NUMBER OF GENERATING TURBINES AND BOILERS AT THIS STATION (≤14)	<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E2 </div> </div>
STATION LOCATION IN COORDINATES	<div style="border: 1px solid black; padding: 2px;"> <div style="display: flex; justify-content: space-between;"> E3 </div> </div>
DESCRIPTION OF STATION

ARGONNE NATIONAL LABORATORY	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY _____		UNIT <div style="font-size: 2em; font-weight: bold;">S</div>														
			TSR _____																
			DATE _____																
UNIT DEFINITION DATA SHEET			STATION OF	UNIT OF	SCENARIO														
STATION AND UNIT NAMES			STATION NAME _____		UNIT NAME _____														
CHECK THE APPROPRIATE BOX FOR THE TYPE OF UNIT. CHECK THE APPROPRIATE BOX FOR THE PRIMARY INPUT FUEL THAT DRIVES THE UNIT. USE THE REMAINING SPACE FOR ADDITIONAL REMARKS. _____ _____ _____ _____ _____ _____ _____ _____ _____			UNIT TYPE		☒	F1													
			1. SINGLE CASE STEAM TURBINE		☐	1													
			2. MULTI-CASE STEAM TURBINE		☐	2													
			3. COMBUSTION TURBINE		☐	3													
			4. BOILER ONLY		☐	4													
			NUCLEAR		☐	5													
			COAL		☐	6													
			RESIDUAL OIL		☐	7													
			DISTILLATE OIL		☐	8													
			NATURAL GAS		☐	9													
OTHER		☐	10																
NEW SOURCE PERFORMANCE STATUS (NSPS): TO FACILITATE AIR QUALITY ANALYSIS, IT IS NECESSARY TO DETERMINE WHAT STANDARDS WILL BE APPLICABLE TO THE UNIT'S EXPECTED PERFORMANCE. THESE STANDARDS ARE A FUNCTION OF BOTH THE UNIT SIZE AND DATE OF CONSTRUCTION. IF THE UNIT IS LESS THAN 73 MW RATED CAPACITY, OR IF CONSTRUCTION WAS INITIATED PRIOR TO DECEMBER 23, 1971, <i>NSPS</i> = 0. IF THE UNIT IS LARGER THAN 73 MW, AND CONSTRUCTION WAS BEGUN BETWEEN DECEMBER 23, 1971 AND SEPTEMBER 18, 1978, <i>NSPS</i> = 1. IF THE UNIT IS LARGER THAN 73 MW AND CONSTRUCTION WAS BEGUN AFTER SEPTEMBER 18, 1978, <i>NSPS</i> = 2. REFER TO THE TABLE ABOVE AT RIGHT FOR NSPS CODE. ENTER THE APPROPRIATE NSPS CODE IN THE BOX.			<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th rowspan="2">CONSTRUCTION INITIATION DATE</th> <th colspan="2">SIZE</th> </tr> <tr> <th>≤73 MW</th> <th>>73 MW</th> </tr> <tr> <td>BEFORE 12/23/71</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> </tr> <tr> <td>BETWEEN 12/23/71 AND 7/18/78</td> <td style="text-align: center;">0</td> <td style="text-align: center;">1</td> </tr> <tr> <td>AFTER 9/18/78</td> <td style="text-align: center;">0</td> <td style="text-align: center;">2</td> </tr> </table>		CONSTRUCTION INITIATION DATE	SIZE		≤73 MW	>73 MW	BEFORE 12/23/71	0	0	BETWEEN 12/23/71 AND 7/18/78	0	1	AFTER 9/18/78	0	2	F3
			CONSTRUCTION INITIATION DATE	SIZE															
				≤73 MW	>73 MW														
			BEFORE 12/23/71	0	0														
BETWEEN 12/23/71 AND 7/18/78	0	1																	
AFTER 9/18/78	0	2																	
INDICATE WHETHER UNIT IS A CANDIDATE FOR RETROFIT.			TRUE ☐	FALSE ☐	F4														
INDICATE NORMAL USE FACTORS FOR WINTER AND ANNUAL OPERATIONS AS A DECIMAL FRACTION OF UNIT CAPACITY RATING.			WINTER:	☐ ☐ ☐ ☐	F5														
			ANNUAL:	☐ ☐ ☐ ☐	F6														
FUEL PRICE IN 1980 DOLLARS (\$/MMBTU)			☐ ☐ ☐ ☐	F7															
UNIT NAME: ENTER UP TO 4 CHARACTERS			☐ ☐ ☐ ☐	F8															
UNIT RATED CAPACITY (MW)			☐ ☐ ☐ ☐	G1															
UNIT HEAT RATE (MBTU/KWH)			☐ ☐ ☐ ☐	G2															

CONTINUE TO NEXT PAGE

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY		UNIT (Contd.) S G	
			TSR				
			DATE				
UNIT DATA (Contd.)		SCENARIO		STATION NAME		UNIT NAME	
IF THE UNIT TYPE IS COMBUSTION TURBINE, CHECK THE BOX AT RIGHT AND STOP. IF NOT, PROCEED TO THE NEXT LINE.							☐
IF THE PREDOMINANT FUEL FOR THE UNIT IS NATURAL GAS OR NUCLEAR, CHECK THE BOX TO THE RIGHT AND STOP. OTHERWISE, PROCEED TO THE CORRECT FUEL BELOW.							☐
COAL FUEL TYPE 2	IF THE NEW SOURCE PERFORMANCE STATUS (NSPS) IS EQUAL TO 1, CHECK THE BOX AT RIGHT AND STOP.					☐	
	OTHERWISE, FIND THE CORRECT NSPS CODE AND ENTER THE DATA IN THE SPACE PROVIDED. WHEN DATA IS COMPLETE, CHECK THE APPROPRIATE BOX ON THE RIGHT AND STOP.	NSPS = 0	% SULFUR IN FUEL		<input type="text"/>	<input type="text"/>	G3 ☐
			% ASH IN FUEL		<input type="text"/>	<input type="text"/>	G4 ☐
			EMISSION CONTROL (%) (99.8% = 99.8%)	PART.	<input type="text"/>	<input type="text"/>	G5 ☐
				SO _x	<input type="text"/>	<input type="text"/>	☐
			NO _x	<input type="text"/>	<input type="text"/>	☐	
			NSPS = 2	% SULFUR IN FUEL		<input type="text"/>	<input type="text"/>
	% ASH IN FUEL			<input type="text"/>	<input type="text"/>	G4 ☐	
OIL FUEL TYPE 3 OR 4	IF THE NEW SOURCE PERFORMANCE STANDARD (NSPS) IS EQUAL TO 1, CHECK THE BOX AT RIGHT AND STOP.					☐	
	OTHERWISE, ENTER THE SULFUR CONTENT IN THE FUEL AND CHECK THE BOX AT RIGHT. (1% = 1.000%) STOP.					☐	
OTHER FUEL TYPE 6	CHECK THE BOX AT RIGHT AND FILL IN THE EMISSIONS STANDARDS FOR THE UNIT IN TONS PER MILLION BTU. (1 POUND = 0.0005 TON).					☐	
	TONS/MMBTU					G6 ☐	
	PARTICULATES		<input type="text"/>	<input type="text"/>	<input type="text"/>		
	SO _x		<input type="text"/>	<input type="text"/>	<input type="text"/>		
NO _x		<input type="text"/>	<input type="text"/>	<input type="text"/>

ARGONNE NATIONAL LABORATORY	NATIONAL DISTRICT HEATING/COOLING PROGRAM <h1 style="margin: 0;">DHSM</h1>				COMMUNITY <hr/> TSR <hr/> DATE <hr/>		COST <h1 style="margin: 0;">C</h1> A
	FUEL COST DATA SHEET						
	ENTER THE COST OF FUEL IN THE LOCAL AREA. IF DELIVERY PRICES OR RATES VARY AS A FUNCTION OF CONSUMPTION, SELECT AN AVERAGE VALUE FOR EACH TYPE OF USE INDICATED. ENTER ALL VALUES AS DOLLAR PER MILLION BTU. SUGGESTED CONVERSION FACTORS ARE INDICATED BELOW.						

	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL/ INSTITUTIONAL	INDUSTRIAL SPACE HEAT	LARGE BLDG. COOLING	INDUSTRIAL PROCESS HEAT	
NATURAL GAS	•	•	•	•	X	•	1.
OIL	•	•	•	•	X	•	2.
COAL	•	•	•	•	X	•	3.
ELECTRICITY	•	•	•	•	•	•	4.
EXISTING DISTRICT STEAM	•	•	•	•	•	•	5.

USE THIS SPACE FOR COMPUTATIONS, AS NECESSARY. TYPICAL HEAT VALUES FOR EACH FUEL TYPE ARE LISTED FOR YOUR REFERENCE. IF STANDARD LOCAL VALUES ARE DIFFERENT, USE THEM.

NATURAL GAS: 1,016 BTU/C.F.

DISTILLATE OIL: 138,690 BTU/GAL.

RESIDUAL OIL: 149,690 BTU/GAL.

ANTHRACITE COAL: 25.2 MMBTU/TON

ELECTRICITY: 3,412 BTU/KWH.

STEAM: 1,000 BTU/LB.

EXAMPLES:

ELECTRICITY @ 5.75¢/KWH
 $\frac{\$0.0575}{3412} \times 1,000,000 =$
\$16.85/MMBTU.

OIL (DISTILLATE) @ 1.20/GAL.
 $\frac{\$1.20}{149,690} \times 1,000,000 =$
\$8.016/MMBTU

NATURAL GAS @ 47.2¢/100 C.F.
 $\frac{\$0.472}{100} \times \frac{1,000,000}{1,016} =$
\$4.657/MMBTU

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY		EMISSIONS E A B		
			TSR					
			DATE					
EMISSIONS INPUT DATA SHEET							END USE ONLY:	A1 F
END USE EFFICIENCIES, BY FUEL TYPE AND END USE: ENTER BELOW THE AVERAGE FUEL EFFICIENCIES IN DECIMAL FRACTIONS. (50% EFFICIENCY WOULD BE 0.500). IF DEFAULT VALUES ARE DESIRED, LEAVE THE FOLLOWING SECTION BLANK AND CHECK THE BOX TO THE RIGHT.							DEFAULT	A2
END USE FUEL TYPE	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL INSTITUTIONAL	INDUSTRIAL SPACE HEAT	LARGE BLDG. COOLING	INDUSTRIAL PROCESS HEAT		
NATURAL GAS	☐	☐	☐	☐	☒	☐	2.1	
OIL	☐	☐	☐	☐	☒	☐	2.2	
COAL	☐	☐	☐	☐	☒	☐	2.3	
ELECTRICITY	☐	☐	☐	☐	☐	☐	2.4	
EXISTING DISTRICT STEAM	☐	☐	☐	☐	☐	☐	2.5	
OIL AND COAL USE CHARACTERISTICS, BY END USE SECTOR: FOR EACH FUEL AND END USE, ENTER THE APPROPRIATE DATA. IF THERE IS NO SIGNIFICANT FUEL CHARACTERISTIC VARIATION BY USE TYPE. ALL VALUES IN THE LINE WILL BE EQUAL.							REC 6	
OIL & COAL CHARACTERISTICS:	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL/ INSTITUTIONAL	INDUSTRIAL SPACE HEAT	INDUSTRIAL PROCESS HEAT			
DISTILLATE FRACTION OF OIL USE (50% = 0.500)	☐	☐	☐	☐	☐		B1	
PERCENT SULFUR IN DISTILLATE OIL, BY WEIGHT (1.5% = 1.500)	☐	☐	☐	☐	☐		B2	
PERCENT SULFUR IN RESIDUAL OIL, BY WEIGHT (2.4% = 2.400)	☐	☐	☐	☐	☐		B3	
PERCENT SULFUR IN COAL, BY WEIGHT (3% = 3.000)	☐	☐	☐	☐	☐		B4	
PERCENT ASH IN COAL, BY WEIGHT (1.3% = 1.300)	☐	☐	☐	☐	☐		B5	
HEAT CONTENT OF FUELS: SPECIFY THE HEAT CONTENT OF THE FUELS LISTED TO THE LEFT. (TYPICAL VALUES ARE GIVEN IN PARENTHESIS).	COAL (25.2)				☐	MMBTU TON	B6	
	RESIDUAL OIL (149.69)				☐	MBTU GAL	B7	
	DISTILLATE OIL (138.69)				☐	MBTU GAL	B8	
	NATURAL GAS (1016.0)				☐	BTU CF	B9	

APPENDIX F
SAMPLE COMPLETED WORKSHEETS

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NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY PIQUA TSR J. DOE DATE 8/4/81	COMMUNITY D A	
	COMMUNITY DEMAND DATA SHEET		COMMUNITY CODE (ANL USE)		
	ORIGIN GRID SQUARE COORDINATES: USE WESTERN-MOST GRID LINE FOR X-COORDINATE. REFER TO SAMPLE GRID MAP.		X: 1		
ANL USE: REGION (1, 2, 3 or 4)					
HEATING DATA:		ANL USE:	COOLING DATA:	ANL USE:	
LENGTH OF HEATING SEASON (HRS.)	5860 A3		DESIGN TEMPERATURE (1%)	90 °F A6	
HEATING DEGREE DAYS	6000 A4		MEAN COINCIDENT WET BULB	75 °F A7	
DESIGN TEMPERATURE (077%)	6 °F A5		COOLING DEGREE DAYS	1200 A8	
SCALING FACTORS. THE FOLLOWING FACTORS AFFECT THE ENERGY DEMAND DENSITY TO BE SERVED AT THE DISTRICT HEATING SYSTEM. INITIALLY, ALL VALUES SHOULD BE 1.000 AS A DEFAULT; THIS CAN BE CHANGED LATER. IF YOU WISH TO USE THE DEFAULT VALUES, CHECK THE BOX ON THE RIGHT AND LEAVE THE REMAINDER OF THIS SHEET BLANK.					
	DEFAULT ☐				
USE SECTOR	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL/ INSTITUTIONAL	INDUSTRIAL SPACE HEAT	SPACE COOLING
FUEL TYPE					
NATURAL GAS	1.000	1.000	1.000	1.000	
OIL	1.000	1.000	1.000	1.000	
COAL	1.000	1.000	1.000	1.000	
ELECTRICITY	1.000	1.000	1.000	1.000	
EXISTING DISTRICT STEAM	1.000	1.000	1.000	1.000	
DOMESTIC HOT WATER	1.000	1.000	1.000	1.000	
SPACE COOLING: ELECTRIC					1.000 A10
EXISTING DISTRICT STEAM					1.000 A11
FLOOR SPACE SCALING	1.000	1.000	1.000	1.000	1.000 A12
INDUSTRIAL PROCESS HEAT DEMAND FACTOR					1.000 A13
FUEL MIX SCALING FACTORS (1.000 RECOMMENDED):					
NATURAL GAS					
OIL					
COAL					
ELECTRICITY					
EXISTING DISTRICT STEAM					

Enter the western-most grid coordinate as an integer value.

Enter the scaling factors[†] for space heating[†] in the 20 locations provided by end use and fuel type. A complete version of default[†] values is provided in Appendix D. A list of the assumed default values appears in Table D.1.

These factors account for known variations from normalized values. For example, if all residential high-density buildings were of quite recent construction, a scaling factor of 0.75 might be considered an appropriate adjustment to reflect higher insulation values or other design or mechanical-system improvements.

The scaling factors for domestic water heating and space cooling are analogous to space heating and are also described in Table D.1. Their use should be considered identical to above.

Floor-space scaling factors are used to determine sectors to be served by a district heating system. Initially, one ought to consider all sectors. In later runs, should no service to low-density residential and only a 50% hookup to space cooling seem either desirable or likely, these service penetrations may be accounted for.

The industrial heat-demand factor for process heat[†] is directly analogous to the above floor-space scaling factors.

NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM	COMMUNITY PIQUA TSR J. DOE DATE 8/4/81		GRID SQUARE D			
	GRID SQUARE DEMAND DATA SHEET					
	GRID COORDINATES: (SOUTHWEST CORNER OF SQUARE) X: 3 Y: 3					
FLOOR SPACE INVENTORY: (ENTER THE GROSS FLOOR AREA OF EACH LAND USE TYPE IN MILLIONS OF SQUARE FEET. FOR EXAMPLE, 3,200,000 S.F. WOULD BE: <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 3 2 0 0 </div>		LOW DENSITY RESIDENTIAL HIGH DENSITY RESIDENTIAL COMMERCIAL/INSTITUTIONAL INDUSTRIAL LARGE BUILDING COOLING				
INDICATE THE LOW TEMPERATURE (<200°F) INDUSTRIAL PROCESS HEAT REQUIREMENTS THAT MAY BE MET BY A DISTRICT HEATING SYSTEM. ENTER DATA IN ANNUAL USE REQUIREMENTS (BILLION (10 ⁹) BTU/YR.). FOR EXAMPLE, REQUIREMENTS OF 13,462,000,000 BTU/YR. WOULD BE ENTERED AS: <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 3 4 6 2 </div>		<div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 1.83 0 </div>				
ENTER THE DECIMAL FRACTION OF SOURCE FUEL FOR EACH OF THE FOLLOWING (FOR EXAMPLE: 50% = 0.500)						
USE	SPACE HEATING ONLY RESIDENTIAL HIGH AND LOW DENSITY	HOT WATER ONLY RESIDENTIAL HIGH AND LOW DENSITY	HEATING AND HOT WATER COMMERCIAL/INSTITUTIONAL	HEATING AND HOT WATER INDUSTRIAL	LARGE BLDG. COOLING	INDUSTRIAL PROCESS HEAT
NATURAL GAS	0.850	0.850	0.850	0.410		0.650
OIL	0.040	0.040	0.040	0.190		0.300
COAL	0.000	0.000	0.000	0.000		0.000
ELECTRICITY	0.090	0.090	0.090	0.370	1.000	0.000
EXISTING DISTRICT STEAM	0.020	0.020	0.020	0.030	0.000	0.050
CHECK SUM	1.000	1.000	1.000	1.000	1.000	1.000
	1.000 C1	1.000 C1	1.000 C1	1.000 C1	1.000 C2	1.000 C3

For accuracy in later references, keep track of the sequence of input and the total number of encoded grid squares.

Enter the grid coordinates as integer numbers.

The approximate floor space for each of four major land uses must be given in 10⁶ ft². For example, if roughly half the grid square is single-family detached housing with a gross floor-area ratio (FAR) of 0.125 (1500-ft² houses on 1/4-acre lots), the value would be 0.125 x 43,560 ft²/acre x 247.105 ac/km² x 50% = 673,000 ft², or a value of 0.673. For the Piqua example, the following square foot-ages have been encoded into grid square 3,3:

Low density residential	473,000 ft ²
High density residential	70,000 ft ²
Commercial/institutional	165,000 ft ²
Industrial	165,000 ft ²
Large-building cooling	117,000 ft ²

Here, the total built spaces (854,000 ft², excluding large-building cooling), is equivalent of a gross FAR of 0.08.

Estimate the low temperature heat requirement in 10⁹ Btu/yr. Any plant managers in the grid square could probably provide a rough estimate for their operations.

For each type of end use, provide the fraction of energy supplied by each fuel type. If, for example, 75% of the space heating for low density residential is provided by natural gas, 15% by fuel oil, 2% by coal, and 8% by electricity, the following numbers would be filled in:

Natural gas	0.750
Oil	0.150
Coal	0.020
Electricity	0.080
District steam	0.000

Check Sum = 1.000 (or 100%)

This process is continued for all end uses. If there is no known variation between grid squares in the community, it is not necessary to continue to reenter the same data for every square; the program will retain the most recent entry.

NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY Piqua TSR J. DOE DATE 8/4/81	SCENARIO S																		
	SCENARIO DEFINITION SHEET																					
	BOUNDARY DEFINITION: MARK "T" (TRUE) IF ALL GRID SQUARES IN THE COMMUNITY WILL BE USED IN THIS SCENARIO. IF NOT, MARK "F" (FALSE) AND INCLUDE THE SCENARIO BOUNDARY SHEET IMMEDIATELY FOLLOWING THIS SHEET. A MAP DELINEATING THE DESIRED GRID SQUARES MAY BE SUBMITTED FOR ANL TO ENCODE.																					
SECTOR DEFINITION: IN A SIMILAR MANNER AS ABOVE, INDICATE WHICH OF THE VARIOUS END USES WILL BE INCLUDED IN THE SCENARIO FOR ANALYSIS. ("T" = INCLUDED; "F" = NOT INCLUDED.)		<table border="1"> <tr> <td>RESIDENTIAL, LOW DENSITY</td> <td>☒</td> <td>F</td> </tr> <tr> <td>RESIDENTIAL, HIGH DENSITY</td> <td>☒</td> <td>F</td> </tr> <tr> <td>COMMERCIAL/INSTITUTIONAL</td> <td>☒</td> <td>F</td> </tr> <tr> <td>INDUSTRIAL SPACE HEAT</td> <td>☒</td> <td>F</td> </tr> <tr> <td>LARGE BUILDING COOLING</td> <td>☒</td> <td>F</td> </tr> <tr> <td>INDUSTRIAL PROCESS HEAT</td> <td>☒</td> <td>F</td> </tr> </table>			RESIDENTIAL, LOW DENSITY	☒	F	RESIDENTIAL, HIGH DENSITY	☒	F	COMMERCIAL/INSTITUTIONAL	☒	F	INDUSTRIAL SPACE HEAT	☒	F	LARGE BUILDING COOLING	☒	F	INDUSTRIAL PROCESS HEAT	☒	F
RESIDENTIAL, LOW DENSITY	☒	F																				
RESIDENTIAL, HIGH DENSITY	☒	F																				
COMMERCIAL/INSTITUTIONAL	☒	F																				
INDUSTRIAL SPACE HEAT	☒	F																				
LARGE BUILDING COOLING	☒	F																				
INDUSTRIAL PROCESS HEAT	☒	F																				
COSTING: SELECT EITHER LOW (1) OR HIGH (2) COSTS. LOW (1) RECOMMENDED.		☒ 2																				
ELECTRICAL REPLACEMENT COSTS DUE TO DISTRICT HEATING		50! %																				
ESCALATION RATES: REAL ESCALATION RATE FOR ELECTRICITY		(2.6) %																				
REAL ESCALATION RATE FOR DISTRICT STEAM		(1.0) %																				
SERVICE: CONSTRUCTION	BEGIN SERVICE DATE	1983																				
DH/C SYSTEM LIFE (YEARS) (30 YR)	CAPITAL RECOVERY PERIOD	(20 YR)																				
REAL FUEL ESCALATION RATES: (REAL ESCALATION RATES OVER AND ABOVE THE GENERAL RATE OF INFLATION).		<table border="1"> <tr> <td>NUCLEAR</td> <td>1.0</td> <td>%</td> </tr> <tr> <td>COAL</td> <td>2.0</td> <td>%</td> </tr> <tr> <td>RESIDUAL OIL</td> <td>3.6</td> <td>%</td> </tr> <tr> <td>DISTILLATE OIL</td> <td>3.0</td> <td>%</td> </tr> <tr> <td>NATURAL GAS</td> <td>6.2</td> <td>%</td> </tr> <tr> <td>OTHER (SPECIFY)</td> <td>2.0</td> <td>%</td> </tr> </table>			NUCLEAR	1.0	%	COAL	2.0	%	RESIDUAL OIL	3.6	%	DISTILLATE OIL	3.0	%	NATURAL GAS	6.2	%	OTHER (SPECIFY)	2.0	%
NUCLEAR	1.0	%																				
COAL	2.0	%																				
RESIDUAL OIL	3.6	%																				
DISTILLATE OIL	3.0	%																				
NATURAL GAS	6.2	%																				
OTHER (SPECIFY)	2.0	%																				
OTHER REAL ESCALATION RATES:		<table border="1"> <tr> <td>O & M COSTS</td> <td>5.0</td> <td>%</td> </tr> <tr> <td>CAPITAL COSTS</td> <td>2.0</td> <td>%</td> </tr> <tr> <td>DISCOUNT RATE (PV)</td> <td>6.7</td> <td>%</td> </tr> <tr> <td>GENERAL INFLATION</td> <td>8.0</td> <td>%</td> </tr> </table>			O & M COSTS	5.0	%	CAPITAL COSTS	2.0	%	DISCOUNT RATE (PV)	6.7	%	GENERAL INFLATION	8.0	%						
O & M COSTS	5.0	%																				
CAPITAL COSTS	2.0	%																				
DISCOUNT RATE (PV)	6.7	%																				
GENERAL INFLATION	8.0	%																				
UTILITY PRE-TAX RATE OF RETURN		(8.0) %																				
UTILITY A.F.C. RATE (FOR INTEREST CAPITALIZATION IN CONSTRUCTION)		100 %																				
COST CEILING ON ENERGY (\$/MMBTU)		\$ 200.00																				
RESERVE MARGIN (FRACTION OF THERMAL PEAK)		0.000																				

Indicate whether the entire community (all encoded grid squares) will be used in the scenario. In the example of Piqua, Ohio, only a portion of the community is to be modeled.

In a similar manner, indicate if any end-use sectors should be omitted or included in the procedures. For example, if you do not wish to consider space cooling, you would check the "F" (False) box. In the Piqua example, all sectors were considered.

Tables D.4 and D.5 in Appendix D give costing values used by the program. As in the Piqua example, selection of the "low" costs is recommended.

District heating and cooling will replace some electricity output via changed capacity. The percentage here represents the generating reductions that must be replaced by revenues from the district heating system.

Real escalation rates[†] (over and above the general rate of inflation) must be provided. If you estimate that any rate will roughly approximate the rate of inflation, then a value of 0.00 should be entered. For example, in Piqua a long-term inflation rate of 8%, with a real escalation rate for natural gas of 6.2% (which translates to an annual long-term inflation rate of 14.2%), is expected.

Construction and service-initiation dates must be specified by calendar year. Periods of expected service life and capital recovery must also be provided. Values used in the example are typical.

Rate of return[†] (before taxes) for the utility. Here, a value of 8% was selected.

Utility annual fixed charge rate represents the cost of borrowing money for the utility during construction financing.

Maximum feasible price for district heating where it would still compete with other energy sources (in \$/10⁶ Btu).

A surplus quantity of heating capacity, beyond design sizing, can meet unexpected perturbations in demand due to exceptional conditions; basically a safety factor.

[illegible]

- Whenever more than one sheet of a type is used, number them for later reference. This can be either the first (1 of 2) or the second (2 of 2) sheet for the scenario.

Indicate how many grid squares will be mapped and listed.

If providing a map for graphic definition is easier, check the box and ANL will list the grid squares. (Be sure to include the map in the data submission to your TSR.)

List the grid squares in this space. Note that the grid squares must be referenced by their sequence number in ascending order, from left to right, bottom to top.

Check here if a second (continuation) sheet is needed.

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM	COMMUNITY PIQUA	STATION
		TSR J. DOE	S
		DATE 8/4/81	E
STATION DATA SHEET		1 OF 1	SCENARIO NAME
STATION NAME - UP TO 8 CHARACTERS.		3 SFD	
NUMBER OF GENERATING TURBINES AND BOILERS AT THIS STATION (≤14)		1	
STATION LOCATION IN COORDINATES		6.1 2.9	
DESCRIPTION OF STATION			

Keep track of how many stations there are, and how many have been encoded.

For ease of reference, up to eight characters and blanks may be used to name the station. For example, Coal Station Number 4 could be named "COALST#4".

Indicate the number of units[†] in the station.

Give the station location as accurately as possible. If, for example, the station is located in grid square 61,52 -- slightly south of the center -- the location might be 61.5, 52.4.

STOP. THIS DATA SHEET IS COMPLETE. FOR EACH GENERATING TURBINE OR BOILER AT THIS STATION A UNIT DEFINITION DATA SHEET MUST BE SUPPLIED. EACH UNIT DEFINITION DATA SHEET CONSISTS OF 2 PAGES, BOTH OF WHICH MUST BE COMPLETED AS PER THE INSTRUCTIONS AND ATTACHED IN SEQUENCES BEHIND THIS STATION DATA SHEET. ONLY WHEN ALL UNITS HAVE BEEN ENTERED ON THE UNIT DEFINITION DATA SHEETS FOR THIS STATION MAY YOU PROCEED TO ENTER THE NEXT STATION DATA SHEET.

IF THIS IS THE LAST STATION, PROCEED TO THE COST DATA SHEET WHEN ALL UNITS HAVE BEEN ENTERED.

NOTE: THERE MUST BE AT LEAST ONE AND NOT MORE THAN FOURTEEN UNITS AT ANY STATION. IF MORE THAN 14 UNITS EXIST AT ANY STATION, ENTER THE FIRST 14 SUCH UNITS AS USUAL AND THEN STOP. CREATE A SECOND "STATION" BY FILLING OUT ANOTHER STATION DATA SHEET FOR THE REMAINING UNITS BY SPECIFYING A "NEW" STATION NAME AND THE SAME UTM GRID COORDINATES. FOR EXAMPLE, THE "MAIN RIVER STATION" FOR AN IMAGINARY COMMUNITY MIGHT BE ENCODED AS BELOW:

NOTE: A TOTAL OF 21 UNITS WERE ASSUMED IN THIS EXAMPLE.

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM	COMMUNITY	STATION
		TSR	S
		DATE	
STATION DATA SHEET		OF	
STATION NAME - UP TO 8 CHARACTERS.		MAIRV-A	
NUMBER OF GENERATING TURBINES AND BOILERS AT THIS STATION (≤14)		14	
STATION LOCATION IN COORDINATES		274.63 192.06	
DESCRIPTION OF STATION			
FIRST SHEET OF 21-UNIT STATION. THE FULL STATION WILL BE CONTINUED ON ANOTHER STATION "PACKAGE" WITH THE SAME LOCATION			
STATION NAME - UP TO 8 CHARACTERS.		MAIRV-B	
NUMBER OF GENERATING TURBINES AND BOILERS AT THIS STATION (≤14)		07	
STATION LOCATION IN COORDINATES		274.63 192.06	
DESCRIPTION OF STATION		CONTINUATION OF "MAIRV-A" STATION.

Grid Square 61,52

Room is also provided for other descriptive information, such as type of construction, capacity, status, etc. Please use this to enter additional information that will supplement what is directly encoded.

 ARGONNE NATIONAL LABORATORY	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY: PIQUA TSR: J. DOE DATE: 8/4/81	UNIT: S F: G
	UNIT DEFINITION DATA SHEET			
STATION AND UNIT NAMES		STATION NAME: PMP S I UNIT NAME: ST 4		
CHECK THE APPROPRIATE BOX FOR THE TYPE OF UNIT. CHECK THE APPROPRIATE BOX FOR THE PRIMARY INPUT FUEL THAT DRIVES THE UNIT. USE THE REMAINING SPACE FOR ADDITIONAL REMARKS.		UNIT TYPE		
		1. SINGLE CASE STEAM TURBINE ☒		
		2. MULTI-CASE STEAM TURBINE ☐		
		3. COMBUSTION TURBINE ☐		
		4. BOILER ONLY ☐		
		NUCLEAR ☐		
		COAL ☒		
		RESIDUAL OIL ☐		
		DISTILLATE OIL ☐		
		NATURAL GAS ☐		
OTHER ☐				
NEW SOURCE PERFORMANCE STATUS (NSPS): TO FACILITATE AIR QUALITY ANALYSIS, IT IS NECESSARY TO DETERMINE WHAT STANDARDS WILL BE APPLICABLE TO THE UNITS EXPECTED PERFORMANCE. THESE STANDARDS ARE A FUNCTION OF BOTH THE UNIT SIZE AND DATE OF CONSTRUCTION. IF THE UNIT IS LESS THAN 73 MW RATED CAPACITY, OR IF CONSTRUCTION WAS INITIATED PRIOR TO DECEMBER 23, 1971, NSPS = 0. IF THE UNIT IS LARGER THAN 73 MW, AND CONSTRUCTION WAS BEGUN BETWEEN DECEMBER 23, 1971 AND SEPTEMBER 18, 1978, NSPS = 1. IF THE UNIT IS LARGER THAN 73 MW AND CONSTRUCTION WAS BEGUN AFTER SEPTEMBER 18, 1978, NSPS = 2. REFER TO THE TABLE ABOVE AT RIGHT FOR NSPS CODE. ENTER THE APPROPRIATE NSPS CODE IN THE BOX.		CONSTRUCTION INITIATION DATE		SIZE
		BEFORE 12/23/71		<73 MW >73 MW
		BETWEEN 12/23/71 AND 7/18/78		0 1
		AFTER 9/18/78		0 2
INDICATE WHETHER UNIT IS A CANDIDATE FOR RETROFIT.		TRUE ☒ FALSE ☐		
INDICATE NORMAL USE FACTORS FOR WINTER AND ANNUAL OPERATIONS AS A DECIMAL FRACTION OF UNIT CAPACITY RATING.		WINTER: 0.683 ANNUAL: 0.671		
FUEL PRICE IN 1980 DOLLARS (\$/MMBTU)		1.79		
UNIT NAME: ENTER UP TO 4 CHARACTERS		ST 4		
UNIT RATED CAPACITY (MW)		7.5 MW		
UNIT HEAT RATE (MBTU/KWH)		12.6		

CONTINUE TO NEXT PAGE

Careful record-keeping will be extremely valuable if several alternatives are considered. Keep future confusion to a minimum by numbering each station and each unit within the station.

The type of unit is indicated here. For the Piqua example, a single-case steam turbine is indicated.

Additional information -- e.g., unit model number, manufacturer, and date of installation -- may also be desirable. Although not encoded, such information is a valuable aid in evaluating the model output; it may be recorded in the space provided.

Check the predominant fuel input. Here, it is coal.

Emissions and air quality depend on the "class" of performance requirements the unit will be subject to. Find which "class" (or NSPS code) is applicable for this unit. Here, because of the size, NSPS = 0. This is important to know in filling out the performance specifications for emissions below.

If the unit is not to be considered for possible retrofit (and hence will not be partially derated), check "F" (False). Here, the unit will be considered for retrofit.

Normal capacity factors (winter and annual) must be provided. Here, the unit issued at an average of 68% of its rated capacity (roughly 5.12 of 7.5 MWe) in the winter and 67% on an annual basis.

Enter the fuel prices in dollars per million Btu. Here, as with the baseload example, coal is costed at \$1.79/10⁶ Btu.

Indicate the unit's rated capacity. The turbine in this example is rated at 7.5 MW.

The heat rate (10⁶ Btu/kWh) must be provided as well. Here, the heat rate of 12.6 10⁶ Btu/kWh indicates an implicit turbine efficiency (including boiler and generator) of 27% ($\eta = 0.27$).

	NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY PIQUA TSR J. DOE DATE 8/4/81		UNIT (Contd.) S G	
	UNIT DATA (Contd.)		SCENARIO		STATION NAME		
			R3SDF		PMPSI		
IF THE UNIT TYPE IS COMBUSTION TURBINE, CHECK THE BOX AT RIGHT AND STOP. IF NOT, PROCEED TO THE NEXT LINE.							
IF THE PREDOMINANT FUEL FOR THE UNIT IS NATURAL GAS OR NUCLEAR, CHECK THE BOX TO THE RIGHT AND STOP. OTHERWISE, PROCEED TO THE CORRECT FUEL BELOW.							
COAL FUEL TYPE 2	IF THE NEW SOURCE PERFORMANCE STATUS (NSPS) IS EQUAL TO 1, CHECK THE BOX AT RIGHT AND STOP.						
	OTHERWISE, FIND THE CORRECT NSPS CODE AND ENTER THE DATA IN THE SPACE PROVIDED. WHEN DATA IS COMPLETE, CHECK THE APPROPRIATE BOX ON THE RIGHT AND STOP.	NSPS = 0	% SULFUR IN FUEL		1.000		
			% ASH IN FUEL		8.000		
		EMISSION CONTROL (%) (99.8% = 99.8%)	PART.	99.8			
			SO _x	99.8			
			NO _x	99.8			
NSPS = 2	% SULFUR IN FUEL						
	% ASH IN FUEL						
OIL FUEL TYPE 3 OR 4	IF THE NEW SOURCE PERFORMANCE STANDARD (NSPS) IS EQUAL TO 1, CHECK THE BOX AT RIGHT AND STOP.						
	OTHERWISE, ENTER THE SULFUR CONTENT IN THE FUEL AND CHECK THE BOX AT RIGHT. (1% = 1.000%) STOP.						
OTHER FUEL TYPE 6	CHECK THE BOX AT RIGHT AND FILL IN THE EMISSIONS STANDARDS FOR THE UNIT IN TONS PER MILLION BTU. (1 POUND = 0.0005 TON).						
	TONS/MMBTU						
	PARTICULATES						
	SO _x						
NO _x							

The remainder of this two-part data sheet deals with air quality and emissions. In all cases, check the appropriate box, depending on the kind of unit, its fuel type, and the NSPS code.

Here, because the fuel is coal, and because of the unit type and size, the following data have been entered:

1% sulfur in fuel

8% ash in fuel, by weight

Emission controls: 99.8% for particulates, SO_x, and NO_x.

Similar information is to be supplied for other fuels.

	NATIONAL DISTRICT HEATING/COOLING PROGRAM				COMMUNITY PIQUA		COST	
	DHSM				TSR J. DOE		C	
					DATE 8/4/81			
FUEL COST DATA SHEET								
ENTER THE COST OF FUEL IN THE LOCAL AREA. IF DELIVERY PRICES OR RATES VARY AS A FUNCTION OF CONSUMPTION, SELECT AN AVERAGE VALUE FOR EACH TYPE OF USE INDICATED. ENTER ALL VALUES AS DOLLAR PER MILLION BTU. SUGGESTED CONVERSION FACTORS ARE INDICATED BELOW.								
	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL/ INSTITUTIONAL	INDUSTRIAL SPACE HEAT	LARGE BLDG. COOLING	INDUSTRIAL PROCESS HEAT		
NATURAL GAS	3.40	3.40	3.15	2.50	X	2.50		
OIL	6.60	6.60	6.10	5.20	X	5.20		
COAL	1.50	1.50	1.50	1.50	X	1.50		
ELECTRICITY	15.50	15.50	17.50	17.50	17.50	17.50		
EXISTING DISTRICT STEAM	5.00	5.00	5.00	5.00	5.00	5.00		
USE THIS SPACE FOR COMPUTATIONS, AS NECESSARY. TYPICAL HEAT VALUES FOR EACH FUEL TYPE ARE LISTED FOR YOUR REFERENCE. IF STANDARD LOCAL VALUES ARE DIFFERENT, USE THEM.								
NATURAL GAS: 1,016 BTU/C.F. DISTILLATE OIL: 138,690 BTU/GAL. RESIDUAL OIL: 149,690 BTU/GAL. ANTHRACITE COAL: 25.2 MMBTU/TON ELECTRICITY: 3,412 BTU/KWH STEAM: 1,000 BTU/LB.					<div style="border: 1px solid black; padding: 5px;"> <p>EXAMPLES:</p> <p>ELECTRICITY @ 5.75¢/KWH</p> $\frac{\\$0.0575}{3412} \times 1,000,000 =$ <p>\$16.85/MMBTU.</p> <hr/> <p>OIL (DISTILLATE) @ 1.20/GAL.</p> $\frac{\\$1.20}{149,690} \times 1,000,000 =$ <p>\$8.016/MMBTU</p> <hr/> <p>NATURAL GAS @ 47.2¢/100 C.F.</p> $\frac{\\$0.472}{100} \times \frac{1,000,000}{1,016} =$ <p>\$4.657/MMBTU</p> </div>			

For each space provided, it is necessary to enter the normalized cost of fuel per 10⁶ Btu. Since this is not the usual means of pricing for many kinds of fuels, conversion factors are provided to give generally accepted heat content (Btu) for common units of fuel. Cost differences will occur for a single fuel across types of uses if there are different rate schedules or delivery prices for the various fuels. If such differences do not exist in your community, all cost values for a single fuel would be the same.

NATIONAL DISTRICT HEATING/COOLING PROGRAM DHSM		COMMUNITY PIQUA		EMISSIONS		
		TSR J. DOE		E A B		
		DATE 8/4/81				
EMISSIONS INPUT DATA SHEET						
END USE EFFICIENCIES, BY FUEL TYPE AND END USE: ENTER BELOW THE AVERAGE FUEL EFFICIENCIES IN DECIMAL FRACTIONS. (50% EFFICIENCY WOULD BE 0.500). IF DEFAULT VALUES ARE DESIRED, LEAVE THE FOLLOWING SECTION BLANK AND CHECK THE BOX TO THE RIGHT.						
END USE	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL INSTITUTIONAL	INDUSTRIAL SPACE HEAT	LARGE BLDG. COOLING	INDUSTRIAL PROCESS HEAT
NATURAL GAS	0.578	0.578	0.578	0.578		0.578
OIL	0.554	0.554	0.554	0.554		0.554
COAL	0.500	0.5	0.5	0.5		0.5
ELECTRICITY	0.0	0.0	0.0	0.0	0.0	0.0
EXISTING DISTRICT STEAM	0.0	0.0	0.0	0.0	0.0	0.0
OIL AND COAL USE CHARACTERISTICS, BY END USE SECTOR: FOR EACH FUEL AND END USE, ENTER THE APPROPRIATE DATA. IF THERE IS NO SIGNIFICANT FUEL CHARACTERISTIC VARIATION BY USE TYPE, ALL VALUES IN THE LINE WILL BE EQUAL.						
OIL & COAL CHARACTERISTICS:	RESIDENTIAL LOW DENSITY	RESIDENTIAL HIGH DENSITY	COMMERCIAL INSTITUTIONAL	INDUSTRIAL SPACE HEAT	INDUSTRIAL PROCESS HEAT	
DISTILLATE FRACTION OF O.I. USE (50% = 0.500)	1.0	1.0	0.77	0.61	0.61	
PERCENT SULFUR IN DISTILLATE OIL, BY WEIGHT (1.5% = 1.500)	0.2	0.2	0.2	0.2	0.2	
PERCENT SULFUR IN RESIDUAL OIL, BY WEIGHT (2.4% = 2.400)	0.8	0.8	0.8	0.8	0.8	
PERCENT SULFUR IN COAL BY WEIGHT (3% = 3.000)	0.7	0.7	0.7	0.7	0.7	
PERCENT ASH IN COAL, BY WEIGHT (1.3% = 1.300)	1.3	1.3	1.3	1.3	1.3	
HEAT CONTENT OF FUELS: SPECIFY THE HEAT CONTENT OF THE FUELS LISTED TO THE LEFT. (TYPICAL VALUES ARE GIVEN IN PARENTHESIS).	COAL (25.2)			25.2	MMBTU	86
	RESIDUAL OIL (149.69)			149.69	MBTU	87
	DISTILLATE OIL (138.69)			138.69	MBTU	88
	NATURAL GAS (1016.0)			1016.0	BTU	89

The assumed efficiencies of space heating, space cooling, water heating, and industrial process equipment are shown below. Adjustments to these factors can be made in the input to the emissions module.

Building Type	End Use	Gas	Oil	Coal	Elec- tric ¹	Dis- trict Steam ²
Res. low density	Space heat & hot water	0.6	0.5	0.5	0.3	0.64
Res. high density	Space heat & hot water	0.6	0.5	0.5	0.3	0.64
Com./ inst.	Space heat & hot water	0.6	0.5	0.5	0.3	0.64
Indus- trial	Space heat & hot water	0.6	0.5	0.5	0.3	0.64
large bldg.	Cool- ing	-	-	-	0.62	0.43
Indus- trial	Pro- cess	0.6	0.5	0.5	0.3	0.64

¹Assumes 33% generation efficiency and 90% transmission/distribution efficiency. For cooling, COP of 2.1 is assumed.

²Assumes 78% thermal generation efficiency and 82% transmission/distribution efficiency. For cooling, absorption chiller COP of 0.67 is assumed.

Five fuel-gas characteristics are required by end use sectors. Thus, if there is a significant known difference between distillate oil and coal, for example, or between the residential and commercial/ industrial sectors, these differences may be accounted for.

Enter the heat content of fuels in the space provided. Note that units of measurement and commonly accepted default values are provided.

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APPENDIX G

MAPPING A DHSM STUDY AREA AND CONSTRUCTING ITS GRID SYSTEM

Using the district heating strategy model (DHSM) assumes that two important preliminary tasks have been completed. The first task consists of selecting and mapping the area to be modeled. Depending on local conditions, this may be a region, city, or an area with obviously good potential for using a district heating and cooling system. The second task consists of overlaying the study area with a system of 1 km by 1 km grid squares. The grid squares describe the location of various features used in the model.

Step 1: Acquire or Produce a General Study-Area Map

This should be a large regional map showing at least three sets of geographical data.

- Boundaries of the study area selected by a local decision-making process -- but in no case containing more than 450 grid squares with demand data (174 square miles) within a total gridded area measuring at most 32 km from east to west and 50 km from north to south.
- Boundaries of political jurisdictions in the region.
- Natural physical barriers to development of a district heating system

Detailed descriptions of each of these map features are provided below. Other information (such as streets and highways) may be included but is not required. An example of a minimal general study-area map for a community is shown in Fig. G.1.

Before constructing a map, community energy planners should check to see if a usable map has already been produced by groups such as regional planning agencies, transportation authorities, the U.S. Geological Survey (USGS), or special metropolitan districts. Any large-scale map of the study area can be used provided it shows regional and political boundaries and barriers to development. The most useful base maps are the USGS 7-1/2 minute topographic maps, which can be fastened together to form a single map to cover large areas. For cities, the USGS maps may not have sufficient detail.

If a large study-area map must be drawn from scratch, community planners should be guided by certain principles in drawing required boundaries and showing other necessary information. The principles are described below.

Regional Boundaries. Examples of boundaries that can be used to define a study area for implementing district heating are those of a standard metropolitan statistical area (SMSA), a county, a city, or the jurisdiction of a regional planning commission. In an ideal situation these boundaries would coincide. Determining the appropriate study-area boundaries is a basic

Fig. G.1 Minimal Study-Area Map

political decision which, for the purposes of this discussion is assumed to precede the actual mapping procedure. If such a decision has not in fact been made prior to mapping, boundaries must be determined before mapping can proceed very far.

Political Jurisdictions. After the boundaries of the study area have been determined and mapped, the boundaries of each major political jurisdiction must be mapped. These include municipalities and counties.

Developmental Constraints. Next, planners must identify and map those physical features in a study area that could severely restrict or even bar the use of distribution piping for a district heating and cooling system. The following features represent such possibilities.

- Bodies of water: rivers, lakes, reservoirs, swamps, wetlands, and flood plains of significant land area -- all of which constitute current restraints in the development of a district heating system.
- Unsuitable terrain: mountains, steeply sloping areas, rock zones, cemeteries, areas of mudslide potential, etc. -- which actually bar development of a district system.
- Open space with a permanent no-development-allowed status: federal and state facilities and local reserves for sensitive environments.
- Other areas that cannot be developed: special local conditions may preclude development on certain parcels of land.

Power Plants. These include electric and thermal generating plants within about 15 miles of a study-area boundary; such plants might be considered thermal sources for a district heating and cooling system and should therefore be shown on the map.

Step 2: Plot a System of 1 km by 1 km Grid Squares

Using Cartesian Coordinates,* Establish the Grid System. Place transparent drawing material over the study-area map prepared in step 1 and locate a point at least 1 km west 1 km south of the region's boundary. This point will be your grid origin; record its coordinates as 1,1** and draw a pair of perpendicular lines through it. (See Fig. G.2.) Now draw a 1-km grid system, as shown in Fig. G.3. No more than 450 grid squares with demand data can be used in the DHSM, due to programming constraints. In addition, the 450 squares must be contained within a matrix whose total size is no larger than 32 km (east-west) by 50 km (north-south). Larger regions must be reduced in size.

Number the Grid Squares. Each square assigned demand data in the final grid system is to be given an identifying number. The numbering system used

*A system for locating a point in a plane by specifying its distance from two axes (x and y) at right angles to each other and intersecting at a point called an origin (0). Any Cartesian-coordinate system (such as state-plan coordinates or Universal Transverse Mercator) may be used if its use is well established in the region, if the origin is located at the southwest corner of the study area, and if all locations within the study area have positive x and y coordinates. Systems such as latitude and longitude cannot be used. If every grid square is not precisely 1 km · 1 km, then DHSM cost calculations for the transmission, loop, and distribution systems will not be correct.

**The first number represents the x, or east-west value; the second represents the y, or north-south, value.

for the map in Fig. G.3 is also shown in Fig. G.4. The numbering system is used for identification purposes. To facilitate locating grid squares on the map, they should be numbered from left to right starting on the bottom row of the matrix, then left to right on the row just above the bottom row, and so on. Only squares with demand data need be numbered.

Construct a Scenario. In developing scenarios for testing in the DHSM, the grid squares containing the highest thermal demands usually should be included. These squares need not be contiguous. Two hypothetical scenarios using the numbered map are shown in Figs. G.4 and Fig. G.5.

Power-plant locations must be specified using the same coordinate system so they can be put into the model. These locations must be exactly specified, not rounded to the nearest kilometer.

CARTESIAN COORDINATE SYSTEM

Fig. G.2 Cartesian Coordinates with Which Grid Squares are Superimposed on a Study-Area map

Fig. G.3 A DHSM Grid System Superimposed on a Hypothetical Study-Area Map

Fig. G.4 The Same Study-Area Map Shown in Fig. G.3, This Time with DHSM-Selected Grid Squares Numbered

Fig. G.5 The Same Map Shown in Figs. G.3 and G.4, This Time with Other Squares Numbered for Another DHSM Scenario†

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APPENDIX H

SAMPLE ANNOTATED COMPUTER OUTPUT FROM THE
DISTRICT HEATING STRATEGY MODEL

This appendix depicts and describes parts of a computer output for the DHSM run that was completed for Piqua, Ohio, a city of 20,030 located about 25 mi. north of Dayton. Piqua is in the early stages of building a district heating system. An output of the DHSM is fairly long because there are 31 different page formats, some of which are frequently repeated. Each format contains information useful to the analyst.

Formats identified as "data echoes" show the input data used for the scenario being studied, including all community characteristics and assumptions being tested. Formats identified as "calculation results" show the output data, or numbers generated by the model from information in the data echoes; the DHSM computer program performs the calculations.

H.1 ANNOTATED OUTPUT

DHSM output is not as formidable as it first appears. The 31 page formats that follow all provide useful data, although some are more useful than others. Table H.1 classifies the pages numbered 1,2,3,4,8,9,10,11,12,13, 14,19,20, and 25 as data echoes -- the term describes the function of these pages, repeating the input data. The echoes perform a useful function by simply presenting the data used by the community and ANL for making the run. The choices define the scenario.

The remaining 16 formats represent calculation results and thus provide a wealth of information about the community, scenario, and possible district heating and cooling system. These are also classified in Table H.1 according to specific area of output data.

The output is divided into four major groups, each focused on a module in the program. These four groups -- demand, supply, cost, and emissions -- are discussed in Secs. H.2 through H.5.

H.2. DEMAND OUTPUTS

Formats 5,6, and 7 show the energy demands for the community as a whole and for grid square subareas within the community. Format 15 (and 27-28 for fuel use) show demand calculations for the area within the scenario. The two major types of demands calculated are peak and annual.

Peak demands are the maximum quantities of heat needed at any specified time. Generally, peaks are used to calculate the size of equipment needed for the system. In the model, peaks are used to determine the power-plant retrofits required; units are converted to district heating until the peak demand is met. The model uses annual demands to calculate the quantity and cost of fuel needed for the existing situation and for future district heating and cooling.

Form DDFA

Name of Community: PIQUARecord A

A1. X co-ordinate(1) of western edge of grid (km):...	1
A2. National region number (from map DDFA1):.....	2
A3. Length of heating season (hours):.....	5860
A4. Seasonal heating degree days for the community:..	6000
A5. Minimum design temperature for heating (deg. F):..	6.000
A6. Maximum design temperature for cooling (deg. F):..	90.00
A7. Mean coincident wet bulb temperature (deg. F):...	75.00
A8. Annual cooling degree days (see map DDFA12):.....	1200

A9. Space heating demand factor scaling(2)-

1. Natural gas -	
Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000
2. Oil -	
Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000
3. Coal -	
Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000
4. Electricity -	
Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000
5. Existing district steam system -	
Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

1 Round to nearest whole kilometer.

2 Values of unity are recommended (in order to obtain the default values), unless special local knowledge is available.

PAGE FORMAT 1

DATA ECHO

- Describing climatic data input from ANL.
- Describing demand data input from the Community Demand Data Sheet.
- Only one page of output will have this format.

A10. Hot water demand scaling(3) by building type -

Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

A11. Cooling demand scaling(4)-

Electric:.....	1.000
Existing district steam:.....	1.000

A12. Floor space scaling(5) by building type -

Residential low density heating & h.w.:.....	1.000
Residential high density heating & h.w.:.....	1.000
Commercial/Institutional heating & h.w.:.....	1.000
Industrial heating & h.w.:.....	1.000
Large building cooling:.....	1.000

A13. Industrial process heat demand scale factor(6):.. 1.000

A14. Fuel mix scaling -

1. Natural gas -

Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

2. Oil -

Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

3. Coal -

Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

4. Electricity -

Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

5. Existing district steam system -

Residential low density:.....	1.000
Residential high density:.....	1.000
Commercial/Institutional:.....	1.000
Industrial:.....	1.000

3 Values of unity are recommended (in order to obtain the default values), unless special local knowledge is available.

4 as above

5 as above

6 as above

PAGE FORMAT 2

DATA ECHO

- Describing data input from the Community Data Base Sheet.
- Only one page of output will have this format.

Form DDFBC

Name of Community: PIQUARecord B

B1. X co-ordinate of southwest corner of gridsquare

to the nearest kilometer:..... 3

B2. Y co-ordinate of southwest corner of gridsquare

to the nearest kilometer:..... 3

B3. Floor space by building type (in millions of square feet) -

Residential low density heating & hot water:..... .4730Residential high density heating & hot water:..... 7.700E-02Commercial/Institutional heating & hot water:..... .1460Industrial heating & hot water:..... .1650Large building cooling:..... .1175

B4. Industrial low temperature (<200 deg. F) process

heat requirements which may be met by a district

heating system in units of billion Btu/year:..... 11.83B5. Equivalent stack height for emissions (meters):... .0Record C

C1. Fuel mix by building and end-use category(1)-

1. Residential low and high density - Heating only -

Do Natural gas:..... .8500these Oil:..... 4.100E-02sum Coal:..... 3.000E-03to Electricity:..... 9.100E-02unity? Existing district steam:..... 1.500E-02

2. Residential low and high density - Hot water only -

Do Natural gas:..... .8500these Oil:..... 4.100E-02sum Coal:..... 3.000E-03to Electricity:..... 9.100E-02unity? Existing district steam:..... 1.500E-02

3. Commercial/Institutional - Heating and hot water -

Do Natural gas:..... .8510these Oil:..... 1.500E-02sum Coal:..... 4.000E-03to Electricity:..... .1030unity? Existing district steam:..... 2.700E-02

4. Industrial - Heating and hot water -

Do Natural gas:..... .4090these Oil:..... .1890sum Coal:..... .0to Electricity:..... .3670unity? Existing district steam:..... 3.500E-02

1 The sum over fuel types in a given category should equal unity.

PAGE FORMAT 3

DATA ECHO

- Describing data input from the community that is used to determine heat demands for one grid square; from the Grid Square Demand Data Sheet.
- There is one page of output like this for each grid square on the community's grid map.
- The remaining pages like this one for Piqua have been removed to shorten this description. The Piqua study included 54 grid squares.

C2. Air conditioning mix by floorspace fractions(2)-

Electricity:.....	1.000
Existing district steam:.....	.0

C3. Fraction(3) of industrial process heat final demand met by various fuels -

Do	Natural gas:.....	.6470
these	Oil:.....	.2980
sum	Coal:.....	.0
to	Electricity:.....	.0
unity?	Existing district steam:.....	5.500E-02

PAGE FORMAT 4

DATA ECHO

- Describing community data input used to determine heat demands for one grid square; from the Grid Square Demand Data Sheet.
- This page format appears only for grid squares the community has indicated demand large-building air conditioning or industrial process heat.
- Again, many pages similar to this one appear in the Piqua example; for purposes of brevity, only one is shown here.

2 These two fractions should sum to unity.

3 Fractions should sum to unity.

PAGE FORMAT 5

CALCULATION RESULTS (described below)

19 1 3
 RESIDENTIAL LOW DENSITY HEATING & HOT WATER
 RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
 COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
 INDUSTRIAL HEATING & HOT WATER
 LARGE BUILDING COOLING
 INDUSTRIAL PROCESS

20 2 3
 RESIDENTIAL LOW DENSITY HEATING & HOT WATER
 RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
 COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
 INDUSTRIAL HEATING & HOT WATER
 LARGE BUILDING COOLING
 INDUSTRIAL PROCESS

21 3 3
 RESIDENTIAL LOW DENSITY HEATING & HOT WATER
 RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
 COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
 INDUSTRIAL HEATING & HOT WATER
 LARGE BUILDING COOLING
 INDUSTRIAL PROCESS

- Several pages like this one describe the heat demands in each of the community's grid squares. Demands are shown broken down by various demand types and fuels.

- This half page shows results from Piqua's grid squares 19, 20, and 21.

- Note that each building type has its own line.

- The number of pages of output with this format will equal the number of grid squares divided by six.

Grid
square
number

Coordinates
of the grid
square, X
and Y axes,
respectively.

Data
Echo
of floor-
space data
input from
the commun-
ity.

Calculated annual demands
for various fuel types.

As an example, this figure shows that each year 850 million Btu of final demand for space and water heating is met by natural gas in the residential low-density structures of grid square 19. To find the fuel demand in Btu, the 850 million must be divided by the efficiency factor for natural-gas equipment.

PEAK DEMAND
(THERMAL HW)

HNTR. SUMR.

ELECTRIC CREDITS
ENERGY CAPACITY(MW)

GNH/Y HNTR. SUMR.

NONHNTR
FIN. DEM
B.BTU/Y

FLOORSPACE MILLIONSQFT	FINAL DEMANDS BILLION BTU/Y					PEAK DEMAND (THERMAL HW)		ELECTRIC CREDITS ENERGY CAPACITY(MW)			NONHNTR FIN. DEM B.BTU/Y
	GAS	CIL	COAL	ELECT.	DSS.	HNTR.	SUMR.	GNH/Y	HNTR.	SUMR.	
0.0110	0.85	0.04	0.00	0.05	0.01	0.10	3.61	0.02	0.01	0.00	0.05
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
0.0070	0.40	0.01	0.00	0.02	0.01	0.05	3.60	0.01	0.00	0.00	0.01
0.0200	0.33	0.14	0.0	0.11	0.05	0.08	3.60	0.03	0.01	0.00	0.01
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
0.0	0.91	0.42	0.0	0.0	0.08	0.05	3.65	0.0	0.0	0.0	0.47
0.0130	1.00	0.05	0.00	0.06	0.02	0.12	3.61	0.02	0.01	0.00	0.06
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
0.0200	1.15	0.02	0.01	0.05	0.04	0.14	3.60	0.01	0.01	0.00	0.02
0.0980	1.86	0.70	0.0	0.52	0.25	0.38	3.61	0.17	0.06	0.00	0.06
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
0.0	4.58	2.11	0.0	0.0	0.39	0.24	3.24	0.0	0.0	0.0	2.34
0.4730	36.37	1.70	0.13	2.31	0.60	4.36	3.22	0.75	0.25	0.02	2.19
0.0770	3.77	0.18	0.01	0.25	0.10	0.42	3.64	0.08	0.02	0.00	0.36
0.1460	8.38	0.12	0.04	0.33	0.29	1.05	3.62	0.11	0.04	0.00	0.17
0.1650	3.14	1.13	0.0	0.88	0.42	0.65	3.61	0.29	0.11	0.00	0.11
0.1175	0.0	0.0	0.0	5.34	0.0	0.0	1.20	0.83	0.0	0.63	5.34
0.0	7.66	3.53	0.0	0.0	0.65	0.40	3.40	0.0	0.0	0.0	3.92

Summer and
winter peak
thermal
demands,
the maximum
heat re-
quired at
any one
point in
time
(instantan-
eous peak).

Electric capacity
currently serving
heating require-
ments. District
heating/cooling
will, in effect,
eliminate the need
for this capacity.
Total annual sav-
ing are shown in
gigawatt-hours per
year; reductions
in seasonal capaci-
ties are shown in
megawatts.

The nonwinter
final demand
(billion Btu per
yr) shows the
amount of heat
required by the
city during non-
winter hours; use-
ful as a gauge of
year-round demand.

DISTRICT HEATING --- DEMAND --- CITY: PIQUA

PAGE FORMAT 6

CALCULATION RESULTS (see below)

DEMAND FACTORS, 1000 BTU/SQFT

	SPACE HEATING				HOT	LARGE BUILDING COOLING
	GAS	OIL	COAL	ELEC.	DSS. WATER	ELEC. DSS.
RESIDENTIAL LOW DENSITY HEATING & HOT WATER	76.5	73.5	75.5	39.7	70.6	14.0
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER	43.5	43.5	43.5	21.3	70.6	14.0
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER	63.9	51.3	62.9	18.4	70.6	3.6
INDUSTRIAL HEATING & HOT WATER	44.5	35.8	43.5	12.6	70.6	2.0

DATA ECHO: demand-factor input from community or, if defaulted, inserted by the model.

SUMMARY RESULTS FOR THE CITY OF PIQUA

	FLOORSPACE MILLIONSQFT	FINAL DEMANDS BILLION BTU/Y				PEAK DEMAND (THERMAL MW)		ELECTRIC CREDITS ENERGY CAPACITY(MW)		NONWTR FIN. DEM	
		GAS	OIL	COAL	ELEC.	DSS.	WTR.	SUMR.	WTR.	SUMR.	B.BTU/Y
RESIDENTIAL LOW DENSITY HEATING & HOT WATER	9.962	765.9	35.8	2.7	48.7	12.6	91.8	4.7	15.8	5.3	0.5
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER	0.436	21.3	1.0	0.1	1.4	0.6	2.4	0.2	0.5	0.1	0.0
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER	3.881	222.8	3.2	1.0	8.8	7.8	23.0	0.5	2.9	1.0	0.1
INDUSTRIAL HEATING & HOT WATER	3.293	62.6	23.5	0.0	17.6	8.4	12.9	0.2	5.7	2.1	0.1
LARGE BUILDING COOLING	3.698	0.0	0.0	0.0	168.1	0.0	0.0	37.6	26.1	0.0	19.9
INDUSTRIAL PROCESS	0.0	185.2	85.3	0.0	0.0	15.7	9.6	9.6	0.0	0.0	0.0

CALCULATION RESULTS:

Final demands and other data (as in FORMAT 5) but for the entire community rather than each grid square. Explanations of column headings may be found on FORMAT 5.

21.270 1257.9 148.8 3.8 244.6 45.1 144.7 52.8 51.0 8.6 20.5 317.9

THE FOLLOWING BUILDING TYPES ARE INCLUDED IN THE PEAK DEMAND MAP:

RESIDENTIAL LOW DENSITY HEATING & HOT WATER
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
INDUSTRIAL HEATING & HOT WATER
LARGE BUILDING COOLING
INDUSTRIAL PROCESS

The community's peak demand map is shown in FORMAT 7. This provides a list of the user-specified building types considered in the map. Peak demand is the instantaneous thermal peak.

THE ARITHMETIC AVERAGE PEAK DEMAND OVER ALL 54 GRIDSQUARES IS 2.7 THERMAL MEGAWATTS.

IN EACH GRIDSQUARE ON THE MAP, THE UPPER FIGURE IS THE GRIDSQUARE NUMBER, AND THE LOWER IS PEAK DEMAND IN MEGAWATTS.

There will be only one page of output with this format.

DISTRICT HEATING --- DEMAND --- CITY: PIEUA

	1	2	3	4	5	6	7	8	9
	46	47	48	49	50	51	52	53	54
	0	0	0	1	0	1	1	2	1
6	37	38	39	40	41	42	43	44	45
	0	1	3	9	9	1	1	1	0
5	28	29	30	31	32	33	34	35	36
	0	3	7	10	23	10	2	2	0
4	19	20	21	22	23	24	25	26	27
	0	1	7	11	13	6	1	0	0
3	10	11	12	13	14	15	16	17	18
	0	0	5	2	5	1	0	0	0
2	1	2	3	4	5	6	7	8	9
	0	0	0	0	0	0	0	0	0
1									

PAGE FORMAT 7

CALCULATION RESULTS:

- Peak demand map, showing coordinates and demands per square kilometer; upper figure is grid-square number, lower is its peak demand in megawatts.
- The densest peak demands are in the central city, with a surrounding area of fairly high demands.
- Only one page of output will have this format.

Form SDFAName of Community: PIQUAScenario name (8 character code): WS08Record A

A1. Will all available grid squares (as defined in forms DDFBC) be used in this scenario? (Enter T for true, F for false.):.....F
If answer to above is F, attach form SDFB.

A2. Sectors to be included in this scenario - (T if to be included, F otherwise)
Residential low density:.....T
Residential high density:.....T
Commercial/Institutional:.....T
Industrial space heat:.....T
Large building cooling:.....T
Industrial process heat:.....T

A3. District heating costing(1) (use "1" - low):.....1

A4. Fraction of electrical replacement costs due to district heating system:......5000

Note:

All escalation and inflation rates are expressed as decimal fractions, not percent.

A5. Real escalation rate for electricity:.....1.000E-02
A6. Real escalation rate for district steam:.....1.000E-02
A7. Start of D.H. construction (calendar year):.....1980
A8. In-service year for district heating system:.....1983
A9. Lifetime of D.H. system (years):.....30
A10. Capital recovery period for DH system (years):.....30
A11. Escalation rate for fuels -
Nuclear:.....1.000E-02
Coal:.....2.000E-02
Residual oil:.....3.000E-02
Distillate oil:.....3.000E-02
Natural gas:.....3.000E-02
Other fuels(2):.....2.000E-02

1 Selects certain costing defaults.

2 "Other fuels" refers to any significant fuel not already covered under the preceding fuel categories.

PAGE FORMAT 8DATA ECHO

- Explaining the scenario under study; from the Scenario Definition Sheet, with data input from community and ANL.
- Only one page of output will have this format.

Form SDFA

District Heating & Cooling

Form SDFA

A12. Escalation rate for O&M costs:..... 5.000E-03
A13. Escalation rate for capital costs:..... 2.000E-02
A14. Discount rate for present value calculations:.... 1.000E-02
A15. General inflation rate:..... 7.000E-02
A16. Utility pre-tax rate of return:..... 8.000E-02
A17. Utility A.F.C. rate (for capitalization
of interest during construction):..... 8.000E-02
A18. Cost ceiling (\$/MMBtu) on delivered energy
for plants converted to district heating:..... 20.00
A19. Reserve margin (fraction of thermal peak):..... .0

PAGE FORMAT 9

DATA ECHO

- Showing a continuation of economic assumptions governing the scenario; from the Scenario Definition Sheet, with input from community and ANU.
- Only one page of output will have this format.

Form SDFBName of Community: PICUAScenario name (8 character code): HS08

This form is required if and only if question SDEA.A1 was answered "false".

Record B

B1. Number of gridsquares to be included
in this scenario:.....12

B2. List gridsquare numbers to be included in
this scenario. (Refer to demand input or
demand output maps for numbers;
order listed is not critical.)

12 14 21 22 23 24 30 31 32 33

40 41

PAGE FORMAT 10**DATA ECHO**

- Showing a continuation of scenario description, delineating grid squares included in the analysis; from the Boundary Identification Sheet, with input from community and ANL.
- Only one page of output will have this format provided the answer to A1 on FORMAT 8 is F. If T, FORMAT 10 will not appear.

Form SDFCD

District Heating & Cooling

Form SDFCD

Form SDFCD

New baseload boiler definition

Name of Community: PIQUAScenario name (8 character code): HS03 Record C

C1. Boiler fuel type(1) code:..... 2
 C2. Plant co-ordinates(2) -
 X co-ordinate (km units):..... 6.100
 Y co-ordinate (km units):..... 2.900
 C3. Fuel price(3) (\$/MMBtu):..... 1.790
 C4. Thermal heat rate (MBtu/kWh):..... 4.300
 C5. New Boiler Cost (Low) (\$/kW):..... 90.00
 C6. New Boiler Cost (High) (\$/kW):.....
 C7. O&M Cost For New Boiler (Low) (\$/kW):..... 3.000
 C8. O&M Cost For New Boiler (High) (\$/kW):.....

Record D (Required if SDFCD.C1 = 2,3,or 4.)

D1. Weight percent sulfur in fuel:..... 1.000
 D2. If SDFCD.C1=2, then enter
 weight percent ash in fuel:..... 8.000

 1 Codes are : 1 - nuclear (not available),
 2 - coal,
 3 - residual oil,
 4 - distillate oil, and
 5 - natural gas.

2 Plant location in kilometers.
 These values should not be rounded to the
 nearest kilometer.

3 1980 dollars.

PAGE FORMAT 11

DATA ECHO

- Describing new boiler location and other parameters; input from ANL.
- One page of output will have this format because only one new baseload boiler may be used in the model.
- The reason for specifying a new baseload boiler is to enable the model to add new capacity to service all the demand specified in the service district boundary if a station's capacity would otherwise be too low.

Form SDFE

Name of Community: PIQUAScenario code: NS08Name of Station: PHPS1

Record E

E1. Station code name (limit 8 characters):.....PHPS1E2. Number of units at this station:.....6E3. Station co-ordinates¹⁾ -X co-ordinate (km units):.....6.100Y co-ordinate (km units):.....2.900

1 Plant location in kilometers.
These values should not be rounded to the
nearest kilometer.

PAGE FORMAT 12

DATA ECHO

- Describing an electric generating station that may provide heat to the district heating and cooling system; from the Electric Generating Station Data Sheet.
- There will be several pages of output with FORMAT 12, one for each electric generating station being considered in the community. One FORMAT 12 will precede a number of FORMAT 13s, the FORMAT 12 page describing the whole station and the FORMAT 13 pages describing the units within the station.

Form SDDFG

Name of Community: PIQUAScenario: HS08Station code: PMPS1Name of unit: ST4Record F

- F1. Turbine type(1)-
Description: SINGLE-CASE ; Code:..... 1
- F2. Fuel type(2)-
Description: COAL ; Code:..... 2
- F3. New source performance status (Schedule NSPS):..... 0
- F4. Is this unit a candidate for retrofit?
(Enter T for true, F for false.):..... T
- F5. Normal winter capacity factor:..... .6830
- F6. Normal annual capacity factor:..... .6710
- F7. Fuel price in 1980 dollars per MMBtu:..... 1.790
- F8. Unit code name (limit 4 characters):..... ST4
- F9. Turbine/Boiler Retrofit Cost (Low) (\$/kW):..... 41.85
- F10. Turbine/Boiler Retrofit Cost (High) (\$/kW):.....
- F11. Electric Capacity Replacement Cost (Low) (\$/kW):..... 314.0
- F12. Electric Capacity Replacement Cost (High) (\$/kW):.....

Record G

- G1. Unit capacity in megawatts:..... 7.500
(MW electric if SDDFG.F1=1,2,or 3; MW thermal otherwise.)
- G2. Unit heat rate (thousand Btu/kWh):..... 12.60

1 Turbine types are

- 1 - single-case steam turbine,
- 2 - multi-case steam turbine,
- 3 - combustion turbine, and
- 4 - heating boiler only.

2 Fuel types are

- 1 - nuclear,
- 2 - coal,
- 3 - residual oil,
- 4 - distillate oil,
- 5 - natural gas, and
- 6 - other fuel, not encompassed by types 1-5.

PAGE FORMAT 13

DATA ECHO

- Describing a single unit within the station described in the earlier FORMAT 12; from the Unit Definition Data Sheet.
- For each FORMAT 12, the number of pages with FORMAT 13 will equal the number of units within the station being described.

63. Percent sulfur in fuel (%):..... 1.000
64. Percent ash in fuel (%):..... 8.000
65. Emissions control (per cent) -
 1. particulates(%):..... 99.80
 2. SOx(%):..... 99.80
 3. NOx(%):..... 99.80
66. Emissions (tons/MMBtu) -
 1. particulates:.....
 2. SOx:.....
 3. NOx:.....

PAGE FORMAT 14

DATA ECHO

- Showing a continuation of *FORMAT 13*, with information needed to run the emissions portion of the model; from the Unit Definition Data Sheet.
- If the emissions portion is used, each *FORMAT 13* will also have a *FORMAT 14*, the total number of *FORMAT 14* pages being equal to the total number of units in the community.

DISTRICT HEATING --- SUPPLY --- CITY: PIQUA --- SCENARIO: HS08

COST SCENARIO: LOW

THE FRACTION ELECTRIC CAPACITY COSTS ASCRIBED TO THE D.H.S. SCENARIO IS 0.500

THE DISTRICT STEAM SYSTEM SCENARIO'S ENERGY FRACTION IS 0.734

THE DISTRICT STEAM SYSTEM SCENARIO'S CAPACITY FRACTION IS 0.754

PAGE FORMAT 15

THE FOLLOWING BUILDING TYPES ARE INCLUDED IN THIS RUN:

RESIDENTIAL LOW DENSITY HEATING & HOT WATER

RESIDENTIAL HIGH DENSITY HEATING & HOT WATER

COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER

INDUSTRIAL HEATING & HOT WATER

LARGE BUILDING COOLING

INDUSTRIAL PROCESS

THIS RUN USED ONLY THE FOLLOWING 12 GRID SQUARES IN PIQUA :

12 14 21 22 23 24 30 31 32 33 40 41

OUTPUT FINANCIAL ASSUMPTIONS

FIXED CHARGE RATE: 8.9%

DISCOUNT RATE (REAL): 1.0%

INFLATION RATE: 7.0%

REAL ESCALATION RATES

CAPITAL: 2.0%

OSM: 0.5%

FUELS:

NUC 1.0%

COAL 2.0%

RES 3.0%

DIST 3.0%

GAS 3.0%

MISC 2.0%

START OF CONSTRUCTION: 1980

IN-SERVICE DATE: 1983

RATE OF RETURN: 8.0%

A.F.C. RATE: 8.0%

CAPITAL RECOVERY PERIOD: 30 YEARS

LIFETIME OF SYSTEM: 30 YEARS

DATA ECHO (above line only)

- Describes financial and other operating assumptions; from the Scenario Definition Sheet, with input from community or ANL.
- Only one page of output will have this setup.
- Indicates grid squares used in the scenario from Scenario Definition Sheet.

END USES

FINAL DEMAND, TRILLION BTU

HEATING & HOT WATER 1.0

LARGE BUILDING COOLING 0.1

INDUSTRIAL PROCESS 0.2

TOTALS 1.3

THERMAL DEMAND FOR 250 DEG.F. HOT WATER 1.4 TRILLION BTU

	ELECTRICAL GENERATION GWH	HEATRATE MMBTU/MWH	FRACTION ELECTRIC ENER.CR.	THERMAL GENERATION GWH	HEATRATE MMBTU/MWH
ANNUAL	271.	12.917	0.132	131.	5.250
WINTER	186.	13.004	0.106	94.	5.250

CALCULATION RESULTS (below line only)

- Describes basic supply/demand data for the scenario and limited number of grid squares being considered.
- Thermal demand limited to the grid squares listed in the data echo above.
- Factors in conversion of efficiency losses, including those due to absorption cooling at 67% efficiency.

DISTRICT HEATING --- SUPPLY --- CITY: PIQUA --- SCENARIO: WS08

ALL COSTS ARE IN 1980 PRESENT WORTH DOLLARS OVER LIFETIME OF D.H.S., EXCEPT WHERE OTHERWISE NOTED.
STATIONS WHOSE COST IS LESS THAN \$ 20.00 PER MMBTU

RANK	STATION FUEL	ELECTRIC CAPACITY THERMAL (IN MEGAWATTS) CAPACITY ORIGINAL W/D.H. (MW)			BASE D.H.S THERMAL FUEL FUEL EN.DEL. (TR.BTU)(TR.BTU)(TR.BTU)			ANNUAL COSTS IN MILLIONS OF DOLLARS							\$/MMBTU	
		TRANSM.	RETRO ELECTRIC OR CAP REPLACE	PLANT O&M	TRANSM. O&M	FUEL	TOTAL									
1	GEO THERM MISC	0.0	0.0	15.08	0.552	0.405	0.237	0.012	0.008	0.0	0.021	0.003	0.477	0.521	2.286	
2	PHPS1 COAL	40.17	18.22	88.44	3.251	1.277	1.115	0.017	0.024	0.048	0.382	0.004	2.695	3.170	2.953	
TOTAL	Station Identifiers from FORMAT 12.	40.17	18.22	103.52	3.803	1.682	1.352	0.030	0.032	0.048	0.402	0.007	3.172	3.691	2.731	
This shows the rank order of stations and units that may be retro-fitted, from best to worst in terms of cost.		Shows the derating, or loss, of electric generating capacity due to retrofit, and the gain in peak thermal power for the district heating system.			BASE FUEL shows the annual quantity of fuel used at the plant for electric generation currently. DHS FUEL shows the additional fuel required to operate in the cogeneration mode.			Shows costs for the retrofit of plants and construction of the transmission system. The TRANSM (transmissions) costs represent the annual costs of debt service and repayment of principal. RETRO or CAP provides costs for adapting the present units to cogeneration mode. ELECTRIC REPLACE shows costs for adding new electric generating equipment to make up for the derating caused by district heating. PLANT AND TRANSM O&M show operating and maintenance costs for these two items. FUEL shows annual fuel costs, a minus sign indicating a decrease in costs. These, it must be noted, are total costs at the thermal plants, not community-wide total costs for fuels.							Shows cost per million Btu of heat energy. Useful for evaluating costs from the different plants and between scenarios. Provides a common basis for comparison.	
NUCL = nuclear COAL = coal RESI - residual oil DIST = distillate oil GAS = natural gas GEO THERM = geothermal MISC = other fuel					THERMAL EN. DEL. shows the thermal output of the plants after retrofit.											

NOTE: ABOVE REFLECTS 38.0% OF THE AVAILABLE PHPS1 COAL THERMAL OUTPUT USED FOR SPECIFIED DEMAND. ITS CAPACITIES HAVE NOT BEEN SCALED BY 38.0% HERE, HOWEVER. IN CALCULATING THERMAL PEAKING STATION CAPACITY AND PEAK THERMAL CAPACITY (SEE NEXT TABLE), ONLY THE THE SCALED PORTION OF PHPS1 COAL IS USED.
FOR A MATCH OF SUPPLY AND DEMAND, USE THE FOLLOWING PARAMETERS.
95.1 MEGAWATTS OF DEMAND TO BE ELIMINATED, OR
155.1 MEGAWATTS OF DEMAND TO BE ADDED.

In some runs, this note will show that the demand to be met by these units is less than the supply these units can provide. The underutilization suggests that the system may be run more efficiently if demand is dropped (95.1 MW) or added (155.1 MW) by adding to or subtracting from the number of grid squares in the scenario.

PAGE FORMAT 16 - CALCULATION RESULTS

- Describes engineering calculations and economic results for all stations that can provide thermal power at or below a ceiling price specified by the community.

- The number of plants and units, and thus the number of pages with FORMAT 16, will vary depending on the community, scenario, and ceiling price. Plants shown will supply entire demand in the scenario's grid squares.

Note: 1980 dollars

DISTRICT HEATING --- SUPPLY --- CITY: PIQUA --- SCENARIO: WSJ8

A TOTAL WINTER ELECTRIC DERATING	8.35 MEGAWATTS	TOTAL SUMMER ELECTRIC DERATING	7.73 MEGAWATTS
B NET WINTER ELECTRIC CAPACITY LOSS	1.58 MEGAWATTS	NET SUMMER ELECTRIC CAPACITY LOSS	0.0 MEGAWATTS
C WINTER ELECTRIC CAPACITY CREDIT	6.76 MEGAWATTS	SUMMER ELECTRIC CAPACITY CREDIT	12.59 MEGAWATTS

D CAPACITY PERMANENTLY DERATED 21.95 MEGAWATTS

	CAPACITY MEGAWATTS	ANNUAL CAPITAL COSTS, \$MILLION	INVESTMENT COSTS/KWH CURR\$	BOILERS INCLUDED
E THERMAL PEAKING STATIONS				
F NEW PEAKING BOILER	79.44	0.09	38.14	
TOTALS	79.44	0.09	38.14	

G ANNUAL THERMAL ENERGY DELIVERED 1.35 TRILLION BTU

PEAK WINTER THERMAL DEMAND 115.33 MEGAWATTS

H PEAK SUMMER THERMAL DEMAND 45.13 MEGAWATTS

PEAK THERMAL CAPACITY 128.14 MEGAWATTS

I THERMAL RESERVE ON PEAK -0.00%

PAGE FORMAT 17

CALCULATION RESULTS

- Describes changes in electric generating capacity due to district heating.
- Describes new boiler required, if any.
- Describes peak demands for scenario.
- Only one page of output will have this format.

LINE BY LINE DESCRIPTION

- Shows the seasonal loss in electric generating capacity, total -- which does not include consideration of the electric demand that will be reduced by the district heating system.
- Shows the seasonal loss in capacity, net -- which does take the demand reduction into consideration.
- Shows the reduction in demand for electricity due to district heating/cooling.
- Shows capacity permanently lost, due to conversion of single-stage turbines to cogeneration. Other turbines may be used to generate their full electric capacity if heat is not required.
- Shows costs for new boiler capacity needed to meet peak loads.
- System-wide annual thermal energy delivered.
- Seasonal peak demands, system wide.
- Peak supply available, system wide.
- Indicates whether the system, as designed, has thermal reserve built in.

ADISTRICT HEATING --- SUPPLY --- CITY: PIQUA --- SCENARIO: WS03

ALL COSTS ARE IN 1980 PRESENT WORTH DOLLARS OVER LIFETIME OF D.H.S., EXCEPT WHERE OTHERWISE NOTED.
STATIONS WHOSE COST IS AT LEAST \$ 20.00 PER MMBTU, OR WHOSE ENERGY IS NOT NEEDED

ANNUAL COSTS IN MILLIONS OF DOLLARS																
RANK	STATION	FUEL	ELECTRIC CAPACITY (IN MEGAWATTS)		THERMAL CAPACITY (MM)	BASE FUEL (TR.BTU)	D.H.S FUEL (TR.BTU)	THERMAL EN.DEL. (TR.BTU)	-----							
			ORIGINAL	M/D.H.					TRANSM.	RETRO OR CAP REPLACE	ELECTRIC	PLANT Q&H	TRANSM. Q&H	FUEL	TOTAL	\$/MMBTU
3	PHPS1	DIST	20.00	18.00	40.00	0.381	0.041	0.156	0.037	0.010	0.011	0.059	0.009	0.323	0.443	2.934
	PHPS1	COAL	[1]	[1]	3.0	[1]	0.04	0.02	0.02	0.00	0	0.01	0.01	0.03	0.11	5.55
	GEOTHERM	MISC	[1]	[1]	4.9	[1]	0.15	0.09	0.01	0.00	0	0.01	0.00	0.17	0.20	2.44

[1] THESE ARE PORTIONS OF EXISTING UNITS' D.S.S. ENERGY AND FUEL (26.6%) AND CAPACITY (24.6%) WHICH ARE NOT AVAILABLE FOR THE D.H.S. SCENARIO, SINCE 73.4% OF EXISTING STEAM SYSTEM ENERGY AND FUEL USE, AND 75.4% OF WINTER PEAK DEMAND, IS INSIDE THE D.H.S. SCENARIO. ORIGINAL AND RETROFIT ELECTRIC CAPACITY AND BASE FUEL USE ARE ALREADY ACCOUNTED FOR IN ABOVE LISTS OF ACCEPTED OR REJECTED PLANTS.

PAGE FORMAT 18

66

CALCULATION RESULTS

- Sketches engineering information about the remaining plants and units. The plants and units listed here either:
 - (1) have no thermal energy available because they are located far outside the scenario boundaries, or
 - (2) are expensive to operate and thus less feasible from a cost standpoint than the other plants.
- Only one page of output will have this format.

Form EDFA
Emissions input data

Name of Community: PIQUA

Record A

A1. Is NEDS point source output data available?
(Enter T if true, F if false.):..... F

A2. Fuel efficiencies(1) by fuel type and end use -

1. Natural gas -

Residential low density:.....	<u>.5780</u>
Residential high density:.....	<u>.5780</u>
Commercial/Institutional:.....	<u>.5780</u>
Industrial space heat:.....	<u>.5780</u>
Large building cooling:.....	<u>XXXXXXXXXX</u>
Industrial process heat:.....	<u>.5780</u>

2. Oil -

Residential low density:.....	<u>.5540</u>
Residential high density:.....	<u>.5540</u>
Commercial/Institutional:.....	<u>.5540</u>
Industrial space heat:.....	<u>.5540</u>
Large building cooling:.....	<u>XXXXXXXXXX</u>
Industrial process heat:.....	<u>.5540</u>

3. Coal -

Residential low density:.....	<u>.5000</u>
Residential high density:.....	<u>.5000</u>
Commercial/Institutional:.....	<u>.5000</u>
Industrial space heat:.....	<u>.5000</u>
Large building cooling:.....	<u>XXXXXXXXXX</u>
Industrial process heat:.....	<u>.5000</u>

4. Electricity -

Residential low density:.....	<u>.0</u>
Residential high density:.....	<u>.0</u>
Commercial/Institutional:.....	<u>.0</u>
Industrial space heat:.....	<u>.0</u>
Large building cooling:.....	<u>.0</u>
Industrial process heat:.....	<u>.0</u>

5. Existing district steam system -

Residential low density:.....	<u>.0</u>
Residential high density:.....	<u>.0</u>
Commercial/Institutional:.....	<u>.0</u>
Industrial space heat:.....	<u>.0</u>
Large building cooling:.....	<u>.0</u>
Industrial process heat:.....	<u>.0</u>

1 These are end-use efficiencies (decimal). To obtain the default values, simply leave blank.

PAGE FORMAT 19

DATA ECHO

- Showing emissions input from the community, for the Emissions Input Data Sheet.
- Only one page of output will have this format.

Form EDFBName of Community: PIQUARecord B

B1. Distillate fraction of oil use by end-use -

Residential low density:	1.000
Residential high density:	1.000
Commercial/Institutional:	.7700
Industrial space heat:	.6100
Industrial process heat:	.6100

B2. Percent sulfur by weight in distillate oil -

Residential low density:	.2000
Residential high density:	.2000
Commercial/Institutional:	.2000
Industrial space heat:	.2000
Industrial process heat:	.2000

B3. Percent sulfur by weight in residual oil -

Residential low density:	.8000
Residential high density:	.8000
Commercial/Institutional:	.8000
Industrial space heat:	.8000
Industrial process heat:	.8000

B4. Percent sulfur by weight in coal by sector -

Residential low density:	.7000
Residential high density:	.7000
Commercial/Institutional:	.7000
Industrial space heat:	.7000
Industrial process heat:	.7000

B5. Percent ash by weight in coal by sector -

Residential low density:	1.300
Residential high density:	1.300
Commercial/Institutional:	1.300
Industrial space heat:	1.300
Industrial process heat:	1.300

B6. Heat content of coal(1) (MMBtu/ton):..... 24.00

B7. Heat content of residual oil(2) (MMBtu/kgal):.... 148.0

B8. Heat content of distillate oil(3) (MMBtu/kgal):.. 137.0

B9. Heat content of nat gas(4) (MMBtu/million cu.ft): 1030.

1 Typical value for coal: 24 MMBtu/ton.

2 Typical value for residual oil: 148 MMBtu/thousand gallons.

3 Typical value for distillate oil: 137 MMBtu/thousand gallons.

4 Typical value for natural gas: 1000 MMBtu/million cubic feet.

PAGE FORMAT 20

DATA ECHO

- Showing a continuation of FORMAT 19; from the Emissions Input Data Sheet.
- Only one page of output will have this format.

DISTRICT HEATING --- EMISSIONS --- CITY: PIQUA --- SCENARIO: WS08

	BEFORE DISTRICT HEATING				AFTER DISTRICT HEATING			
	ANNUAL FUELUSE TR.BTU	EMISSIONS PART.	IN TONS/YEAR SO _x	NO _x	ANNUAL FUELUSE TR.BTU	EMISSIONS PART.	IN TONS/YEAR SO _x	NO _x
NEHBLBLR COAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHPS1 COAL DISTIL.	3.25 0.38	17.3 7.0	5.1 4.9	2.4 94.4	4.02 0.33	21.4 6.0	6.4 4.2	3.0 82.0
GEOOTHERM MISC.	0.55	0.0	0.0	0.0	0.55	0.0	0.0	0.0

PAGE FORMAT 21

CALCULATION RESULTS

- Shows emissions, fuel use, and fuel types for each station and unit considered for retrofit.
- The number of pages of this type will depend on the number of units considered.
- Emissions in tons per year; PART signifies particulate matter, SO_x signifies sulfur oxides, and NO_x signifies nitrogen oxides.

	BEFORE DISTRICT HEATING				AFTER DISTRICT HEATING			
	ANNUAL FUELUSE TR.BTU	EMISSIONS PART.	IN TONS/YEAR SOx	NOx	ANNUAL FUELUSE TR.BTU	EMISSIONS PART.	IN TONS/YEAR SOx	NOx
TOTAL FOR ALL STATIONS: ELECTRIC SYSTEM								
NUCLEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COAL	3.11	16.6	4.9	2.3	3.94	21.0	6.2	3.0
RESIDUAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DISTIL.	0.38	7.0	4.9	94.4	0.33	6.0	4.2	82.0
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MISC.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FOR ALL STATIONS: STEAM SYSTEM								
NUCLEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COAL	0.14	0.7	0.2	0.1	0.08	0.4	0.1	0.1
RESIDUAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DISTIL.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MISC.	0.55	0.0	0.0	0.0	0.55	0.0	0.0	0.0
TOTAL FOR ALL STATIONS:								
NUCLEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COAL	3.25	17.3	5.1	2.4	4.02	21.4	6.4	3.0
RESIDUAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DISTIL.	0.38	7.0	4.9	94.4	0.33	6.0	4.2	82.0
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MISC.	0.55	0.0	0.0	0.0	0.55	0.0	0.0	0.0
TOTALS	4.18	24.3	10.0	96.8	4.90	27.5	10.6	85.0

PAGE FORMAT 22

CALCULATION RESULTS

- Shows results from the emission package, broken down by fuel type and electric generating plants and new steam-only plants.
- Only one page of this setup will appear.
- This is a condensation and summary of data from FORMAT 21.

DISTRICT HEATING --- EMISSIONS --- CITY: PIQUA --- SCENARIO: HS08

			ANNUAL FUELUSE TR.BTU		ANNUAL EMISSIONS PART. (TONS)	SO _x (TONS)	NO _x (TONS)
GRIDSQUARE # 21:	3	3					
RESIDENTIAL LOW DENSITY HEATING & HOT WATER	0.07	AREA	0.36	0.50	2.69		
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER	0.01	AREA	0.04	0.05	0.28		
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER	0.01	AREA	0.11	0.09	0.89		
INDUSTRIAL HEATING & HOT WATER	0.01	AREA	0.07	0.50	0.73		
INDUSTRIAL PROCESS	0.02	AREA	0.19	1.48	1.93		
TOTALS	0.12	AREA	0.75	2.62	6.51		
GRIDSQUARE # 22:	4	3					
RESIDENTIAL LOW DENSITY HEATING & HOT WATER	0.14	AREA	0.78	1.08	5.84		
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER	0.00	AREA	0.00	0.00	0.02		
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER	0.01	AREA	0.08	0.07	0.67		
INDUSTRIAL HEATING & HOT WATER	0.00	AREA	0.02	0.17	0.24		
INDUSTRIAL PROCESS	0.01	AREA	0.06	0.50	0.65		
TOTALS	0.16	AREA	0.94	1.82	7.42		

PAGE FORMAT 23

CALCULATION RESULTS

- Shows fuel use and emissions at each grid square in the community.
- The number of pages with this setup is equal to half the community's grid squares (data for two squares appear on each page).
- Input data used in the Piqua example did not include the NEDS data file. The model therefore calculated area emissions using the input fuel-use data. With the NEDS file, point sources may also be included, and emissions would then be reported:

AREA (as above)

PT SH (point emissions from space heating)

PT OTH (other point emissions)

DISTRICT HEATING EMISSIONS CITY: PIQUA SCENARIO: WS08
 FIXED CHARGE RATE: 8.9%
 SUPPLY SCENARIO: WS08
 COST SCENARIO: LOW
 D.H.S. FRACTION ELECTRIC REPLACEMENT CAPACITY COSTS 0.50

THIS RUN USED THE FOLLOWING BUILDING TYPES:
 RESIDENTIAL LOW DENSITY HEATING & HOT WATER
 RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
 COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
 INDUSTRIAL HEATING & HOT WATER
 LARGE BUILDING COOLING
 INDUSTRIAL PROCESS

THIS RUN USED THE FOLLOWING 12 OF THE 54 GRIDSQUARES IN PIQUA
 12 14 21 22 23 24 30 31 32 33 40 41

ENTIRE CITY HEATING DEMAND AND LOCAL FUEL USE

ADJUSTED EFFICIENCIES

BUILDING TYPE	GAS	OIL	COAL
RESIDENTIAL LOW DENSITY HEATING & HOT WATER	0.58	0.55	0.50
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER	0.58	0.55	0.50
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER	0.58	0.55	0.50
INDUSTRIAL HEATING & HOT WATER	0.58	0.55	0.50
INDUSTRIAL PROCESS	0.58	0.55	0.50

PAGE FORMAT 24

DATA ECHO

- Restating basic scenario assumptions from the Scenario Definition Sheet.
- Only one page with this format will appear.
- States fuel efficiencies from the Emissions Input Data Sheet.

CALCULATION RESULTS

Provides community-wide emissions before and after district heating to illustrate potential air-quality benefits for the grid squares in the scenario.

	BEFORE DISTRICT HEATING					AFTER DISTRICT HEATING				
	ANNUAL FUELUSE TR.BTU	AREA	ANNUAL EMISSIONS PART. (TONS)	SOx (TONS)	NOx (TONS)	ANNUAL FUELUSE TR.BTU	AREA	ANNUAL EMISSIONS PART. (TONS)	SOx (TONS)	NOx (TONS)
RESIDENTIAL LOW DENSITY HEATING & HOT WATER	1.4	AREA	7.5	10.4	56.6	0.2	AREA	1.2	1.6	8.7
RESIDENTIAL HIGH DENSITY HEATING & HOT WATER	0.0	AREA	0.2	0.3	1.6	0.0	AREA	0.0	0.0	0.1
COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER	0.4	AREA	2.8	2.4	23.7	0.1	AREA	0.8	0.7	6.7
INDUSTRIAL HEATING & HOT WATER	0.2	AREA	1.3	9.9	14.5	0.0	AREA	0.4	3.2	4.7
INDUSTRIAL PROCESS	0.5	AREA	4.5	35.8	46.6	0.2	AREA	1.5	11.7	15.2
TOTALS	2.5	AREA	16.4	58.9	143.0	0.5	AREA	3.9	17.2	35.4

Form CDFA
Cost data

Name of Community: PIQUA

Record A

A1. On-site fuel prices(1) in 1980 dollars/MMBtu -

1. Natural gas (\$/MMBtu) -	
Residential low density:.....	3.400
Residential high density:.....	3.400
Commercial/Institutional:.....	3.150
Industrial space heat:.....	2.500
Large building cooling:.....	XXXXXXXXXX
Industrial process heat:.....	2.500
2. Oil (\$/MMBtu) -	
Residential low density:.....	6.600
Residential high density:.....	6.600
Commercial/Institutional:.....	6.100
Industrial space heat:.....	5.200
Large building cooling:.....	XXXXXXXXXX
Industrial process heat:.....	5.200
3. Coal (\$/MMBtu) -	
Residential low density:.....	1.500
Residential high density:.....	1.500
Commercial/Institutional:.....	1.500
Industrial space heat:.....	1.500
Large building cooling:.....	XXXXXXXXXX
Industrial process heat:.....	1.500
4. Electricity (\$/MMBtu) -	
Residential low density:.....	15.50
Residential high density:.....	15.50
Commercial/Institutional:.....	17.50
Industrial space heat:.....	17.50
Large building cooling:.....	17.50
Industrial process heat:.....	17.50
5. Existing district steam system (\$/MMBtu) -	
Residential low density:.....	5.000
Residential high density:.....	5.000
Commercial/Institutional:.....	5.000
Industrial space heat:.....	5.000
Large building cooling:.....	5.000
Industrial process heat:.....	5.000

1 Recommended conversion factors:

Natural gas	1,016 Btu/ cubic ft.
Distillate oil	138,690 Btu/gallon.
Residual oil	149,590 Btu/gallon.
Anthracite coal	25.2 MMBtu/ton.
Electricity	3,412 Btu/kwh.
Steam	1000 Btu/pound.

PAGE FORMAT 25

DATA ECHO

- Restating fuel prices; input from community (Fuel Cost Data Sheet).
- Only one page of this format will appear.

COST SCENARIO: LOW

D.H.S. FRACTION ELECTRIC REPLACEMENT CAPACITY COST: 0.50

PAGE FORMAT 26

THIS RUN USED THE FOLLOWING BUILDING TYPES:
 RESIDENTIAL LOW DENSITY HEATING & HOT WATER
 RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
 COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
 INDUSTRIAL HEATING & HOT WATER
 LARGE BUILDING COOLING
 INDUSTRIAL PROCESS

THIS RUN USED THE FOLLOWING 12 OF THE 54 GRIDSQUARES IN PIQUA
 12 14 21 22 23 24 30 31 32 33 40 41

FINANCIAL ASSUMPTIONS	
FIXED CHARGE RATE:	8.9%
DISCOUNT RATE (REAL):	1.0%
INFLATION RATE:	7.0%
REAL ESCALATION RATES	
CAPITAL:	2.0%
O&M:	0.5%
FUELS:	
NUCL	1.0%
COAL	2.0%
RESI	3.0%
DIST	3.0%
GAS	3.0%
MISC	2.0%
START OF CONSTRUCTION:	1980
IN-SERVICE DATE:	1983
RATE OF RETURN:	8.0%
A.F.C. RATE:	8.0%
CAPITAL RECOVERY PERIOD:	30 YEARS
LIFETIME OF SYSTEM:	30 YEARS

CALCULATION RESULTS

- Capital Costs

DATA ECHO

- Showing financial assumptions input from community and ANL (Scenario Definition Sheet).
- Only one page of this format will appear, see below.
- The data echo is identical to FORMAT 15.

DISTRICT HEATING SYSTEM CAPITAL COSTS (UNLESS OTHERWISE NOTED, IN MILLION 1980 DOLLARS)

FIXED COSTS	TRANSMISSION	LOOP	DISTRIBUTION	PLANT RETROFIT	BUILDING RETROFIT	REPLACEMENT CAPACITY	THERMAL PEAKER	TOTAL
1 TOTAL INVESTMENT (AT START-UP)	1.033	14.932	31.335	1.120	12.317	1.666	3.030	65.432
2 TOTAL LIFETIME COSTS	0.836	12.802	26.865	0.960	10.560	1.428	2.598	56.058
3 AVERAGE ANNUAL COSTS	0.030	0.427	0.895	0.032	0.352	0.048	0.087	1.870
4 COSTS/MMBTU	0.023	0.328	0.633	0.025	0.270	0.037	0.067	1.437
1. Initial capital required per component.	Transmission-system capital costs, i.e., piping from stations to loop or distribution.	Thermal-loop piping costs.	Distribution piping costs; pipe from transmission or loop to individual buildings.	Capital cost of converting necessary plants to cogeneration.	Costs of retrofitting consumer buildings for district heating and cooling.	Capital costs to replace lost electric generation equipment capacity.	Cost of peaking boilers.	
2. Capital required over 30-yr life, equal to item 3 x 30 with rounding; doesn't include Item #1.								
3. Average annual capital costs.								
4. Costs per million Btu; useful in comparing systems.								
VARIABLE COSTS	TRANSMISSION O&M	LOOP O&M	DISTRIBUTION O&M	PLANT O&M	FUEL	TOTAL		
O&M and Fuel Costs								
AVERAGE ANNUAL COSTS	0.007	0.108	0.227	0.402	3.172	3.918		
COSTS/MMBTU	0.006	0.083	0.175	0.309	2.437	3.010		

TOTAL COST OF FINAL DEMAND \$ 4.447 PER MMBTU

Cost per million Btu of heat using this scenario; useful as a common basis for comparing among different scenarios.

DISTRICT HEATING --- COSTING --- CITY: PIQUA --- SCENARIO: W308

THERMAL DEMAND, FUEL USE AND COSTS WITH EXISTING SYSTEM											
SPACE HEATING & HOT WATER CITYWIDE BEFORE D.H.				AREA NOT IN D.H.S.				AREA IN D.H.S.			
	DEMAND	ANNUAL	ANNUAL	DEMAND	ANNUAL	ANNUAL	DEMAND	ANNUAL	ANNUAL	DEMAND	ANNUAL
	COSTS	FINAL	FUEL	COSTS	FINAL	FUEL	COSTS	FINAL	FUEL	COSTS	FINAL
	\$/MMBTU	TR.BTU	TR.BTU	\$/MMBTU	TR.BTU	TR.BTU	\$/MMBTU	TR.BTU	TR.BTU	\$/MMBTU	TR.BTU
RESIDENTIAL LOW DENSITY	8.908			8.908			8.908				
GAS		0.766	1.325		0.117	0.203		0.649	1.122		
OIL		0.036	0.065		0.005	0.010		0.030	0.055		
COAL		0.003	0.005		0.000	0.001		0.002	0.005		
ELECTRIC		0.049	0.162		0.007	0.025		0.041	0.137		
OTHER		0.013	0.020		0.002	0.003		0.011	0.017		
TOTAL, ALL FUELS		0.866	1.577		0.132	0.241		0.733	1.336		
TOTAL, ON-SITE FUELS		0.804	1.395		0.123	0.213		0.681	1.182		
RESIDENTIAL HIGH DENSITY	8.898			8.898			8.898				
GAS		0.021	0.037		0.002	0.003		0.020	0.034		
OIL		0.001	0.002		0.000	0.000		0.001	0.002		
COAL		0.000	0.000		0.000	0.000		0.000	0.000		
ELECTRIC		0.001	0.005		0.000	0.000		0.001	0.004		
OTHER		0.001	0.001		0.000	0.000		0.001	0.001		
TOTAL, ALL FUELS		0.024	0.044		0.002	0.003		0.023	0.041		
TOTAL, ON-SITE FUELS		0.022	0.039		0.002	0.003		0.021	0.036		
COMMERCIAL/INSTITUTIONAL	7.966			7.966			7.966				
GAS		0.223	0.386		0.063	0.109		0.160	0.277		
OIL		0.003	0.006		0.001	0.002		0.002	0.004		
COAL		0.001	0.002		0.000	0.001		0.001	0.001		
ELECTRIC		0.009	0.029		0.002	0.008		0.006	0.021		
OTHER		0.008	0.012		0.002	0.003		0.006	0.009		
TOTAL, ALL FUELS		0.244	0.435		0.069	0.123		0.175	0.312		
TOTAL, ON-SITE FUELS		0.227	0.393		0.064	0.111		0.163	0.232		
INDUSTRIAL	9.243			9.243			9.243				
GAS		0.063	0.108		0.020	0.035		0.042	0.073		
OIL		0.024	0.042		0.003	0.014		0.016	0.029		
COAL		0.0	0.0		0.0	0.0		0.0	0.0		
ELECTRIC		0.018	0.059		0.006	0.019		0.012	0.040		
OTHER		0.008	0.013		0.003	0.004		0.006	0.009		
TOTAL, ALL FUELS		0.112	0.223		0.036	0.072		0.076	0.151		
TOTAL, ON-SITE FUELS		0.086	0.151		0.028	0.049		0.058	0.102		

PAGE FORMAT 27

CALCULATION RESULTS

- Shows thermal demands, fuel use, and costs for the existing heating and cooling supply situation.
- To be used to compare current situation to district heating supply system.
- Calculations are for areas inside and outside the district system.
- Only one page of this format will appear.

DISTRICT HEATING --- COSTING --- CITY: PIQUA --- SCENARIO: WS08

THERMAL DEMAND, FUEL USE AND COSTS WITH EXISTING SYSTEM

	CITYWIDE BEFORE D.H.			AREA NOT IN D.H.S.			AREA IN D.H.S.		
	DEMAND COSTS \$/MMBTU	ANNUAL FINAL DEMAND TR.BTU	ANNUAL FUEL DEMAND TR.BTU	DEMAND COSTS \$/MMBTU	ANNUAL FINAL DEMAND TR.BTU	ANNUAL FUEL DEMAND TR.BTU	DEMAND COSTS \$/MMBTU	ANNUAL FINAL DEMAND TR.BTU	ANNUAL FUEL DEMAND TR.BTU
LARGE BUILDING COOLING	8.333			8.333			8.333		
GAS		0.0	0.0		0.0	0.0		0.0	0.0
OIL		0.0	0.0		0.0	0.0		0.0	0.0
COAL		0.0	0.0		0.0	0.0		0.0	0.0
ELECTRIC		0.168	0.271		0.066	0.107		0.102	0.164
OTHER		0.0	0.0		0.0	0.0		0.0	0.0
TOTAL, ALL FUELS		0.168	0.271		0.066	0.107		0.102	0.164
TOTAL, ON-SITE FUELS		0.0	0.0		0.0	0.0		0.0	0.0
INDUSTRIAL PROCESS	8.087			8.087			8.087		
GAS		0.185	0.320		0.060	0.105		0.125	0.216
OIL		0.085	0.154		0.028	0.050		0.057	0.104
COAL		0.0	0.0		0.0	0.0		0.0	0.0
ELECTRIC		0.0	0.0		0.0	0.0		0.0	0.0
OTHER		0.016	0.025		0.005	0.008		0.011	0.017
TOTAL, ALL FUELS		0.286	0.499		0.093	0.163		0.193	0.336
TOTAL, ON-SITE FUELS		0.270	0.474		0.088	0.155		0.182	0.319
TOTAL, ALL BUILDINGS	8.600			8.488			8.634		
GAS		1.258	2.176		0.262	0.454		0.996	1.722
OIL		0.149	0.269		0.042	0.076		0.107	0.193
COAL		0.004	0.008		0.001	0.001		0.003	0.006
ELECTRIC		0.245	0.526		0.032	0.159		0.163	0.367
OTHER		0.045	0.070		0.012	0.019		0.033	0.052
TOTAL, ALL FUELS		1.700	3.049		0.399	0.709		1.301	2.340
TOTAL, ON-SITE FUELS		1.410	2.452		0.305	0.531		1.106	1.922

PAGE FORMAT 28

CALCULATION RESULTS

- Shows a continuation of
FORMAT 27, with totals.
- Only one page with this
format will appear.

DISTRICT HEATING --- COSTING --- CITY: PIQUA --- SCENARIO: WS08

PAGE FORMAT 29 - (One page with this format)
CALCULATION RESULTS (Explained Below)

COSTS AND BENEFITS

YEAR	THOUSAND CURRENT DOLLARS								THOUSAND 1980 PRESENT WORTH DOLLARS							
	DISTRICT CAPITAL	HEATING O&M	SYSTEM FUEL	COSTS TOTAL	AVOIDED COSTS FUEL	EQUIP. TOTAL	BENEFITS -COSTS		DISTRICT CAPITAL	HEATING O&M	SYSTEM FUEL	COSTS TOTAL	AVOIDED COSTS FUEL	EQUIP. TOTAL	BENEFITS -COSTS	
1983	5812.	1004.	3485.	10301.	11325.	624.	11950.	1648.	4614.	797.	2767.	8178.	8990.	496.	9486.	1309.
1984	5812.	1079.	3799.	10690.	12407.	681.	13088.	2398.	4272.	793.	2792.	7858.	9120.	500.	9620.	1762.
1985	5812.	1160.	4141.	11113.	13594.	742.	14336.	3223.	3956.	790.	2818.	7563.	9252.	505.	9757.	2193.
1986	5812.	1247.	4513.	11573.	14894.	809.	15703.	4130.	3663.	786.	2844.	7293.	9386.	510.	9896.	2603.
1987	5812.	1341.	4919.	12072.	16320.	881.	17202.	5129.	3391.	782.	2870.	7044.	9523.	514.	10037.	2993.
1988	5812.	1441.	5362.	12616.	17834.	961.	18845.	6229.	3140.	779.	2897.	6816.	9662.	519.	10181.	3365.
1989	5812.	1549.	5845.	13206.	19598.	1047.	20645.	7439.	2908.	775.	2924.	6607.	9804.	524.	10328.	3721.
1990	5812.	1666.	6371.	13849.	21478.	1141.	22620.	8771.	2692.	772.	2951.	6415.	9949.	529.	10477.	4063.
1991	5812.	1791.	6944.	14547.	23540.	1244.	24784.	10237.	2493.	768.	2978.	6239.	10096.	534.	10629.	4390.
1992	5812.	1925.	7569.	15306.	25801.	1356.	27156.	11850.	2303.	764.	3006.	6078.	10246.	533.	10784.	4706.
1993	5812.	2069.	8250.	16132.	28280.	1478.	29758.	13626.	2137.	761.	3034.	5932.	10399.	543.	10942.	5010.
1994	5812.	2224.	8993.	17030.	30999.	1611.	32610.	15581.	1979.	757.	3062.	5798.	10554.	543.	11103.	5305.
1995	5812.	2391.	9802.	18006.	33982.	1756.	35738.	17732.	1832.	754.	3090.	5676.	10713.	554.	11266.	5590.
1996	5812.	2571.	10684.	19067.	37253.	1914.	39167.	20100.	1697.	750.	3119.	5566.	10874.	559.	11433.	5867.
1997	5812.	2763.	11646.	20222.	40841.	2036.	42928.	22706.	1571.	747.	3148.	5465.	11038.	564.	11602.	6137.
1998	5812.	2971.	12694.	21477.	44777.	2274.	47051.	25574.	1455.	743.	3177.	5375.	11206.	569.	11775.	6400.
1999	5812.	3193.	13837.	22342.	49095.	2479.	51574.	28732.	1347.	740.	3206.	5293.	11376.	574.	11951.	6658.
2000	5812.	3433.	15032.	24327.	53832.	2702.	56534.	32207.	1247.	737.	3236.	5219.	11550.	580.	12130.	6910.
2001	5812.	3690.	16439.	25942.	59029.	2945.	61974.	36032.	1155.	733.	3266.	5154.	11727.	585.	12312.	7158.
2002	5812.	3967.	17919.	27698.	64731.	3210.	67941.	40243.	1069.	730.	3296.	5095.	11907.	590.	12497.	7402.
2003	5812.	4265.	19531.	29608.	70986.	3499.	74485.	44877.	990.	726.	3327.	5043.	12090.	596.	12686.	7643.
2004	5812.	4585.	21289.	31686.	77850.	3814.	81664.	49978.	917.	723.	3357.	4997.	12277.	601.	12879.	7882.
2005	5812.	4928.	23205.	33946.	85382.	4157.	89539.	55593.	849.	720.	3389.	4957.	12468.	607.	13075.	8118.
2006	5812.	5298.	25294.	36404.	93646.	4531.	98177.	61773.	786.	716.	3420.	4922.	12662.	613.	13274.	8352.
2007	5812.	5695.	27570.	39078.	102715.	4939.	107653.	68576.	728.	713.	3452.	4892.	12859.	618.	13477.	8535.
2008	5812.	6123.	30051.	41986.	112656.	5383.	118050.	76054.	674.	710.	3484.	4867.	13060.	624.	13684.	8817.
2009	5812.	6582.	32756.	45150.	123588.	5868.	129456.	84306.	624.	706.	3516.	4846.	13265.	630.	13895.	9049.
2010	5812.	7075.	35704.	48592.	135574.	6396.	141970.	93379.	578.	703.	3548.	4829.	13474.	636.	14109.	9280.
2011	5812.	7606.	38917.	52335.	148729.	6972.	155701.	103365.	535.	700.	3581.	4816.	13686.	642.	14323.	9512.
2012	5812.	8176.	42420.	56408.	163167.	7599.	170766.	114353.	495.	697.	3614.	4806.	13902.	647.	14550.	9744.
TOTAL	174365.	103810.	475032.	753207.	1733964.	85098.	1819062.	1065853.	56098.	22372.	95167.	173638.	337114.	17048.	354163.	180525.

Lifetime of district system (years from startup date)

Annual capital costs, including debt service.

Operation/maintenance costs.

Fuel costs, including inflation adjustment.

Sum of previous columns.

Fuel and equipment costs projected if current situation is continued.

Total avoided costs minus total DHS costs.

Same calculations as at left but with present-worth dollars.

MANHATTAN DISTRICT HEATING --- COSTING --- CITY: PIQJA --- SCENARIO: WS08

*** FINANCIAL SUMMARY ***

CUMULATIVE NET BENEFITS 175. MILLION 1980 PRESENT WORTH DOLLARS

SAVINGS-TO-INVESTMENT RATIO (N.P.W.) 4.16

DISCOUNTED PAYBACK PERIOD 8.9 YEARS

YEAR OF CASH FLOW TURNAROUND

CURRENT DOLLARS: 1983

PRESENT WORTH DOLLARS: 1983

*** FUEL USE SUMMARY ***

FUEL USE AND SAVINGS, TRILLION BTU

FUEL	BEFORE DISTRICT HEATING			AFTER DISTRICT HEATING			NET SAVINGS		
	UTILITY	BUILDING	TOTAL	UTILITY	BUILDING	TOTAL	UTILITY	BUILDING	TOTAL
NUCLEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COAL	3.251	0.008	3.259	4.018	0.001	4.019	-0.766	0.006	-0.760
RESIDUAL	0.0	0.078	0.078	0.0	0.025	0.025	0.0	0.053	0.053
DISTIL.	0.381	0.191	0.572	0.331	0.050	0.382	0.050	0.140	0.191
GAS	0.0	2.176	2.176	0.0	0.454	0.454	0.0	1.722	1.722
MISC.	0.552	0.0	0.552	0.552	0.0	0.552	0.0	0.0	0.0
TOTALS	4.185	2.452	6.637	4.901	0.531	5.432	-0.716	1.922	1.205

PAGE FORMAT 30

CALCULATION RESULTS

- Financial Summary (above) and Fuel Use Summary (below).
- Total benefits and other vital information; definitions in Appendix A.
- Fuel use over system lifetime for this scenario.
- Only one page with this format will appear.

PAGE FORMAT 31

CALCULATION RESULTS

- *Thermal Load Map. This map is a graphic display of the data found in FORMAT 7 and will be color-coded when delivered.*
- *PMPS1 and boiler plants located in same area (symbols therefore superimposed on each other).*

PEAK THERMAL DEMAND FOR PIQUA

LEGEND FOR PEAK THERMAL DEMAND MAP OF PIQUA

Building sectors included:

RESIDENTIAL LOW DENSITY HEATING & HOT WATER
 RESIDENTIAL HIGH DENSITY HEATING & HOT WATER
 COMMERCIAL/INSTITUTIONAL HEATING & HOT WATER
 INDUSTRIAL HEATING & HOT WATER
 LARGE BUILDING COOLING
 INDUSTRIAL PROCESS

Peak thermal demand ranges:

■ between 22.7 and 22.8 megawatts
 ▨ between 12.7 and 22.7 megawatts
 ▩ between 2.7 and 12.7 megawatts
 ▤ between 1.3 and 2.7 megawatts

Table H.1 Classification of Output Data by Community Area to Which They Apply and by Page Format(s) on Which They Are Presented

Type of Output Data	Applicable Area of Community	Page Format(s) for Data Echoes	Page Format(s) for Calculation Results
Demand	Entire community	1,2	6
Demand	All grid squares	3,4	5,7,31
Demand	Scenario area only		27,28
Cost	Entire community and scenario area	8,9	
Demand	Scenario area only	10,15 ^a	15 ^a
Supply, Cost	Scenario area only	11,12,13,14	16,17,18
Emissions	Entire community	19,20	
Emissions	Entire community and scenario area		21,22
Emissions	Scenario area only	24 ^a	23,24 ^a
Cost	Fuel prices, entire community	25	
Cost	District system, scenario area only	26 ^a	26 ^a ,27,28,29,30

^aFormats on which both data echoes and calculation results are presented. The echo portions of these formats have been determined by scenario input and are valid only for the scenario being run.

Demand data may be used locally for: (1) Verifying the preliminary estimates of other researchers; (2) finding areas of probable high thermal demands that can be the basis for making new scenarios using the areas with the highest thermal densities (and therefore best district-heating potential); and (3) comparing district heating and cooling with other energy-saving strategies. After the current demands are calculated, the effects of increased weatherization or use of other conservation techniques may be tested by changing the demand factor for scaling[†] space heating (format 1) and recording the effects on final demands[†] (format 6). Revised final demands can be compared to final demands of a district heating and cooling scenario (from the cost module, format 28). Because the costs of a district heating and cooling scenario would be known, independent calculations of the other conservation technique's costs would permit a better comparison of alternatives.

The demand map (formats 7 and 31) can be a useful tool in explaining thermal-density concepts to work group members or community residents. Its main function for the analyst is to aid in scenario construction by highlighting grid squares with the highest thermal density.[†]

H.3 SUPPLY OUTPUT

The demand data, economic assumptions (format 9), scenario specifications (format 10), and utility-plant and boiler data (formats 11-14) provide the basis for the model to calculate the available thermal supplies and the costs that may be expected from use of those supplies.

The first page of the report (format 15) gives basic scenario information, starting with the name of the city and the scenario. The "District Steam System Scenario's Fraction" represents that portion of the load of the existing district steam system (DSS) included within the grid squares specified for the scenario. Also on format 15 is a list of building types and end uses, a list of the grid squares included in this scenario, and a list of the various financial assumptions. The last item on format 15 is a summary of the final annual demands for the scenario. The first numbers represent the end use requirements, and the final figure represents the thermal demand for district-heating-system energy at the building after taking into account conversion efficiencies. The final numbers give the electrical and thermal loads -- as well as the electrical credits[†] stemming from replacement by the district system of electricity previously used but no longer needed.

Format 16 lists those stations that have been selected and ranked on the basis of cost (in dollars per 10⁶ Btu delivered) to provide energy for the district heating system. For electrical stations there is generally a moderate reduction in electrical capacity (from ORIGINAL to W/D.H.) and a lesser increase in fuel use (D.H.S. FUEL) to provide the district heating system's thermal energy (THERMAL EN. DEL.). These results are followed by various components of the annual costs associated with the conversion and the average delivered energy cost -- with all costs represented in 1980 present-worth dollars, adjusted by the user-specified inflation and discount rates (reprinted in format 15). The model selects plants in order of their delivered energy costs until the demand is satisfied. It quite often happens that the final plant is only partially loaded. In the event of partial loading, a number of possible supply and demand options can be studied in new scenarios. Partial loading is highlighted by a note on Format 16.

Format 17 shows the generation lost by derating the electrical power plants converted to district heating. For single-case turbines[†] whose capacity[†] is permanently reduced when used for district heating, the total permanently derated capacity also is reported. The report includes a credit for electricity displaced by the district system. Displacement of electrical demand occurs when, for example, absorption cooling in a district system replaces conventional electrical chillers. Although the stations[†] selected up to this point will meet the annual energy demands, they will generally fall short of the peak-load demand; therefore, the model next selects additional thermal-only peaking stations whose costs are included as part of the district heating system. Format 17 concludes with a summary of the annual and peak loads.

Format 18 lists those stations that were not used for the district heating system either because their energy was not needed or their costs were too high. Also on this page may be listed existing district steam-system plants that were not available because they supply areas outside the current scenario.*

The information in formats 15-18 can have two functions. First, it can be the basis for starting an analysis of the availability of capital-cost financing, and it can be used to study whether cogeneration[†] using the selected power plants will have important effects on electric generating reserve margin.[†] Moreover, the \$/MMBtu calculations can be used for comparison against current or projected costs of existing fuels. This comparison may be a marketing tool. Second, the data can be used in developing new scenarios. For example, the first scenario could be run using power-plant fuels that currently exist. The second scenario could test the effects of converting some or all units from using a scarce fuel to using an abundant fuel. Comparisons and cost estimates for the switch could show the advantages or disadvantages involved in such a change. Data from the supply module can be fed automatically into the cost module and combined with data there to provide insights into financing issues.

H.4 COST OUTPUT

As in the supply module, the information in the cost module (formats 26-30) can be used to assess financial feasibility and to compare scenarios.**

The cost-module report (formats 25-30, with calculation results on 26-30) contains a variety of information useful in evaluating the economic attractiveness of a district heating system. The report begins on formats 25 and 26 by identifying the scenario (city, supply scenario, cost scenario) the various financial input data (provided in the supply module), and the calculated fixed charge rate.[†] After this introductory information, a table on format 26 reports district-heating-system costs by various components. The first line of this table gives the investment costs in mixed current dollars, i.e., the dollars spent from the startup year until the in-service date of the district heating system -- including inflation and interest during construction, but without discounting. All of the other costs presented in this table are in dollars discounted to 1980. The next line gives the total discounted lifetime capital costs (not including construction costs), followed by the discounted average annual costs, based

*Most of the information for Section 3.3.2 to this point was provided by the Energy System Research Group.

**Cost-module input, other than current fuel prices (format 25), is from the demand and supply modules; thus, changes in the scenarios described in the earlier modules will be reflected in the cost output. Perhaps one of the more important scenario changes would come from changing the interest rate to reflect differences between public and private financing. Since capital carrying charges (i.e., costs of borrowing for the initial capital costs of district heating) are a large percentage of lifetime costs,[†] a few percentage points in interest rate can make a difference in the final cost of energy delivered (\$/million Btu).

on the user-specified system lifetime. The lifetime costs are divided by the annual final heat demand serviced by the system to give the average cost (per MMBtu) of meeting the demand requirements in the scenario service area. Similar results are reported for the variable costs, such as those for operating and maintenance and district-heating fuel use, and a final average total discounted cost of meeting final demand is reported. The cost per MMBtu listed at the bottom of format 26 is compared to alternate fuel costs shown in format 27.

Formats 27 and 28 report the final demand and fuel consumption by building type and end-use sector with the existing systems. This long table is divided into three major sections: (1) city-wide, before district heating; (2) the portion that is not district heated; and (3) the portion that is district heated. The sum of the second and third, equals the first. Within each section, columns list the annual final demands and fuel consumptions based on conversion efficiencies. For each building type and end-use sector, demand and fuel use are given for each fuel type as total and total on-site† (i.e., not including other fuel such as that used in electrical generation). For each end-use sector, a summary demand cost per MMBtu of final demand is reported. This is the average energy cost discounted to 1980 and weighted by the quantity of each fuel demanded. At the bottom of format 28, the totals for all buildings are reported.

Format 29 gives the year-by-year cash flow of costs and benefits for the district heating system. This is divided into two similar sections -- the first section expressed in current dollars (dollars in the year they are spent) and the second expressed in 1980 dollars. The basis for these calculations are the O&M and fuel-use calculations from the supply module, and the financial assumptions specified by the user.

Format 30 gives financial results starting with the 1980 worth of the cumulative net lifetime benefits (loss) of the district heating system. The second result is the savings-to-investment ratio, which is the ratio of the total system savings from decreased fuel and other costs divided by the investment cost (all in 1980 dollars). This represents the relative economic benefit of the system and can be used to rank competing projects or scenarios. The third result is the discounted payback period,† which reports how many years are needed for the savings to pay back the investment costs. Finally, the calendar year in which the cumulative net cash flows become positive is provided. The final section of format 30 provides a summary table of annual fuel consumption before and after installation of district heating. The utility and on-site energy uses are listed individually and then totalled. The table is a summary of power-plant fuel use by fuel type -- before and after district heating -- for all plants listed in the supply input file. For most fuels there will be no change (if they are not selected for cogeneration operation in the district supply system); or there will be an increase because more fuel is consumed to provide district heating thermal energy. In some cases, if existing district steam plants are not selected for the district heating system, there may be a decrease in fuel consumption. Generally, the fuel used by a utility after district heating (usually coal) will decrease on a Btu basis to about half of the amount used before district heating, representing the greater thermal efficiency of the district heating system over electricity-only operation.

H.5 EMISSIONS OUTPUT

The emissions module calculates total air pollutant emissions (in tons per year) for sulfur oxides, nitrogen oxides, and particulate matter. These calculations are performed for:

1. Tonnage/year put into the air for heating demands served, before and after district heating has been installed for the community as a whole (format 24);
2. Tonnage/year before and after district heating for each electric generating plant (formats 31, 22), and the tonnage/year before and after district heating for each grid square (format 23).

These calculations can help show the decrease in emissions possible through implementation of more efficient, better maintained, and better controlled central-plant equipment in a district heating and cooling system. These data would be of primary interest to utility officials interested in compliance by their plants to government standards, and to air-pollution-control officials concerned with improving air quality.

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APPENDIX I

STANDARD INDUSTRIAL AND COMMERCIAL/INSTITUTIONAL
CLASSIFICATION CODES: TWO SECTORS OF POTENTIAL
IMPORTANCE FOR DHSM INPUT AND OUTPUT DATA

DHSM input and output data are divided into four major classes by land use and building type:

1. Residential, low density;
2. Residential, high density;
3. Commercial/institutional; and
4. Industrial.

The two residential densities are defined in Appendix A. The industrial and commercial/institutional classes, whose major groups are distinguished by individual SIC code numbers, are described below. The major groups in these two types of community land use constitute potential users of the energy produced by a district heating and cooling system.

INDUSTRIAL

Division C. Construction

- Major group 15. Building construction - general contractors and operative builders
- Major group 16. Construction other than building construction - general contractors
- Major group 17. Construction - special trade contractors

Division D. Manufacturing

- Major group 20. Food and kindred products
- Major group 21. Tobacco manufactures
- Major group 22. Textile mill products
- Major group 23. Apparel and other finished products made from fabrics and similar materials
- Major group 24. Lumber and wood product, except furniture
- Major group 25. Furniture and fixtures
- Major group 26. Paper and allied products
- Major group 27. Printing, publishing, and allied industries
- Major group 28. Chemicals and allied products
- Major group 29. Petroleum refining and related industries
- Major group 30. Rubber and miscellaneous plastics products
- Major group 31. Leather and leather products
- Major group 32. Stone, clay, glass, and concrete products
- Major group 33. Primary metal industries
- Major group 34. Fabricated metal products, except machinery and transportation equipment
- Major group 35. Machinery, except electrical

- Major group 36. Electrical and electronic machinery, equipment, and supplies
- Major group 37. Transportation equipment
- Major group 38. Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
- Major group 39. Miscellaneous manufacturing industries

COMMERCIAL/INSTITUTIONAL

Division E. Transportation, communications, electric, gas, and sanitary services

- Major group 40. Railroad transportation
- Major group 41. Local and suburban transit and interurban highway passenger transportation
- Major group 42. Motor freight transportation and warehousing
- Major group 43. U.S. Postal Service
- Major group 44. Water transportation
- Major group 45. Transportation by air
- Major group 46. Pipe lines, except natural gas
- Major group 47. Transportation services
- Major group 48. Communication
- Major group 49. Electric, gas, and sanitary services

Division F. Wholesale trade

- Major group 50. Wholesale trade - durable goods
- Major group 51. Wholesale trade - nondurable goods

Division G. Retail trade

- Major group 52. Building materials, hardware, garden supply, and mobile home dealers
- Major group 53. General merchandise stores
- Major group 54. Food stores
- Major group 55. Automotive dealers and gasoline service stations
- Major group 56. Apparel and accessory stores
- Major group 57. Furniture, home furnishings, and equipment stores
- Major group 58. Eating and drinking places
- Major group 59. Miscellaneous retail

Division H. Finance, insurance, and real estate

- Major group 60. Banking
- Major group 61. Credit agencies other than banks
- Major group 62. Security and commodity brokers, dealers, exchanges, and services
- Major group 63. Insurance
- Major group 64. Insurance agents, brokers, and service
- Major group 65. Real estate

- Major group 66. Combinations of real estate, insurance, loans law offices
- Major group 67. Holding and other investment offices

Division I. Services

- Major group 70. Hotels, rooming houses, camps, and other lodging places
- Major group 72. Personal services
- Major group 73. Business services
- Major group 75. Automotive repair, services, and garages
- Major group 76. Miscellaneous repair services
- Major group 78. Motion pictures
- Major group 79. Amusement and recreation services, except motion pictures
- Major group 80. Health services
- Major group 81. Legal services
- Major group 82. Educational services
- Major group 83. Social services
- Major group 84. Museums, art galleries, botanical and zoological gardens
- Major group 86. Membership organizations
- Major group 89. Miscellaneous services

Division J. Public administration

- Major group 91. Executive, legislative, and general government, except finance
- Major group 92. Justice, public order, and safety
- Major group 93. Public finance, taxation, and monetary policy
- Major group 94. Administration of human resources programs
- Major group 95. Administration of environmental quality and housing programs
- Major group 96. Administration of economic programs
- Major group 97. National security and international affairs

Division K. Nonclassifiable establishments

- Major group 99. Nonclassifiable establishments