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A Geographic Market Suitability Analysis for Low- and Intermediate-Temperature Solar IPH Systems

Volume I

A. Keith Turner
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A Division of Midwest Research Institute

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PREFACE

More than 18 months ago scientists at the Solar Energy Research Institute (SERI) developed the initial ideas for a geographic market suitability analysis for solar industrial process heat systems. At the Colorado School of Mines (CSM), near SERI, considerable work over the past few years had been completed by Dr. A. Keith Turner and his associates on a refined, computer-assisted approach to map and analyze many geographic suitability factors. Through integration of SERI ideas with the capabilities which existed at the Colorado School of Mines, this analysis and final report was completed. SERI provided overall management, funding and technical guidance on the project through Michael DeAngelis. Drs. A. Keith Turner and Joseph C. Weber were co-principal investigators at the Colorado School of Mines. Several graduate students also worked on the project. Steve Smith, Janet Lindimore, Bill Jones, Mike Brazie, and Sargon Jabri were the primary students involved. Mary Mittag patiently typed the many versions of the manuscript. The authors of this report also would like to thank the Department of Energy, through the FY80 Agricultural and Industrial Systems Branch, for support on this project. All work under this task was performed under FY 1979 and 1980 time periods within SERI's Utilities and Industries Division.

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EXECUTIVE SUMMARY

During the past few years, the investigation of markets for solar thermal industrial process heat systems has focused on determining promising types of industries by four-digit SIC (Standard Industrial Classification). Geographical areas as a market focus have been considered primarily based on the varying level of solar radiation throughout the United States. However, there are many other criteria which affect the economics of supply and demand for solar IPH systems, and which vary in different parts of the United States. This study is an assessment of these geographic markets based on market suitability analysis methods which have been refined over the past twenty years by land use planners.

This project used a computer-aided system called "Generalized Map Analysis Planning System" (GMAPS). It performs interactive, cellular, computer mapping and composite mapping, and is less expensive and faster than manually developed map overlay systems. Based on latitude/longitude coordinates and other procedures, GMAPS produced high quality maps in this study based on data at the county and state levels, and across political boundaries by contouring the data results.

The methodology of this study began with the establishment of geographic analysis criteria. The primary criteria used in this study were outputs of different types of low and intermediate temperature solar thermal collectors, air quality constraints for competitive fuels, state solar tax incentives, fuels costs, low use of coal by industry, high growth industrial areas, and energy consumption by industry in different parts of the United States. Twenty-one separate maps were produced based on data and analyses for all of these criteria. Composite maps were then produced by GMAPS by combining the twenty-one separate maps into logical groupings of Supply, Competitive Fuels, and Demand. Matching these groupings to the output maps of different types of collectors produced the final geographic "suitability" maps. The method can produce composites with various weights assigned to different criteria.

Sensitivity analyses also were undertaken. For this purpose, the United States was subdivided into 13 geographical market regions (see Table ES-1). A multidimensional vector analysis was used to compute the regional rankings, based on maximum and average statistical values for each region for four components (solar energy outputs, environmental and tax incentives, economic incentives, and user demands). The calculations also identified the relative importance of these four components in each region. Changes in the relative importance of each component caused adjustments in the regional rankings. Evaluation of these adjustments led to estimates of the sensitivity of each region to changes in the importance of the components, thereby giving a sensitivity measure to these analyses.

The results of this study indicate that the southwest and west are the most attractive geographical markets for solar IPH, based on an equal weighting of the criteria used in this study. The West North Central and East South Central regions of the United States have the least attractive markets according to this analysis. Table ES-2 of the Executive Summary classifies the results of the study for all regions of the United States. Category A represents the most attractive regions, while category D the least attractive

TABLE ES-1

GEOGRAPHICAL MARKET REGIONS

REGION	STATES
1. New England	Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont
2. Mid Atlantic	New York, New Jersey, Pennsylvania
3. South Atlantic	Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia
4. East North Central	Illinois, Indiana, Michigan, Ohio, Wisconsin
5. East South Central 1	Kentucky, Tennessee
6. East South Central 2	Alabama, Mississippi
7. West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
8. West South Central 1	Oklahoma
9. West South Central 2	Arkansas, Louisiana, Texas
10. Mountain 1	New Mexico
11. Mountain 2	Colorado, Idaho, Montana, Utah, Wyoming
12. Mountain 3	Nevada, Arizona
13. Pacific	California, Oregon, Washington
	(Alaska and Hawaii were not ranked in this project)

TABLE ES-2

CATEGORIZATION OF MARKET REGIONS

LOW TEMPERATURE MARKETS (BELOW 100°C)

Category A: Mountain 3, Pacific, Mountain 1

Category B: New England, Mid Atlantic+, West South Central 1, West South Central Central 2

Category C: South Atlantic*, Mountain 2, East North Central

Category D: West North Central*, East South Central 2, East South Central 1

INTERMEDIATE TEMPERATURE MARKETS (100°C TO 288°C)

Category A: Mountain 3, Pacific, Mountain 1

Category B: Mountain 2, New England, Mid Atlantic+, West South Central 1

Category C: South Atlantic, East North Central, West South Central 2*

Category D: West North Central*, East South Central 2, East South Central 1

NOTE: For definition of states within each region, see Table 4.2

*Includes significant non-uniformity in region. When maximum values of data are considered, its rank will improve by one category.

+Includes significant non-uniformity in region. When maximum values of data are considered, its rank decreases by one category.

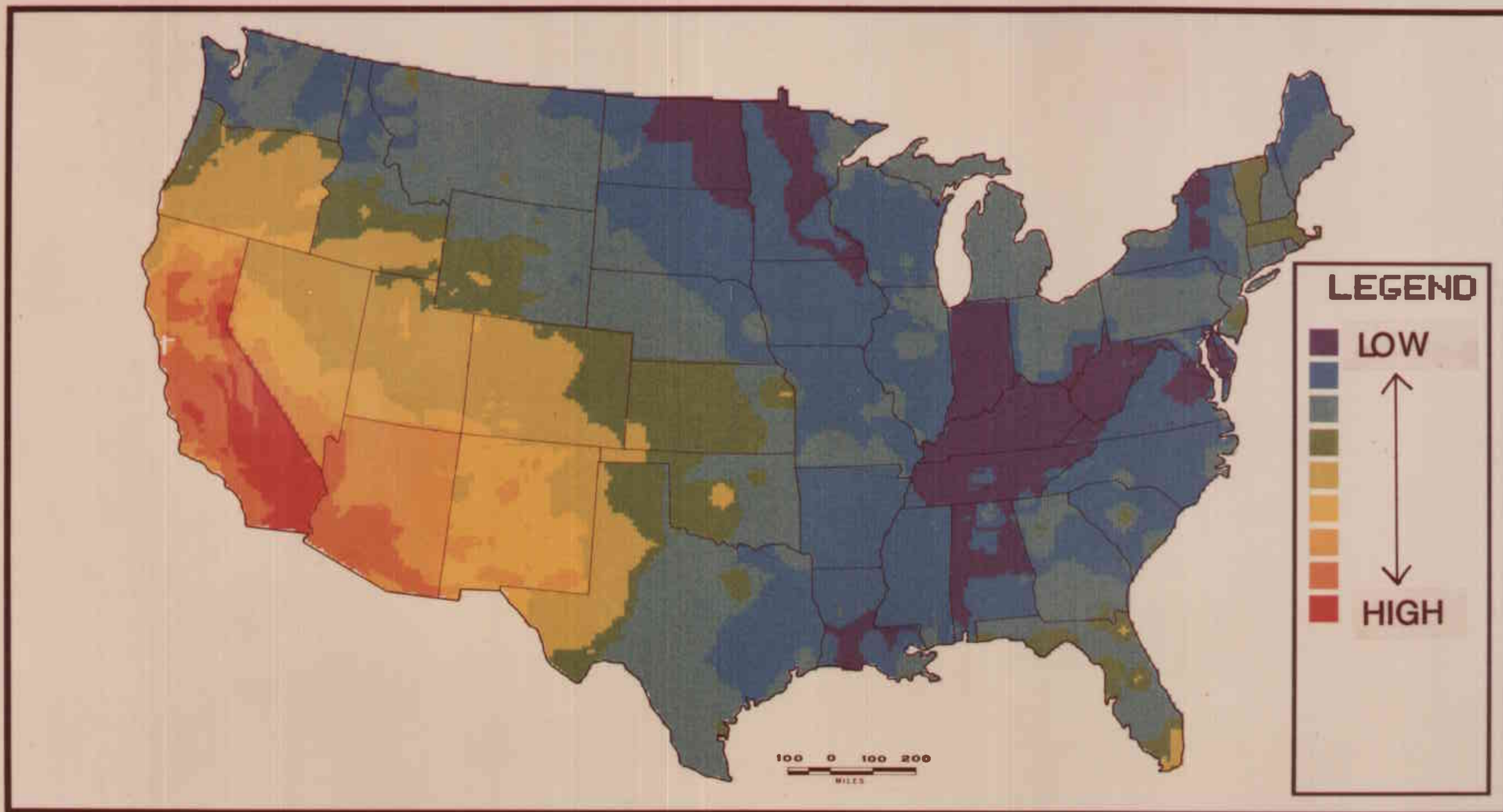
regions. Maps ES-1 and ES-2 of the Executive Summary graphically show these results for parabolic troughs. Map ES-1 is a composite map of the "supply" criteria; i.e., parabolic trough output, air quality constraints, state tax incentives, fuel costs, imported gas, and coal use data. Map ES-2 is a composite map of the "demand" criteria, i.e., intermediate temperature (100°C to 288°C) energy demand and industrial growth data. These maps show more specific areas within regions and states which have attractive markets for solar IPH systems.

However, when different weights are assigned to the various criteria, the results change significantly for some regions of the country. The rankings of the New England and Mid Atlantic regions change significantly when solar collector output data (i.e., a negative impact) or competitive fuels data (i.e., a positive impact) are weighted heavily. The West South Central 2 region also has high sensitivity and changes rank significantly when solar collector output data (i.e., a positive impact), competitive fuels (i.e., a negative impact), and tax and environmental incentives (i.e., a negative impact) are heavily weighted. It also should be noted that the criteria used in this analysis are limited, and there are many site specific criteria, such as land availability and management attitudes, which may result in a viable solar IPH application in a less attractive market region.

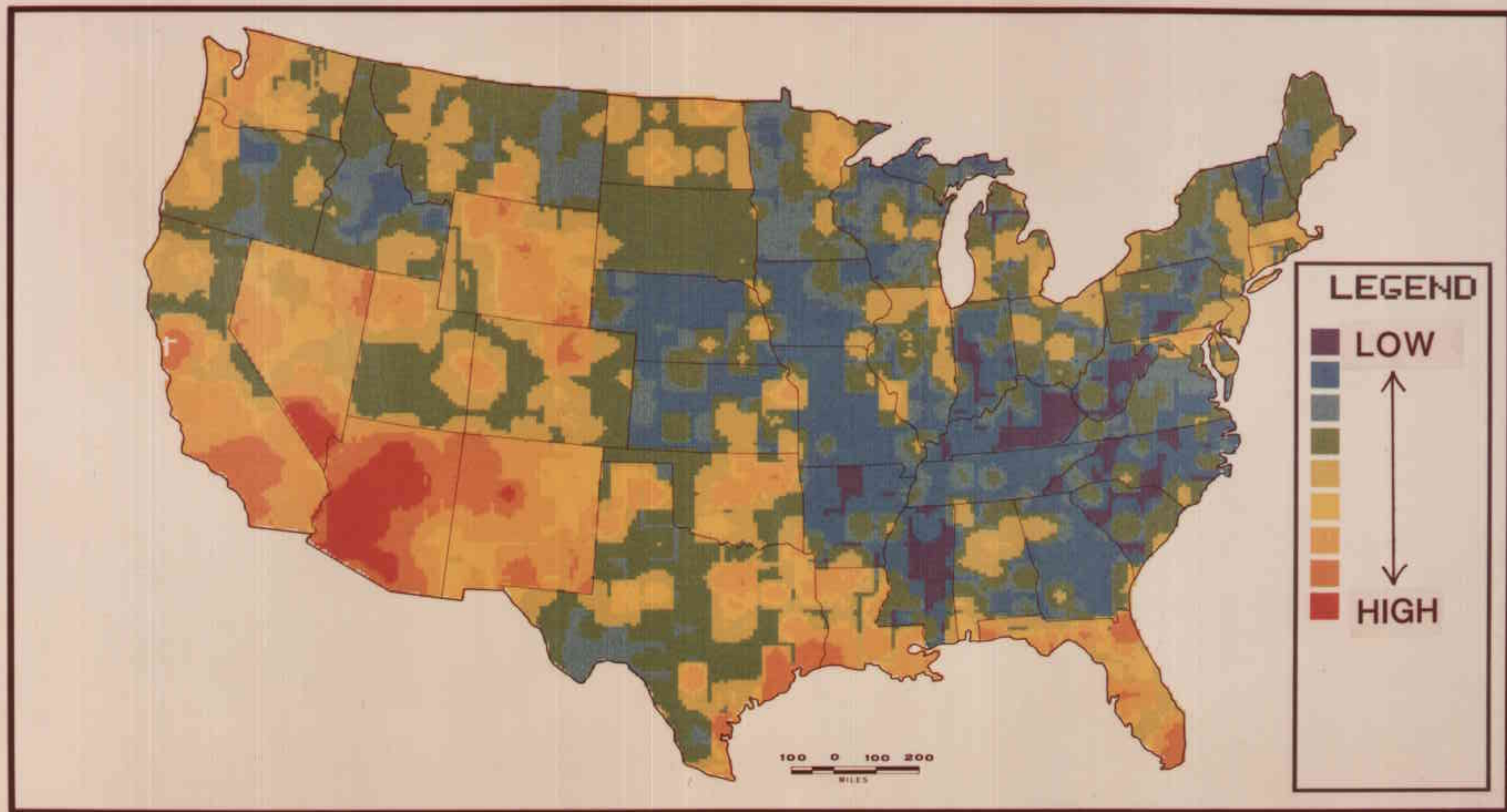
There are a number of reasons why the west and southwest regions are ranked highly in this analysis. Clearly, these parts of the United States generally have high solar radiation, tax and environmental incentives are common, positive industrial growth exists, and conventional fuels are from foreign sources to varying degrees. The northern mountain states (Mountain 2) and the southern plains states (West South Central 1 and 2) have a lower market ranking (with equal weighting of criteria) than the west and southwest. This ranking is similar to the east coast (New England, Mid Atlantic, and South Atlantic) but for different reasons. In these areas, domestic conventional fuels are readily available at lower than national prices. This serves to reduce the ranking of otherwise good areas. The northern mountain states have lower solar values because of latitude, but tend to have positive environmental incentives and one state (Utah) has tax incentives. In the south, these factors are reversed, with insolation gains being offset by fewer tax and environmental incentives. All these areas have industrial growth occurring. A strengthening of tax and environmental incentives, or a weakening of the availability of domestic conventional fuels, would increase the solar IPH market attraction for these regions. Conversely, the east coast maintains a favorable ranking despite the generally low value of solar radiation because of large industrial use of petroleum, an imported and expensive fuel.

The Great Lakes area (East North Central) shows still lower market rank because it is characterized by relatively weak insolation, lack of industrial growth, and a lack of tax and environmental incentives. The area's dependency on relatively expensive conventional fuels, some from foreign sources, and its large industrial base represent the chief factors in favor of solar applications.

The northern plains states (West North Central) and the southern Appalachian regions (East South Central 1 and 2) represent the least attractive geographic markets for solar IPH according to the criteria used in this analysis. The



MAP ES-1 PARABOLIC TROUGH SOLAR ATTRACTIVENESS INDEX



MAP ES-2 INTERMEDIATE TEMPERATURE DEMAND-GROWTH MARKET AREAS dominantly rural character and low insolation values of the northern plains, coupled with a lack of tax or environmental incentives, makes the region a relatively weak market area. The southern Appalachian region forms a weak market for another suite of reasons. In Kentucky and Tennessee, there are no tax or environmental incentives, and a lack of industrial growth and abundant conventional fuels exist. Further to the south, insolation improvements are largely or entirely counteracted by a lack of suitable demands, a continued availability of inexpensive conventional domestic fuels, and a lack of tax and environmental incentives.

This study successfully developed a data base of important geographic analysis factors, and identified those parts of the country with characteristics favorable to commercially available solar IPH systems. Regions of the country which are "sensitive" to the results of the ranking, based on equal weighting, were also determined.

It should be noted that the results of this work will become less valid over time because the state incentives for solar IPH, air quality regulations, and the status of competitive fuels will change in the future. Finally, analyses of this type may well be useful to solar R&D program planning by determining those parts of the United States which are likely to be the beneficiaries of various solar technologies.

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SECTION 1.0

INTRODUCTION

1.1 BACKGROUND

The industrial market for solar energy systems is highly complex. The manufacturing and mining sectors of industry include almost 500 different industries by four-digit Standard Industrial Classification (SIC). The total number of plants in industry exceeds 400,000. Each type of industry has different process requirements which pose varying challenges for solar energy systems. Further, plants within each type of industry often have different processes. Despite this diversity, there are many characteristics of the market and of solar technologies which will indicate where solar industrial process heat (IPH) systems are most likely to compete early with conventional IPH systems. Identifying these near term markets can aid private and public efforts to encourage industry to adopt solar energy early.

Past studies of the industrial market focused on basic data development and/or solar system performance/economic assessments (1-8). This past research and other identified data bases (9-11) provide the groundwork for the determination of near-term industrial markets for solar thermal systems. A convenient subdivision of these near term markets for analytical purposes is by four-digit SIC and by geographical region in the United States. The most meaningful determination of near-term markets will be the combination of promising four-digit SICs in promising geographical regions. Currently, work to determine these near-term markets is ongoing at SERI.

1.2 OBJECTIVES

The focus of this report is to summarize research at SERI and CSM (Colorado School of Mines) on geographical characteristics that provide a competitive advantage to solar thermal IPH systems. These characteristics form the analysis criteria of this research. The criteria may be related to supply (e.g., availability of solar radiation), the status of competitive fuels (e.g., the varying price of conventional fuels throughout the United States), or industrial demand (e.g., industrial plant locations). These criteria are discussed in more detail in Section 2.4.

There were two primary objectives of this research:

- to synthesize an initial data base for many criteria which affect the feasibility of solar thermal systems in regions, states, and local areas of the United States, and

- to determine, based on available data, where solar thermal systems are more likely to compete (technically, economically and institutionally) in the United States with conventional IPH systems in the near-term.

The data base for this analysis was prepared for solar thermal systems that currently are being marketed for industrial applications. Depending on the type of solar technology, these systems are suitable for various process temperatures below 288°C (550°F).

1.3 LIMITATIONS

This research was limited primarily by a small budget; yet extensive data synthesis, mapping and analysis tasks were necessary. A significant amount of the budget funded graduate students for data collection, programming, and analysis efforts. Owing to the small resources available, several additional limitations of significance were apparent. These include the following:

- Adequate data do not exist for some criteria that may affect the viability of solar IPH systems in different parts of the country. Examples of such criteria are the amount of land/roof available at industrial locations, and industrial areas that are most susceptible to energy curtailments (gas is discussed in Section 3.2.1 but good data were not readily available for estimating where oil and electricity shortages might occur).

- Decision-makers from industry were not interviewed to help weight the criteria used in this study. Clearly, industry decision-makers have opinions concerning the relative importance of many of the geographic suitability criteria, but the resources required for a valid study of these opinions were beyond the capabilities of the research project. Through sensitivity analyses of the criteria used in this study, the authors believe that this limitation does not significantly affect the results of this work.

- The study of near-term geographic markets did not include all U.S. states and possessions. Consistent data for some criteria were unavailable or difficult to generate for some areas. Specifically, Alaska, Puerto Rico, the Virgin Islands, and various other possessions were not included in this study, and Hawaii is not shown on the map displays.

- This study was not made deterministic because it is not based on a quantitative analysis of some common denominator in the criteria. For example, a common denominator such as cost could have been used for many criteria, but only at a significantly increased research effort.

- The study is applicable to all solar thermal technologies that can provide process temperatures below 288°C (550°F), but only a generic salt gradient pond, and flat-plate and parabolic trough solar collectors were specifically included in the performance calculations. High-temperature solar collector systems, evacuated tubes, and other variations of the above basic types of collectors were not included in the market study.

SECTION 2.0

GEOGRAPHIC ANALYSIS METHODOLOGY

This section reviews the historical basis, rationale, and technical structure of the geographic analysis methodology. Appendix A discusses it in more depth.

2.1 CONCEPTUAL BACKGROUND

Geographic suitability analysis methods, most notably developed by Hills (12,13) and McHarg (14), have been used extensively for land use planning purposes. Working for the Canadian Province of Ontario, Hills tried to determine forest land areas most compatible for recreation, agriculture, forestry, and wildlife uses. The initial step of Hill's method is to disaggregate a large land area into increasingly smaller areas based on criteria (e.g., soil moisture and soil depth for agriculture) which distinguish an inherent capability of the land units for each land use. Numerical values are assigned for each small land area which can be weighted and later aggregated into a rating for a larger section of land. Capability ratings are based on the inherent physical features of the land; suitability ratings on the potential of the land area to reach its maximum capability through management practices; and feasibility ratings on the potential of the land determined by existing or future socio-economic conditions.

McHarg's (14) approach to geographic analysis relied on a series of maps produced as overlays. Maps are produced for specific sets of criteria for recreation, residential development, and commercial and industrial development. Table 2-1 is a sample set of criteria used in McHarg's early analysis efforts. The maps are characterized by colors or shades of gray to denote high or low suitability for each criterion. All criteria or maps for each separate land use are superimposed. The resulting shades of gray or colors would identify composite suitability for each land use. By superimposing each composite map for each land use, compatibilities and conflicts between land users are readily determined.

2.2 ADVANTAGES OF A COMPUTER ASSISTED METHOD

Many variations of Hill's and McHarg's approaches have been used in land use and other planning activities. These approaches are also suitable for this project because there are many criteria that can identify the geographic suitability of a solar IPH system (see Section 2.4). The only common denominator among them is their geographical location; thus, the comparison of these criteria with industrial location data requires the use of a mapping procedure. Also, a mapping approach highlights the physical locations and size of the various market regions, which are critical to an understanding of the significance of the results.

The normal production of graphic aids is so expensive and slow that their use for data presentation, and particularly for data analysis, has often

TABLE 2-1

PARTIAL EXAMPLE OF McHARG ANALYSIS CRITERIA

Ecological Factor	Ranking Criteria	Value for Land Use* C	P	A	R	I
Climate						
Air Pollution	Incidence		x	x	x	
Tidal Inundation	Incidence			x	x	x
Geology						
Unique Features	Scarcity	x	x		x	
Foundation Conditions	Compressive Strength			x	x	x
Physiography						
Unique Features	Scarcity	x	x			
Land Features of Scenic Value	Distinctive	x	x	x	x	
Water Features of Scenic Value	Distinctive	x	x	x		
Riparian Lands	Vulnerability	x		x	x	x
Beaches Along the Bay	Vulnerability	x	x	x	x	
Surface Drainage	Water/Land Area	x	x	x	x	x
Slope	Gradient			x	x	x

(Also Included:)

Hydrology

Pedology

Vegetation

Wildlife

Land Use

*C = conservation, P = passive recreation, A = active recreation, R = residential development, I = commercial and industrial development.

Source: McHarg, I.M., Design with Nature, 1969.

been limited. The approach of using manually developed map overlays has a number of other disadvantages, including:

- only a limited number of maps may be superimposed;
- it is impossible to weigh some maps as more (or less) important than the others; and
- no permanent record exists of the composite.

Such problems can be largely overcome through the use of a computer-based system. Instead of graphically overlaying tonal transparencies, a computer can be programmed to algebraically combine or "composite" two or more matrices, whose elements have numerical values corresponding to the shaded densities of the manual system. Then the computer can be programmed to produce gray or color tone maps of the resultant composite map, thereby giving a permanent record of the result.

There are many widely accepted techniques for computer-aided graphical display, also the product of many years of individual research. The requirements of this project led to the selection of certain of these techniques which most economically satisfied the needs.

The project utilized a computer-aided geographical analysis system developed by A.K. Turner several years ago (15, 16, 17). The system is called "Generalized Map Analysis Planning Systems" (GMAPS) and it performs interactive, cellular, composite mapping and computer mapping.

2.3 THE GMAPS PROGRAM

The GMAPS programs perform three major functions:

- data entry and display (input-output, or I/O, functions)
- data storage and cataloging, and
- data manipulation, statistical evaluation, and evaluation of new data products.

In its current configuration, GMAPS allows for efficient data coding and entry, in cellular formats, of existing mapped geographical data. The manipulation and rapid display of these data, and the interchange with certain pre-processing and post-processing programs is easily accomplished.

The pre-processing systems include latitude/longitude to X-Y coordinate transformation, contouring, and census data extraction programs. The post-processing programs incorporate certain specialized enhancements to the basic GMAPS capabilities.

GMAPS operates interactively from a computer terminal connected to the Colorado School of Mines computer (a DEC-1091). GMAPS is attractive to use because:

- the user responds to the programs sequence of questions, thereby defining the operations and sequence of operations he wishes the computer to perform;

- the programs allow the user to verify and correct commands, so that meaningless operations are eliminated;

- the system is easily used by laymen;

- the time-sharing concept gives the user access to a high capacity computer at economical cost.

GMAPS represents geographical data in a cellular format such that the map area is converted into a matrix analog. Each matrix element is automatically assigned a geographical position. If each element is small enough, a good representation of the geography is maintained. Each small elemental area is termed a cell (Figure 2-1).

A cellular system leads to economical displays using line printers. These "printer" maps, produced quickly on existing standard equipment, are cost-effective for many planning applications. The maps can be made visually more attractive by causing the overprinting of certain characters to produce a range of tonal densities, or "gray-tone" maps. Photo reductions of the maps are suitable for most reports. Because the printer characters are rectangular (1/8" by 1/10"), some restrictions are imposed on the sampling of source maps in order to prevent distortion. Also, some limitations on the size of output products exist.

The GMAPS program flexibility met the specific demands of this research. For example, economic activities are not uniformly distributed within states; some industries naturally cluster toward major industrial centers, while others are located at the sources of their raw materials. Uniform state-level mapping makes artificially distinguished areas known to be similar along state boundaries. An early use of the GMAPS program in this research showed a difference between western Texas and eastern New Mexico, although none actually exists. However, the effects of industrial concentrations, perhaps in Houston, were reflected many hundreds of miles away. To avoid this problem, the county-by-county Bureau of Census four-digit SIC code tabulations can be combined with other Bureau of Census data which supply the latitude/longitude coordinates of county population centroids. Thus, the tabulations are placed at the centroid of each county. The population centroids are believed most suitable for handling the frequently very large counties found in western states (see Figure 2-2A).

Thus, maps of concentration of industry can be produced by passing an areal filter (or window) over the entire map, counting all centroids falling within the window, and placing the total at the center of the window region. This procedure, shown in Figure 2-2B, will convert the irregularly placed centroid values into a regularly spaced set of concentrations. These concentrations can then be totaled for groups of industries, and contoured to show areas lying above certain threshold levels (see Figure 2-2C).

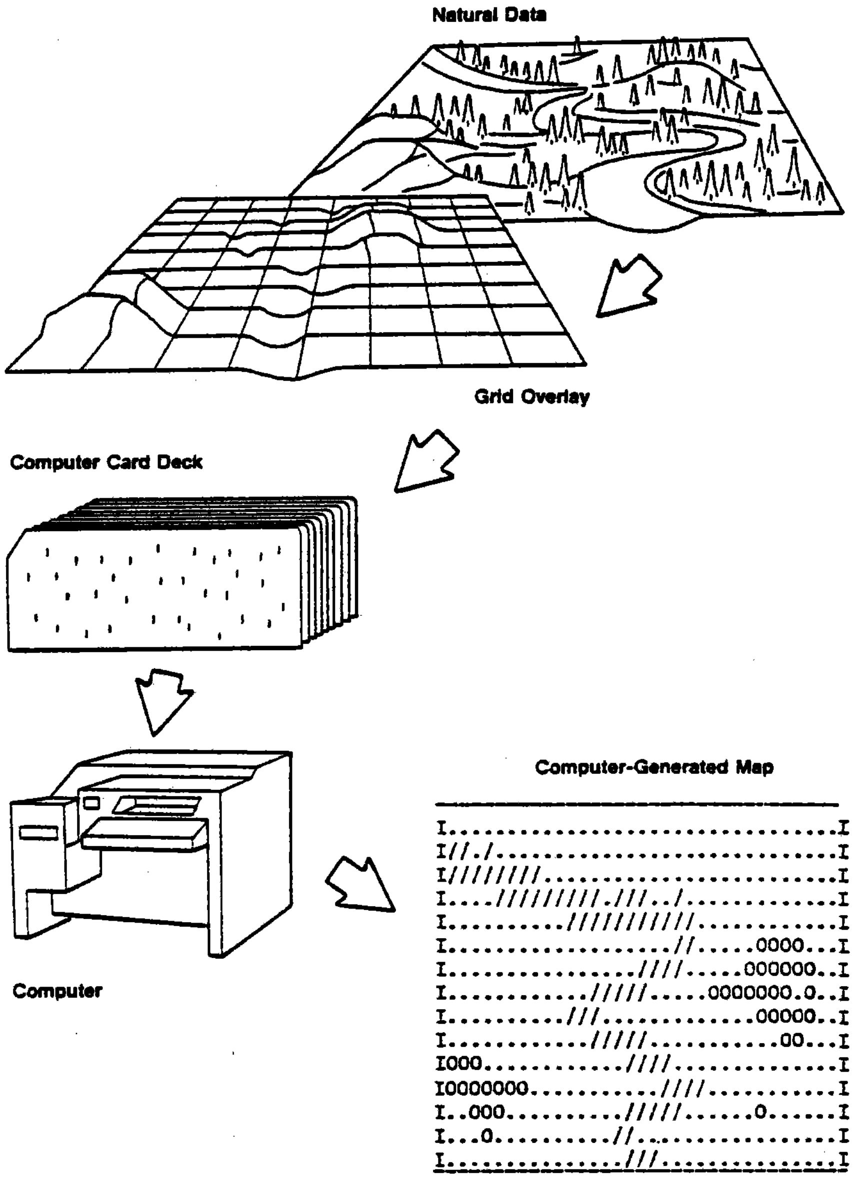


Figure 2-1. Cellular Mapping Data Bank Development

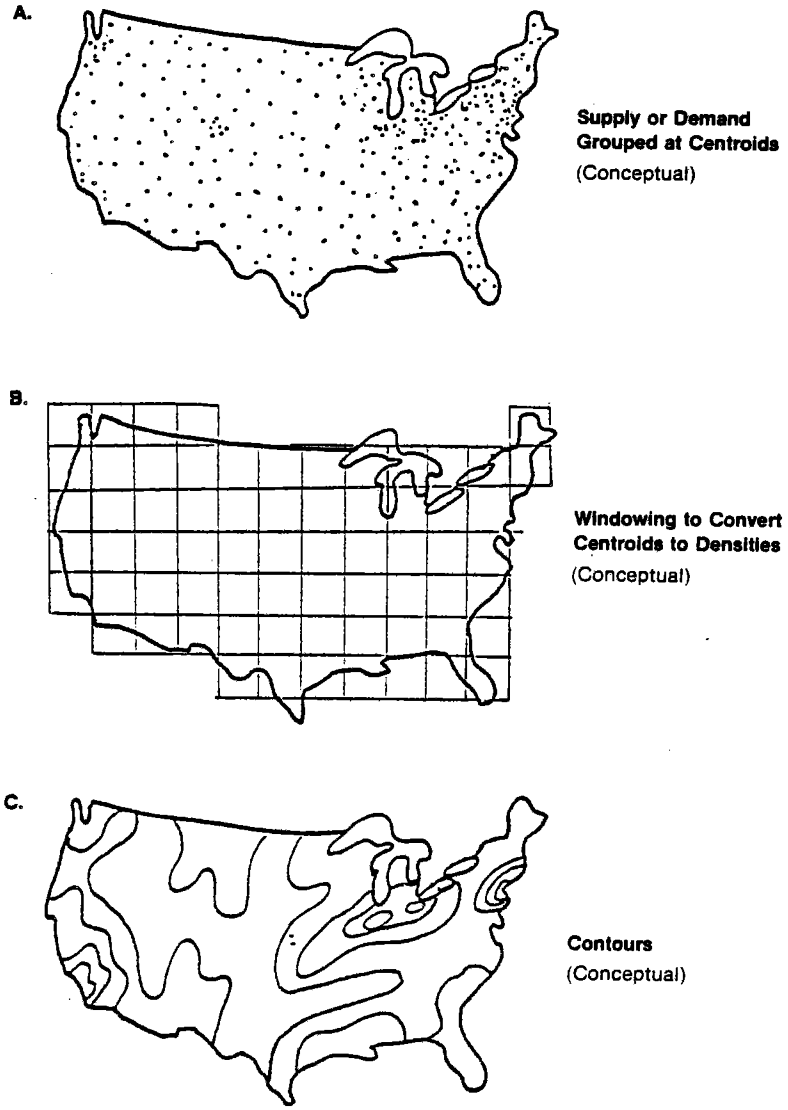


Figure 2-2. Centroids, Windowing, and Contouring as Part of the Mapping Procedure

2.4 GEOGRAPHIC MARKETS CRITERIA

The common characteristic of all geographic suitability efforts is a set of evaluation criteria. For this research, criteria were selected that would indicate a competitive advantage to solar IPH in some geographical area of the United States. These criteria were grouped into three categories (see Figure 2-3): solar supply, competitive fuels, and industrial demand. When combined, they will yield market area rankings.

The Solar IPH Supply Attractiveness Rating (Solar IPHSAR) attempts to measure and rank performance, cost, and legal benefits to solar IPH, for each area within the United States. The Solar IPHSAR concept combines the solar supply and competitive fuels data categories.

To estimate the Solar IPHSAR, a measure of the ability of solar technologies to supply the necessary energy must be developed. This is a function of the insolation available at a site and its characteristic variation due to latitude, climate, and other such factors. It is also a function of the efficiencies and characteristics of different collection technologies. Thus, at a given site, flat-plate collectors will give supplies differing from either parabolic trough collectors or solar ponds. Of course, within any collector class, differences in design will also affect the energy output. For this study, standard designs for flat-plate, parabolic trough, and solar pond systems were assumed.

A second element of the Solar IPHSAR is air quality regulations. The non-polluting nature of installed solar collection systems may be greatly significant in areas affected by air quality standards. In several areas, no significant degradation of the air quality is allowed (Class I PSD air quality regions), or no further adverse changes are permitted (non-attainment areas). In these cases, industries requiring additional fuel burning capacity may be required to purchase and shut down, or clean up, or convert, some existing source of air pollution. In such circumstances, the nonpolluting aspects of installed solar systems may prove very appealing, even when the system costs may be less attractive than the cost of traditional systems.

The third element of the Solar IPHSAR is financial incentives at the state level. These financial incentives can be sales, property, or income tax related. However, the largest incentives usually are the business income tax credits offered for installing a solar energy system.

The status of competitive fuels is the second category of criteria for this analysis and provides the final elements for the Solar IPHSAR. The prospect of energy curtailments in an industrial area is a convincing argument for investigating self-sufficient solar energy systems. However, a clear determination of where curtailments are likely to occur is unavailable, and was beyond the resources of this project. Despite this limitation, some discussion of this important criterion is included in Section 3.0. Other criteria in this category are competitive fuel prices and market shares throughout the United States. Where both fuel prices and market shares of that fuel are high, solar systems may have an improved opportunity to compete with conventional IPH systems.

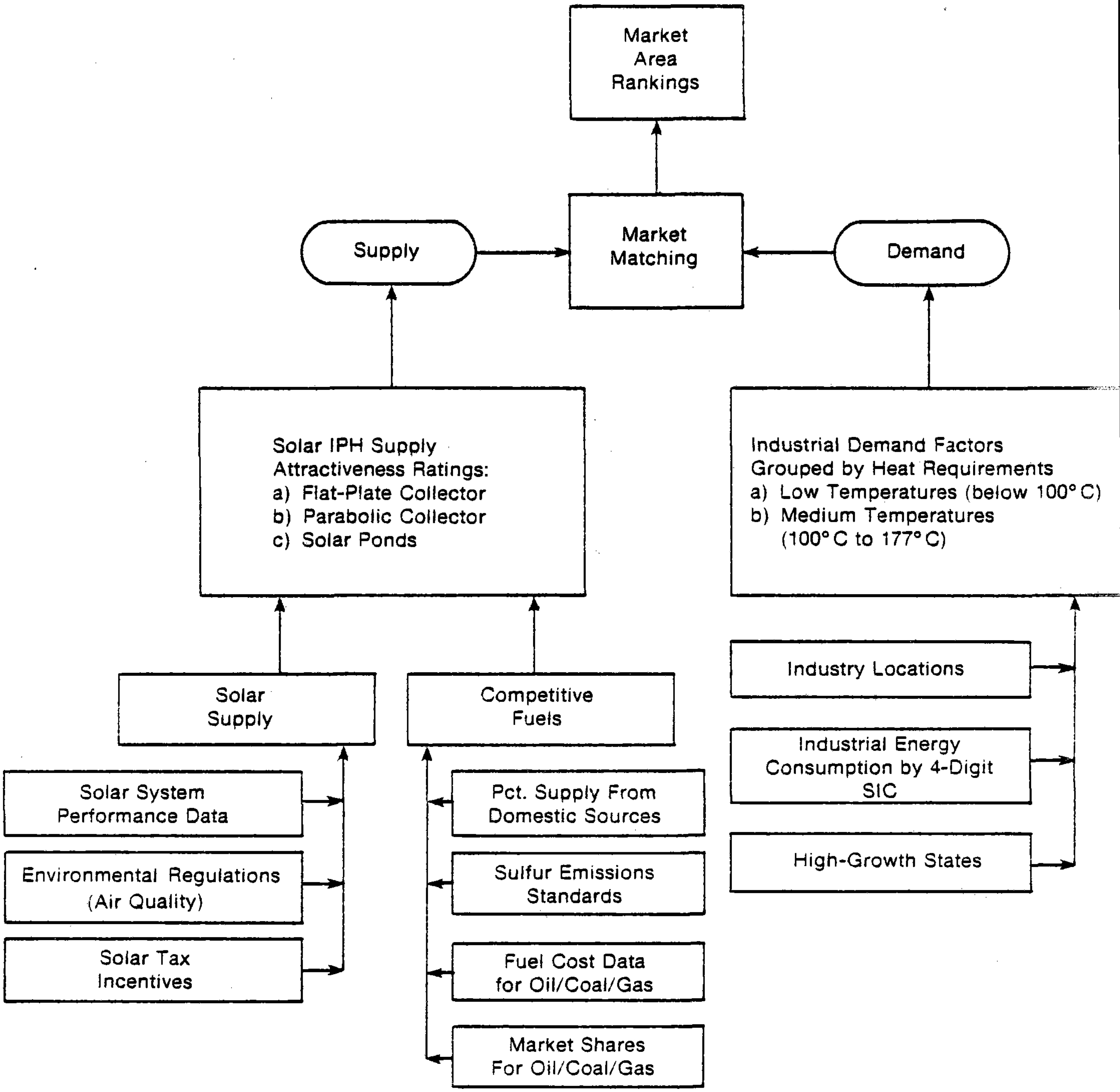


Figure 2-3. Solar IPH Modeling Strategy

The final category of criteria is industrial demand. The demand side is especially important if the objective is to cause retrofitting, or refitting and upgrading, of existing installations. Such upgrading may lead to significant savings of traditional non-renewable fuels. At the national level, at least initially, it appears impractical to identify individual conversion target sites because individual site visits are costly. Rather, it seems best to locate those areas where a concentration of latent demand most likely exists, creating potential marketing targets.

SERI research has already identified a number of industry types that have energy demands by process temperature which can be readily met by solar energy systems. These industries are identified by four-digit SIC codes. Additionally, the distribution of plants by four-digit SIC codes is tabulated by the U.S. Bureau of Census by counties (and by states, and nationally) in a single limited format. This includes the number of plants within each of six employment ranges. No other statistics are consistently available at this level of detail. The primary criteria used to identify industrial demand are industry locations, industry energy consumption, and industrial growth patterns. Industrial growth patterns may indicate opportunities for identifying planned industrial plants which may greatly simplify solar system design, integration with plant processes, and financing issues.

2.5 MARKET MATCHING AND RATING

At this point, the discussion of the concept has led to the development of two classes of product maps (based on a linear combination of criteria), one defining the Solar IPH Supply Attractiveness Ratings and the other defining the user demands (see Figure 2-4). In the actual study there will be three maps measuring solar IPH attractiveness, one for each of the solar pond, flat-plate, and parabolic trough collector systems. Similarly, there will be two maps representing area demands, grouped according to temperature, one representing the low temperature users, and one representing the medium temperature users.

A measure is now required that will

- define a series of market regions within the United States,
- allow the extraction of pertinent statistics describing the Solar IPH attractiveness and user demands for each region,
- allow the comparison and ranking of these market regions, and
- explore the sensitivity of the rankings of these regions to changes in any of the parameters defining the solar IPH attractiveness or user demands. This methodology is called market matching and rating.

2.5.1 Definition of Market Regions

Market regions can be defined in at least two ways. They can be defined administratively, or they can be defined according to concentrations of demand. There are, of course, the standard Federal regions, although in actuality, several government agencies use their own non-standard regions. There are regions defined and used by many economic models, the Bureau of Census data summaries, and so forth, which attempt to group states having similar economic characteristics. The Data Research, Inc. (DRI) reports (18, 19), referred to in greater detail in Section 3, defined a total of 13 regions, which closely follow the more generalized Bureau of Census economic regions. By defining a series of economically cohesive regions, it is possible to evaluate the market potential of each by following the procedure laid out in the next section.

Alternatively, the administrative procedure for defining market regions is possible. However, the administrative imposition of artificial regions may not always be appropriate. For example, the user demand maps may show natural geographic clusterings which reflect real interactions within the market place. There is a danger that administratively defined state groupings may slice through such natural market groups.

As shown in Figure 2-4B, the user demand data can be contoured to show natural groupings. A threshold level of concentration, perhaps the median level, allows the separation of such clusterings from the background. Depending on the selection of the threshold level, these regional clusters can be smaller, sharper, and more precise, or broader and more diffuse.

2.5.2 Analysis and Ranking of Market Areas

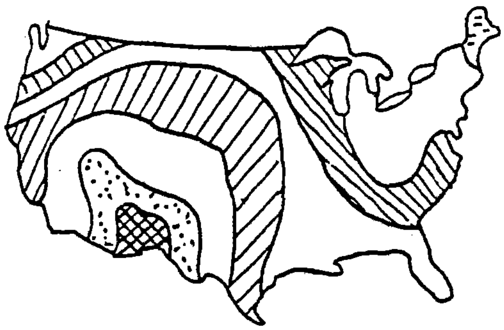
Either method will produce a selection of regional market areas. The next step is to analyze and rank each.

Each region must first be analyzed by overlaying it onto the various data maps representing either solar attractiveness or user demands factors. Within each region, these data factors will show patterns and ranges of their demand or supply characteristics. Each region can, in fact, be characterized by such statistics as its:

- size (area),
- maximum demand value,
- area average demand value,
- highest solar attractiveness,
- lowest solar attractiveness, and
- average solar attractiveness.

These values can be used to rank the various market regions. The method used can be visualized as a vector process. The most simple case is with only two dimensions; however, three, four, or more dimensions can be used just as easily (although it is not possible to show graphically more than 3 dimensions).

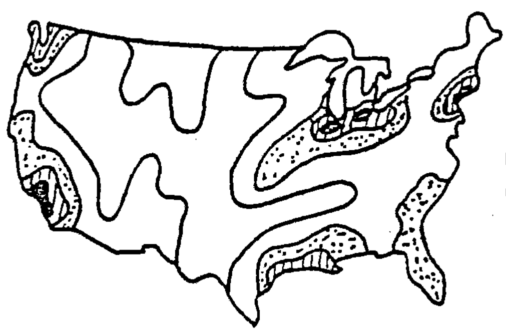
A.



Solar IPH Supply Attraction Ratings (Conceptual)

Cross-hatched Area is Highest

B.



User Demands (Conceptual)

Dark Areas are Higher

Figure 2-4. Conceptual Examples of Solar IPH Attractiveness Rating Map and User Demands Map

The appropriate values of solar attractiveness and user demand for each region can be plotted on a regular graph (refer to Figure 2-5). Each region can, therefore, be represented as a vector extending from the origin (0,0) to the appropriate coordinate location. The length of the vector can be used as a measure of rank, since the longer the vector the longer the radius of the circle required to contain the vector. Secondly, the ratios of the original solar attractiveness and user demand coordinates to the vector length (the cosines of the angles between the vector and the axes) define the loadings of the original factors onto the vector. These loadings measure the relative importance of these input factors to establishing the regional ranking.

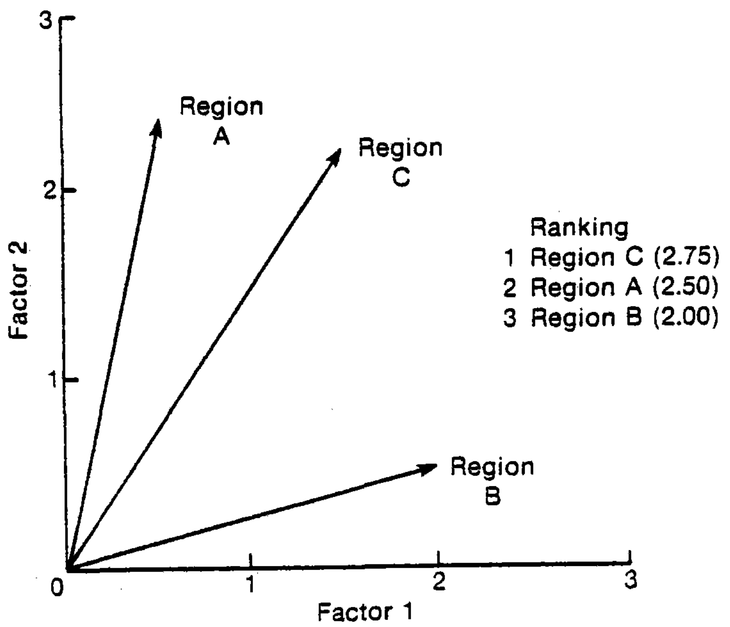
As mentioned previously, the two-dimensional case shown in Figure 2-5 is easily expanded to three or more dimensions. The vector arithmetic still holds. In three dimensions, the circles become spheres and the vectors become the radii of such spheres. In four or more dimensions, the spheres become hyper-spheres.

2.5.3 Analyzing Regional Ranking Sensitivities

Refer again to the two-dimensional model in Figure 2-5. The axes, while remaining perpendicular to each other, can be distorted by lengthening or shortening their scales. This corresponds to making some factors more important than others. Such scale adjustments will affect the regional vectors differently. A vector which nearly parallels an axis that is lengthened will likewise be lengthened, whereas a vector running nearly perpendicular to the axis will be essentially unaffected. This differential adjustment in the lengths of the regional vectors will be reflected in the regional rankings.

This provides an easy procedure for analyzing regional sensitivities. By using a multidimensional vector analysis which includes such factors as environmental incentives, fuel prices, etc., it is possible to adjust the relative importance of these factors and observe the changes in the regional rankings.

A) Two-Factor Vector Ranking with Equal Factor Weights



B) Two-Factor Vector Ranking with Factor 1 Weighted 2.0

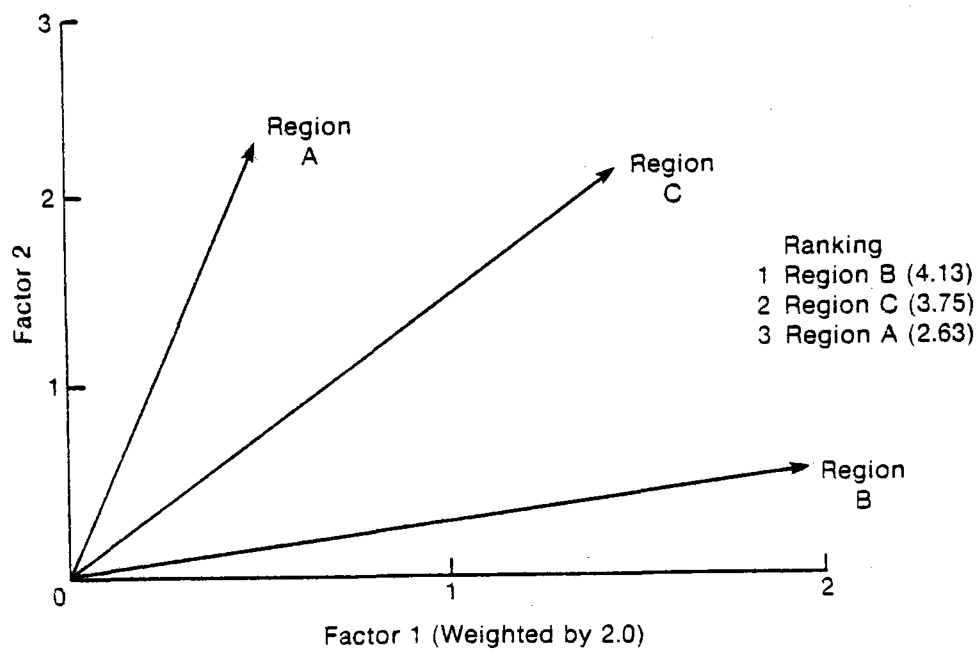


Figure 2-5. Ranking of Marketing Regions by Vector Methods

SECTION 3.0

CATEGORIES AND SOURCES OF DATA FOR ANALYSES

This section describes the data used in the solar IPH suitability analysis. Comments are focused on the types of data used, respective data sources, and a brief on the analytical procedures used to transform the data to the required formats for this project. Appendices B, C, and D critique the data in greater detail, more fully explain data transformation procedures, and comment on data sources that were not used.

Table 3-1 shows the data categories selected for inclusion in the suitability analysis. These categories are topical and can be ordered into three natural data groups; namely, supply, competitive fuels, and demand. The supply data categories are solar collector output, air quality regulations, and solar tax incentives. The competitive fuels data categories are natural gas curtailments; oil, natural gas, and coal prices; and oil, natural gas, and coal market shares. Industry locations, industry energy consumption, and regional industrial growth patterns are the demand data categories.

3.1 SUPPLY DATA CATEGORIES

Supply data categories were defined by either physical capabilities of collector systems, or legal and environmental incentives. The collector systems are generic flat-plate collectors, parabolic trough collectors, and solar ponds. Each collector system is suitable for low-temperature solar IPH applications. Legal and environmental incentives for the use of solar IPH are defined by tax incentives and air quality regulations.

3.1.1 Solar Collector Output

An analytical method for comparing the output of different solar IPH collectors in different parts of the United States has been developed by SERI. This method has been implemented as a flexible, fast-calculating computer code called PROSYS (20). The performance model PROSYS predicts long-term annual energy output for several collector types. PROSYS uses a meteorological data base (METDAT) that specifies the quantity and quality of available solar radiation at 248 U.S. locations. It gives values for a typical day each month, including long-term average daily radiation on a horizontal surface, clearness number, daytime ambient temperature, and cloudiness index (K_T) for each location.

Details of the assumptions underlying each collector type are given in Appendix B. The values of solar energy outputs for each of 230 stations (Alaska excluded) for the assumed configurations of flat-plate, parabolic-trough, and solar pond collectors are given in Appendix E.

For mapping and analysis purposes, the stations in Hawaii and miscellaneous U.S. possessions were not used. Hence, the number of data points dropped to those representing 223 stations. Figure 3-1 shows the analytical procedure followed in preparing the contour maps for each collector system (see MAPS 1, 2, and 3).

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TABLE 3-1

SOLAR INDUSTRIAL PROCESS HEAT DATA CATEGORIES

Data Item Number and Category	Description
Supply Data	
1.	Energy output for flat-plate, parabolic trough, and solar pond collector systems in different regions of the U.S.
2.	Areas where air quality regulations can prevent a company from building a new plant or increasing boiler capacity at an existing plant.
3.	States with solar tax incentives, by magnitude, for industry.
Competitive Fuels Data	
4.	Areas more likely or least likely to have curtailments of natural gas.
5.	Current oil (both residual and distillate), natural gas, and coal price in each state and region of the U.S.
6.	Locations where coal currently is not and probably will not be used by industry in the future.
Demand Data	
7.	Locations of plants by number for 81 different four-digit SIC industries.
8.	States which have a recent history of attracting new industry.
9.	Total energy consumption by state for 81 different four-digit SICs.

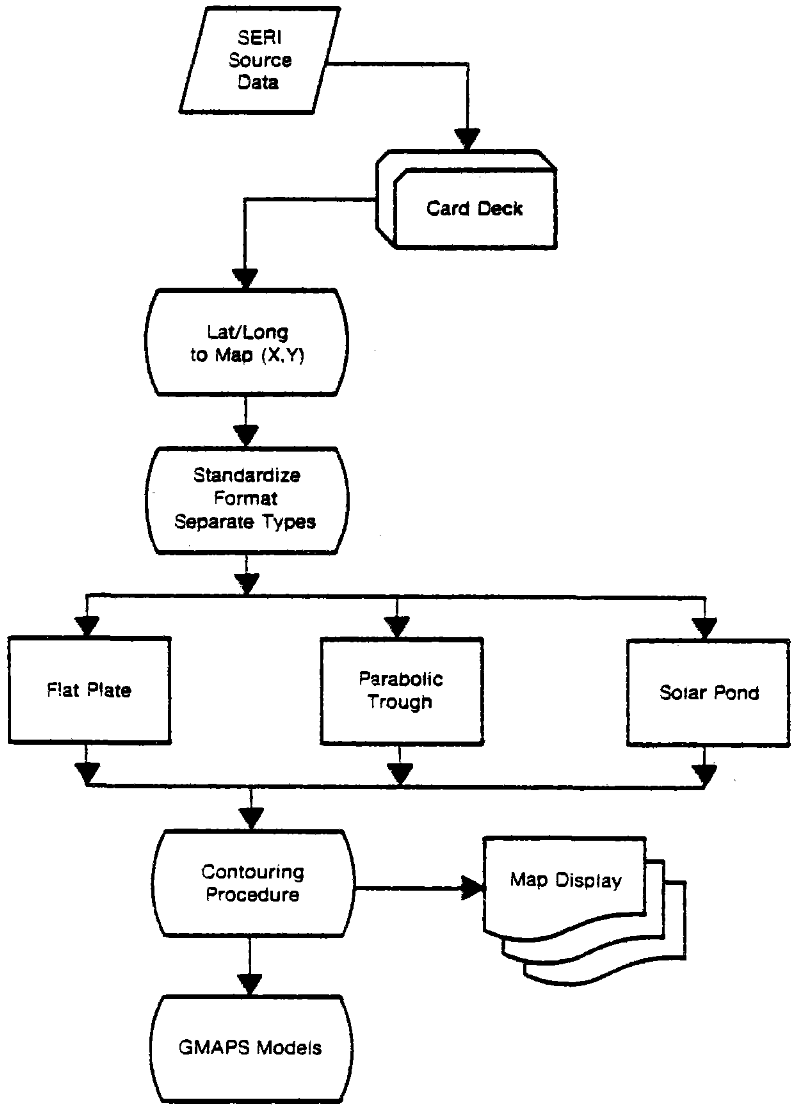

Figure 3-1. Solar System Outputs Methodology for Flat-Plate, Parabolic Trough, and Solar Pond Collectors

Results obtained from the PROSYS simulations were supplied by SERI in the form of a card deck. Each station was located by latitude/longitude coordinates. These were converted by a program containing the equations of the Lambert Conformal Conic Projection to Cartesian X and Y coordinates (in inches) which conformed to the correct position of each station on the base map.

The resulting transformed coordinate data were translated into a standard data format and created a file for each generic collector type. These were processed by a contouring program that produced both sample map displays (see MAPS 1, 2, and 3) and data files that could be entered directly into the GMAPS mapping system data base.

Maps 1, 2, and 3 show the varying geographic output of the three collector types. The numerical output of the different collector types should not be cross-compared. This is because the data represent only a typical collector of each type, and the systems are not similar enough to be accurately compared via maps (e.g., ponds include inherent storage while troughs and flat plates do not; also, different temperature outputs were assumed for each collector type, thereby affecting efficiency). Clearly, the only accurate comparison would be with parallel system configurations, similar operating parameters, and data for mapping cost per unit of output (e.g., $/MMBtu). This was beyond the intent and scope of the research. The current map results are consistent with past work which shows substantially greater output per unit area in the southwest United States in comparison to the northeast or northwest for all three collector types. Also, the geographical variation in performance of salt gradient solar ponds differs from flat-plate and parabolic trough collectors because the required horizontal orientation of ponds causes output to be highly latitude dependent.

3.1.2 Air Quality Regulations

Air pollution control legislation may thwart the installation of new or modified industrial operations in several ways. Basically, there are two legislated mandates that may serve to constrain new development.

In areas that already have experienced industrial development, current air quality is compared to the National Ambient Air Quality Standards (NAAQS). In many cases, such areas presently do not meet such standards and are termed "Non-Attainment Areas". Their additional development is restricted according to the procedures outlined in the appropriate state implementation plan, developed by the state and approved by the EPA. However, similar considerations may also apply to areas that approach, but do not presently exceed, such standards.

A second set of restrictions concerned with "Prevention of Significant Deterioration" (PSD) must also be considered. This applies in parts of the country having "clean air" so that the NAAQS standards are not in jeopardy.

In 1971, the Environmental Protection Agency (EPA) set national ambient air quality standards for five pollutants considered to be most dangerous to human health and welfare. These pollutants and their numerical standard values are identified in Table 3-2. The primary standards endeavor to protect the public health; and the secondary standards, public welfare. Thus, although the two

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TABLE 3-2. SUMMARY OF NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Particulate Matter (TSP)	Annual (Geometric Mean) 24-hour	75 μg/m^3 260 μg/m^3	150 μg/m^3
Sulfur Dioxide (SO_2)	Annual (Arithmetic Mean) 24-hour	80 μg/m^3 (0.03 ppm) 365 μg/m^3 (0.04 ppm)	
	3-hour		1,300 μg/m^3 (0.5 ppm)
Carbon Monoxide (CO)	8-hour	10 μg/m^3 (9 ppm)	Same as primary
	1-hour	40 μg/m^3 (35 ppm)	Same as primary
Nitrogen Dioxide	Annual (Arithmetic Mean)	100 μg/m^3 (0.05 ppm)	Same as primary
Photochemical Oxidants (O_3)	1.1 hour	243 μg/m^3 (0.12 ppm)	Same as primary

Source: EPA Data (Wagner and Deal, 1980) standards do not measure the same thing, and one cannot readily compare their effects, the primary standards are usually more important and thus more restrictive than the secondary standards.

In 1972, states were required to submit to the EPA their State Implementation Plans (State IP) containing control measures to meet these primary and secondary standards by mid-1975 or mid-1977. However, because of the complex nature of many air quality problems, some areas have still not attained the NAAQS. In recognition of this fact, in August of 1977, Congress amended the Clean Air Act by adding Section 107(d). For those areas designated as nonattainment for one or more pollutants, states must now develop additional control programs and plans that, when implemented, will attain NAAQS by 1982 (or 1987 for areas with difficult carbon monoxide or ozone problems), unless extensions are granted on a case-by-case basis.

New plants, or modifications to existing plants, are subject to State IP requirements; i.e., the applicant must indicate measures to contain allowable emissions and must use the latest revisions to the legislation on implementing regulations. In addition to the State IP regulations, new plants are subject to "New Source Performance Standards" (NSPS). The NSPS require the most stringent controls on emissions and advanced state-of-the-art control technologies. The EPA is currently issuing NSPS data (see Appendix B).

In April 1980, the EPA issued a report containing maps and lists of all non-attainment areas as of 31 December 1979 (21). The designation of non-attainment areas is continually changing, however, with updated designations appearing periodically in the Federal Register. Actual levels of pollution are not published; instead, non-attainment is indicated for all or part of a county.

Figure 3-2 shows the basic procedure developed for the analysis of the non-attainment areas. A computer file was created from a Bureau of Census data base file (22) and the current non-attainment designations (21) that contained these data items:

- state and county FIPS code,
- county and state name,
- latitude and longitude coordinates of the county population centroid, and
- five-digit code specifying non-attainment status for the five pollutants defined by the EPA.

Appendix B describes in detail the methodology for analyzing non-attainment areas. For each of the five pollutants, an attainment/non-attainment code was developed (Table 3-3A). The coding was used to develop a status index (SI) which is essentially an ordinal ranking of the constraints. Table 3-3B presents the SI values.

A pollutant severity index (PSI) was developed to account for the differing amounts of each pollutant produced as a function of activity; e.g., burning of coal. Table 3-4 shows the levels of each pollutant produced in t/yr/Btu x

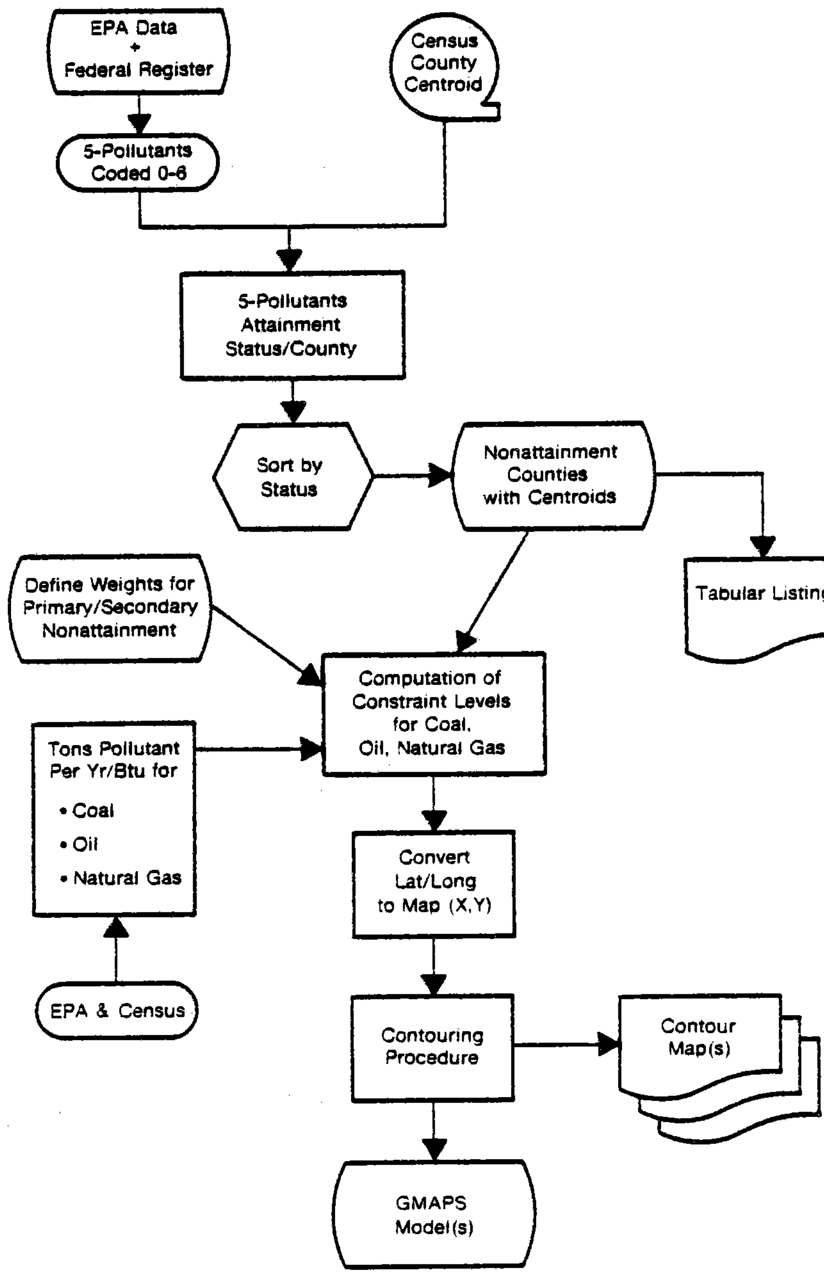

Figure 3-2. **Methodology for Computing the Air Quality for Nonattainment Areas by Fuel Type.** (Products that result are constraints for coal, oil, natural gas, and combined market share.)

TABLE 3-3. NON-ATTAINMENT CODES AND STATUS INDICES

Condition	Does Not Meet Primary	Does Not Meet Primary & Secondary	Does Not Meet Secondary
A. RELATIONSHIP AMONG NAAQS NON-ATTAINMENT CODES*			
All of County	6	4	2
Part of County	5	3	1
B. STATUS INDICES FOR NAAQS NON-ATTAINMENT STATUS CATEGORIES			
All of County	4.0	5.0	2.0
Part of County	2.0	2.5	1.0

*NOTE: Because for CO, NO_2, and O_3, the primary and secondary standards are identical; code 5 will be treated as code 3, and code 6 will be treated as code 4, for these pollutants.

TABLE 3-4. POLLUTION LEVELS FOR FUELS

Fuel	Percent* of Energy Demand	Tons/BTU x 10^9				
		CO	NO_2	Oxidants	SO_2	TSP
Coal	12	26.5	356.3	1409.5	10.9	573.9
Petroleum	19	27.8	219.8	591.4	9.6	62.2
Natural Gas	58	14.7	102.5	11.4	2.4	6.2
Weighted Average for All Fuels	89	19.1	161.8	323.7	5.08	94.7

*The remaining 11% of energy demand is attained from electricity.

Sources: 1975 EPA data for point source pollutants tons/yr and 1976 Census Data industry consumption BTU x 10^{12}

10^9; the values in this table are the data points in the PSI. When multiplied by the appropriate SI, and summed for all pollutants, a single NAAQS constraint level can be computed for each county, for any fuel, or for a market composite case using the weighted average (according to market shares) for each fuel. Utilizing these indices, the NAAQS constraint levels range from 0.0 for a county having full-attainment status to maximum values of 11885.5 for coal, 4554.0 for oil, 868.0 for natural gas, and 3022.5 for a market composite case.

As shown by Figure 3-2, maps of these values were produced by assigning the appropriate constraint levels to each county centroid and contouring the results. The maps for coal, oil, and natural gas are shown as MAPS 4, 5, and 6. These maps show air quality constraints to be greatest in metropolitan areas of the country for all three fuels. These metropolitan areas primarily are in California, the Great Lakes Region, the Northeast, Florida, Texas, Louisiana, Missouri, Nebraska, Utah, and several other parts of the south.

The PSD program established a pre-construction permit system to prevent the degradation of air quality in areas where NAAQS are being met. A new major stationary pollution source, or a source undertaking a major modification, must obtain a permit containing conditions under which its construction and operation may take place.

The PSD program also establishes three classes of air quality which allow various amounts of deterioration. Class I areas, which include international parks, national parks, and wilderness areas, permit only small additional increments of pollutants. Class II permits a moderate degree of air quality deterioration. Finally, Class III allows air quality degradation up to 50 percent of the established secondary NAAQS. This system allows economic growth in some areas while protecting air quality in more pristine environments.

The PSD standards are defined for only two pollutants - particulate matter and sulfur dioxide. Table 3-5 lists the allowable increments for each of the Class I, II, or III PSD categories for each pollutant. Visibility is also considered in Class I PSD areas.

In no case shall the allowable increment violate either the primary or secondary NAAQS. Significant deterioration occurs when the amount of new pollution exceeds these allowable increases, or increments, over naturally occurring baseline levels. The baseline air quality is determined as the conditions occurring at the date of the first PSD permit application for the region. Since each new pollutant source is additive, later applicants may find the allowable increments to have been substantially or even entirely consumed by earlier applicants.

The PSD regulations operate through a series of State IPs developed and submitted by the states, and approved by the EPA. Each plan contains a pre-construction review process, which requires any stationary new major pollution source, or major modification, to comply with both the NAAQS and the applicable PSD regulations. If the region is in non-attainment status, the PSD review process does not apply, and the application must be reviewed according to procedures for non-attainment areas.

TABLE 3-5

MAXIMUM ALLOWABLE INCREASE (INCREMENTS) UNDER PSD REGULATIONS

	Class I	Class II	Class III	Primary Ambient Air Quality Standards (for comparison)
Particulate Matter				
Annual Mean	5	19	37	75
24 Hour Max.	10	37	75	260
SO_2				
Annual Mean	2	20	40	80
24 Hour Max.	5	91	182	365
3 Hour Max.	25	512	700	1300

NOTE: All limitations are stated in micrograms per cubic meter; the 3 hour maximum figure for SO_2 represents the secondary standard rather than a primary standard.

The term "source" has different meanings for non-attainment and PSD review purposes. A source for non-attainment review can be restricted to a specific piece of polluting equipment. A source for PSD can include any contiguous plant whose operations fall under the same two-digit SIC classification.

The basic regulations concerning PSD designations and permitting procedures were readily available in federal documents and from the EPA. Maps showing the extent of the various Class I, II, and III areas are not as available. This project selected a map by Environmental Research Associates of the United States with two overlays showing existing and proposed Class I PSD areas (23).

Figure 3-3 outlines the basic steps used to analyze the impact of the PSD regulations. The existing and proposed Class I PSD areas were plotted on the standard basemap of the United States. Locations of each area were then coded to form a GMAPS base file. Since each such Class I area will have a "buffer zone" surrounding it to prevent significant air quality deterioration within its borders, a series of proximity zones were created around each Class I area. Thus, any data cell lying within a given distance to any data cell classified as a Class I area was changed to reflect its proximity to a Class I area. This process corresponds to the published maps released to date. In actual fact, these zones should vary to account for meteorological and topographic conditions. Nonetheless, buffer zones of 65 and 130 kilometers radius were selected for this study. Figure 3-3 shows the optional inclusion of information concerning Class II and Class III areas. Since such information is not available at this time, this inclusion was not done. The resulting restrictions map (Map 7) shows the Class I areas and the 65 and 130 kilometers radius buffer zones around each. Map 7 shows Class I areas to exist predominantly in the western United States, but also where national parks and wilderness areas are located in the mid-south, Florida, far north, and northeast. As of November 1981, the regulations used in this analysis were current. However, it should be noted that changes are being proposed in the NAAQS and PSD regulations for 1982.

3.1.3 Solar Investment Tax Incentives

In addition to the federal government, many states are legislating incentives for the installation of solar energy devices. The three major types of financial incentives are:

- income tax credit or deduction,
- property tax credit or exemption, and
- sales/excise tax exemption.

The scope and magnitude of these incentives varies from state to state. In many states, the incentives apply only to residential installers of solar energy devices. Other states give credits to commercial/industrial installers of solar energy devices. However, the type of unit eligible for the incentive may not include systems adaptable for solar IPH. Twenty-one states extend

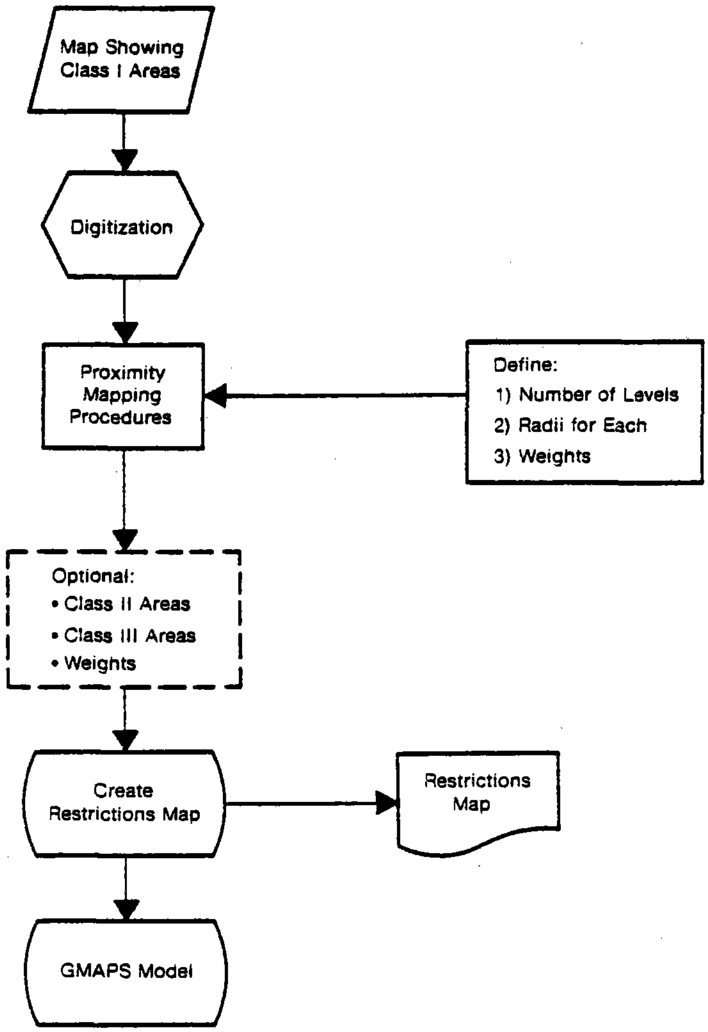

Figure 3-3. Methodology for Computing the Air Quality in Clean Areas (PSD Class I Areas)

incentives to industry for the installation of solar energy devices, but do not explicitly extend these incentives to solar IPH (see Appendix B-3).

Twenty-seven states have been identified as extending incentives to the installation of solar IPH devices (Table 3-6). Appendix F lists these 27 states, describing the types of solar devices eligible for state tax incentives, the type and magnitude of the incentive, and its duration.

The value of the incentive varies depending on the state and the incentive type. The most significant incentive to the business considering investing in solar IPH equipment is the corporate income tax credit. The tax credit, unlike a deduction that reduces gross income, is an amount which directly reduces the business tax liability. Thirteen states (Alaska, Arizona, California, Hawaii, Kansas, North Dakota, Ohio, Oklahoma, Oregon, Rhode Island, Utah, Vermont, and Wisconsin) offer income tax credit incentives that include solar industrial process heat. One state, Massachusetts, has a tax income deduction incentive designed to include solar IPH. Solar IPH systems are also eligible for the federal government's 15 percent energy investment credit (ETC) and the regular 10 percent investment credit (ITC).

Calculation of solar tax incentives for this study included only the above fourteen states. Other forms of tax relief are too localized and were outside the scope of this research. Next to income tax incentives, property tax incentives, usually in the form of deductions, are the most important. The impact of such an incentive is hard to measure, as assessment and mill fixing are usually done locally; this results in varying the magnitude of the incentive within the state. Twenty-three states offer property tax incentives designed to include solar IPH systems.

Sales tax exemptions for solar IPH equipment purchases or rentals are a relatively minor incentive which is offered by eight states. In addition, Massachusetts and Alaska have liberalized their lending laws to enable small businesses or consumers to afford solar energy devices, including low-temperature solar IPH.

The data concerning state solar tax incentives were provided by SERI. The data were in the form of the actual legislative enactments, summary updates through the 1980 legislative sessions, and a report prepared by Insights West, Inc. (24). It is recommended that, if a company wants to install solar IPH equipment, it should contact the State's Department of Revenue or Energy for their interpretation of the relevant legislation. Much of the solar energy legislation is recent, and new state legislation develops quickly.

Figure 3-4 illustrates the methodology used to compute the magnitudes of the solar income tax incentives. (The mapping analysis did not use the values for Alaska and Hawaii as they were outside the scope of this study.) To compare the magnitude of the state corporate income tax incentives, a sample tax calculation was made using two types of corporations, small and large. The small corporation was defined with $25,000 taxable income (therefore, in the 17% federal corporate income tax bracket), and a larger corporation was defined with $1,000,000 taxable income (therefore, in the 46% federal corporate income tax bracket). Other assumptions were also made and are detailed in Appendix B-3.

Table 3-6

SUMMARY OF STATE INCENTIVES FOR GENERAL PURPOSE SOLAR IPH APPLICATIONS

	Solar IPH Incentive Type			
	Income Tax		Property	Sales
State	Credit	Deduction	Tax	Tax
Alaska	Yes	---	---	---
Arizona	Yes	---	Yes	Yes
California	Yes	---	Yes	---
Colorado	---	---	Yes	---
Connecticut	---	---	Yes	Yes
Florida	---	---	Yes	---
Georgia	---	---	Yes	Yes
Hawaii	Yes	---	Yes	---
Iowa	---	---	Yes	---
Kansas	Yes	---	Yes	---
Massachusetts	---	Yes	Yes	Yes
Michigan	---	---	Yes	Yes
Montana	---	---	Yes	---
Nebraska	---	---	Yes	Yes
New Jersey	---	---	Yes	Yes
North Dakota	Yes	---	---	---
Ohio	Yes	---	Yes	Yes
Oklahoma	Yes	---	---	---
Oregon	Yes	---	Yes	---
Rhode Island	Yes	---	Yes	---
South Dakota	---	---	Yes	---
Texas	---	---	Yes	Yes
Utah	Yes	---	---	---
Vermont	Yes	---	Yes	---
Virginia	---	---	Yes	---
Washington	---	---	Yes	---
Wisconsin	Yes	---	Yes	---

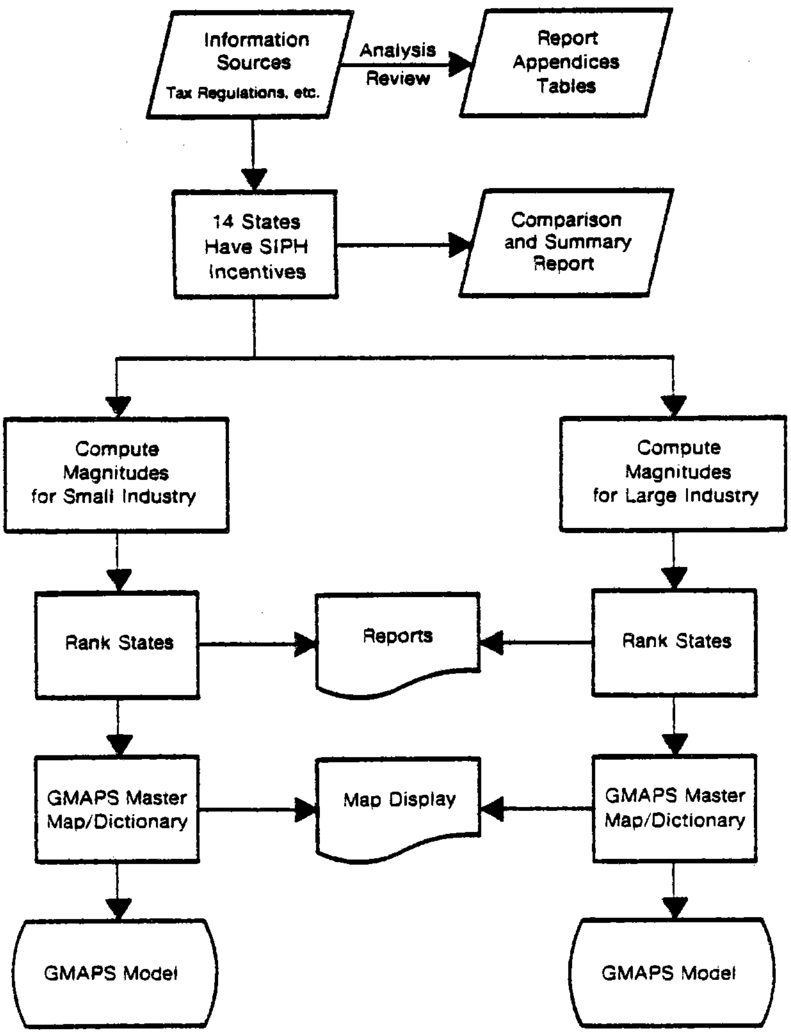

Figure 3-4. Methodology for Computing the Magnitude of Solar Tax Incentives

A ranking of the fourteen states that offer income tax incentives is given in Table 3-7. A more detailed outline of the calculations is given in Appendix B.3. These rankings (less Alaska and Hawaii) were used to produce the tax incentives maps (see MAPS 8 and 9) through use of the Master Map/Dictionary capability of GMAPS. The results for both small and large corporations show that Arizona, California, and Oregon currently provide the most significant financial incentives for solar IPH.

The vagaries of tax laws, rate schedules, and income levels combine to change both the magnitudes of the incentives and the relative rankings of the several states. The incentive magnitude difference between large firms and small firms is noticeable. This is largely attributable to the difference between the marginal federal tax rates for the two arbitrarily selected income levels, in conjunction with the rather modest tax rates at the state levels. For example, in California, the marginal rate of taxation for all taxable income is 9.6 percent. This translates to an amount equal to 62.4 percent of a small firm's federal tax bill and only 24 percent of a large firm's federal tax bill. Hence, relatively speaking, small firms can achieve a greater proportion of tax savings from a given solar IPH investment.

3.2 COMPETITIVE FUELS DATA CATEGORIES

The status of competitive fuels is the second category of criteria used in the research analysis. These criteria relate to potential curtailments of natural gas, prices of conventional fuels, and areas where the prospect for coal use is limited. A discussion of these criteria follows.

3.2.1 Natural Gas Curtailments

Presently, there appears to be adequate gas supplies for all users, both residential and industrial. This is believed a function of recent steep price increases which have caused a flattening of demand. Also, price deregulation of the interstate market has encouraged "new gas" exploration and marketing. At the moment, there is an excess of supply over demand for gas.

As shown in Figure 3-5, the American Gas Association (AGA) (25) estimates that total gas production will rise from the 1978 total of 10.4 TCF (trillion cubic feet) to around 30 TCF by the year 2000; despite a drop of conventional "lower-48" gas supplies during this period. The AGA projects the difference to be covered by "supplemental" gas resources and believes that the bulk of this supplemental gas will come from domestic sources, including Alaskan pipeline gas, coal gasification using existing technologies, and Alaskan liquid natural gas (LNG). According to the AGA, these supplies will be augmented by supplies from Canada and Mexico and other LNG imports from overseas, together with supplies derived from new technologies. Shortages and curtailments may occur, but no one can predict their pattern of occurrence with any certainty.

The only recent major gas curtailments occurred during the 1977-78 heating season. At that time, a combination of adverse weather conditions and economic characteristics (including price regulation of interstate gas shipments) resulted in a pattern of shortages. These conditions have been

TABLE 3-7

MAGNITUDES OF SOLAR IPH INCOME TAX INCENTIVES

	(1) Minimum Investment to Maximize First Year Advantage	(2) Net Present Value of Tax Savings	(3) Magnitude of Incentives - Tax Savings as a Percent Investment
Small Firms			
States without solar IPH income tax incentive	$ 17,000	$ 4,250	25.0
States with solar IPH income tax incentive:			
Arizona	19,096	9,560	50.1
Oregon	20,170	9,613	47.7
California	18,964	8,296	43.7
Alaska	18,188	7,953	43.7
Kansas	17,964	7,491	41.7
Vermont	18,164	6,772	37.3
Oklahoma	17,832	6,376	35.8
Wisconsin	19,060	6,273	32.9
Hawaii	18,252	5,996	32.9
Utah	17,812	5,799	32.6
Massachusetts	27,844	8,958	32.2
Rhode Island	18,200	5,750	31.6
North Dakota	27,100	8,509	31.4
Ohio	17,828	5,287	29.7
Large Firms			
States without solar IPH income tax incentives	1,763,000	440,750	25.0
States with solar IPH income tax incentives:			
Oregon	1,912,292	707,643	37.0
California	1,958,032	697,714	35.6
Arizona	1,978,292	702,065	35.5
Oklahoma	1,829,668	557,860	30.3
North Dakota	1,932,148	575,868	29.8
Hawaii	1,889,260	562,708	29.8
Massachusetts	1,976,472	545,897	27.6
Ohio	1,920,908	526,570	27.4
Wisconsin	1,920,388	526,287	27.4
Alaska	1,772,200	445,750	25.2
Kansas	1,771,180	445,250	25.1
Utah	1,768,520	443,750	25.1
Vermont	1,768,520	443,750	25.1
Rhode Island	1,765,760	442,250	25.0

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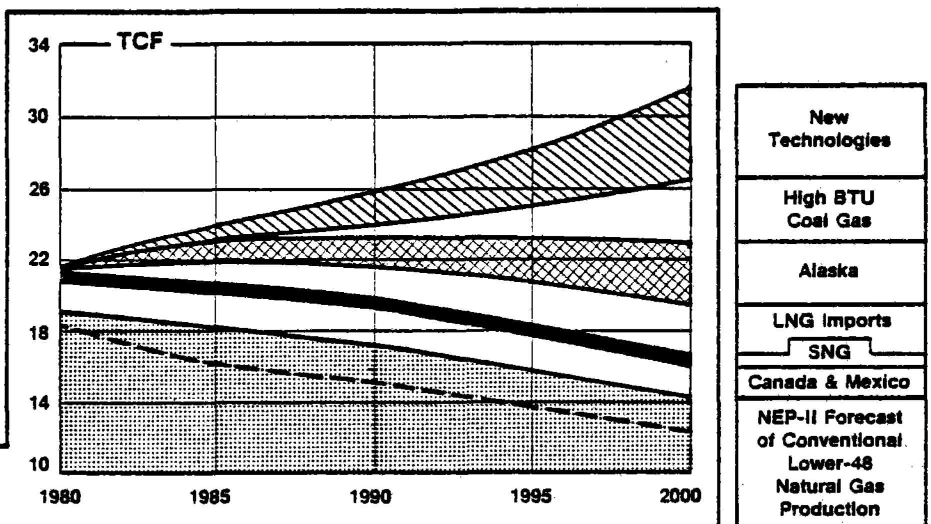
Actual 1978	
LNG Imports	0.1
SNG	0.3
Canada & Mexico	0.9
Supplementals	1.3
Conventional Lower - 48	19.1
Total	20.4



Potential Supplementals	1980	1985	1990	1995	2000	
New Technologies	—	0.9	1.8	3.2	5.0	
High-Btu Coal Gas	—	0.1	0.6	1.8	3.3	
Alaska	—	0.8	1.6	2.5	3.6	
LNG Imports	0.4	1.6	2.0	2.5	3.0	
SNG	0.5	0.5	0.5	0.5	0.5	
Canada & Mexico	1.6	1.9	2.1	2.0	1.8	
	2.5	5.8	8.6	12.5	17.2	Supplementals
	18-19	16-18	15-17	13.5-15.5	12-14	Conventional Lower-48
	20.5-21.5	21.8-23.8	23.6-25.6	26-28	29.2-31.2	Total

Figure 3-5. Gas Supply Projections 1980-1985

reported by the Department of Energy (DOE) (26). During Phase I of this study, these 1977-78 curtailment percentages for each state were used to produce a map of curtailments as a percentage of demand. These curtailments ranged from less than 5 percent to over 60 percent of demand; however, such data represent a single incident, and it is difficult to generalize and project future conditions from this situation.

Alternative methods for modeling the potential for gas shortages were investigated. SERI requested analyses from DRI for data projections of state-by-state gas market shares (as discussed in Section 3.2.3) and source estimates for the natural gas supplies for each state (18,19). These source estimates were in the form of percentages of the gas supply from each of various domestic and foreign sources.

The DRI data suggested a method for modeling potential gas shortages. The sensitivity of any state to gas shortages will be greater where:

- industry is heavily dependent on natural gas for its energy needs, and
- a small percentage of the gas is obtained from domestic sources.

With recent gas deregulation actions, the distinction between inter-state and intra-state gas sources has been substantially eliminated. However, sources from outside the "lower-48" states are less secure and potentially subject to disruption, depending on the type of emergency. Map 14 shows the states where domestic sources are expected to be dominant for industrial gas use. Those states are Texas, Oklahoma, Arkansas, and Louisiana. States with the poorest expected use of domestic gas are along the west and east coasts and near the Great Lakes.

However, the use of domestic gas is only one important criterion for estimating gas shortage/curtailment potential. This criterion is combined with the gas market shares criterion (Map 13) to produce a gas shortage/curtailment potential map (Map 29). That composite map is discussed in Section 4.1.3.

3.2.2 Oil, Natural Gas, and Coal Prices

A variety of data sources were studied to determine the current prices of oil, natural gas, and coal used by industry and disaggregated to the state level. It might be expected that such data would be readily available, but in practice they are not and several problems were encountered.

In connection with its Survey of Manufacturers, the Bureau of Census issues reports entitled "Fuels and Electricity Consumed by Industries" (27). The latest published survey is for 1976. Although older, these data appeared superior to the other data sources because they:

- dealt with industrial purchases, rather than just electrical utility purchases;
- contained breakdowns to two-, three-, and four-digit SIC codes to varying levels of disaggregation;

- contained level-of-use and expenditures information, in addition to prices; and
- have been systematically collected for about ten years, so that trends could be observed.

Information provided by DRI (18, 19) supplied more current price figures for each state and 13 regions (multi-state groupings) for 1978 and 1979-85. DRI also supplied national average prices for each fuel for the period 1960-78. The DRI data on coal prices were based on electric utility price data. This yielded sharply lower prices for coal, when compared with the Bureau of Census data for the same year.

Therefore, the Bureau of Census 1976 price data (27) were used as a baseline and the DRI data supplied inflation estimates (percentage of change) to bring these 1976 prices to current values. The DRI data projections also were used to provide regional inflation indices for each fuel for 1979-85. Figure 3-6 summarizes the combining of Bureau of Census and DRI fuel pricing data in the context of the entire mapping process. The 1985 price estimates for individual fuels were combined into a single weighted composite fuel price index for each state. The weighting was performed by using percent market shares estimates for 1985 for each state and fuel.

This composite price reflects the fuel mix and the prices of each fuel in each state. Thus, it is an estimate of average conventional fuels price for each state. These values were entered into the GMAPS data base through the Master Map/Dictionary procedure and the result is shown as MAP 10. Map 10 shows predominantly the New England States, but also Oregon, South Dakota, and North Carolina having the highest weighted average energy prices for industrial fuel users.

Figure 3-6 shows that maps for each fuel can be produced, as well as the combined fuels map (MAP 10). In this study, only the combined fuels map was used in subsequent analysis (see Section 4.0). Because no single fuel is used significantly by industry in every state, all individual fuels have "no data" in one or more states where such fuel usage is negligible. Accordingly, the composite price data produce the only map that shows a price estimate for every state.

3.2.3 Oil, Coal, and Natural Gas Market Shares Analysis

The DRI report (18, 19) tabulated market share projections for 1979-85 by state and region for coal, natural gas, petroleum, and electricity. They also tabulated the national market shares for these fuels.

Figure 3-7 shows the basic process used in the market share analysis for coal and natural gas. DRI suggested that those states above the national norms should be classed as "high use" and those falling below the norms as "low use". This procedure seemed too crude for the purposes of this study. Consequently, these DRI data were statistically analyzed. In all years there are significant variations about the national market shares, with many states exhibiting low shares. Although these data were not normally distributed, levels of one-half and one standard deviation above and below the national market share values were used to categorize the states. The categorized

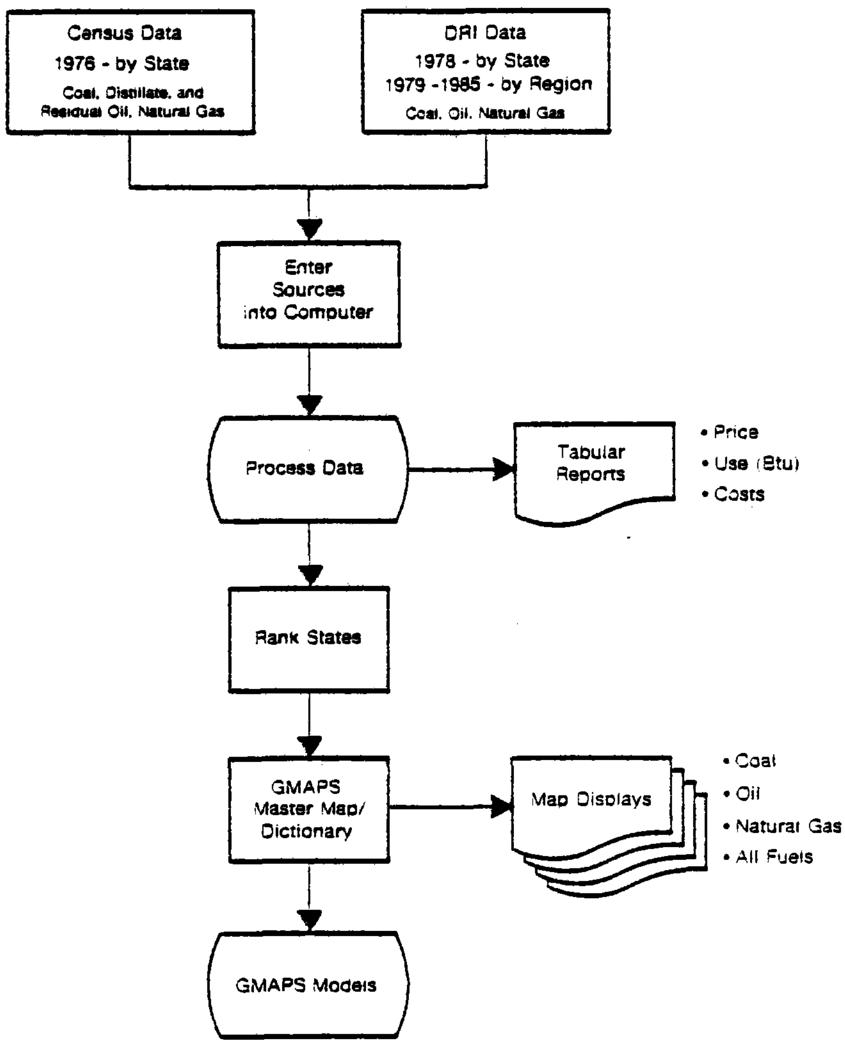


Figure 3-6. Methodology for Computing the Energy Prices for Conventional Fuels

states were entered into the GMAPS data base through the Master Map/Dictionary procedure. Maps for oil, coal, and natural gas (see MAPS 11, 12, and 13) were produced. These data proved useful in several analysis steps, including assessment of the severity of air pollution constraints for conventional fuels (Section 4.0), the potential for future natural gas shortages (Section 3.2.1), and the identification of areas having potential for low coal use (Section 3.2.4).

The states projected to have the largest industrial market shares of petroleum (Map 11) are Massachusetts, Maine, Vermont, Rhode Island, New Hampshire, Connecticut, and New Jersey. The largest industrial market shares of coal (Map 12) are projected for Pennsylvania, Virginia, West Virginia, Ohio, Wisconsin, Indiana, Michigan, South Dakota, Missouri, Tennessee, Wyoming, and Utah. The states projected to have the largest industrial market shares of natural gas (Map 12) are Kansas, Mississippi, Oklahoma, Texas, Louisiana, New Mexico, Nevada, California, and Alaska.

3.2.4 Identification of Low Coal Use Areas

SERI requested that this study identify regions where coal is not now used, and is unlikely to be used in the future (Table 3-1). Such data were not directly available; however, a review of several sources suggested that these conditions might be estimated by several combined data sources. The DRI reports supplied coal market share data for each state (18, 19). Those states exhibiting low coal market shares were assumed to be less likely to be future large-scale coal users because market conditions apparently dictate that coal use is unattractive. Furthermore, the DRI reports listed the anticipated 1985 sulfur emission limits specified by each State IP (19). This information differentiated those states having more stringent emission restrictions from those allowing higher emission levels. Since sulfur emissions are a major problem with coal combustion, those states enacting tighter emission levels are less likely to have heavy future coal use. Similarly, those areas exhibiting non-attainment air quality status are less likely to support present or future large scale coal use.

Accordingly, these three components -- low coal market shares, higher incidence of non-attainment status, and restrictive sulfur emissions -- can be combined as described in Section 4.1.2 to produce the required Low Coal Use Model. These baseline maps are shown as Maps 4, 12, and 15.

3.3 DEMAND DATA CATEGORIES

Data relating to demand for solar IPH is the third category of criteria used in the research analysis. These criteria relate to industrial plant locations, growth, and energy consumption.

3.3.1 Identification of Potential Candidate Industries for Solar IPH

Previous studies conducted at SERI identified 81 industrial classifications as potential users of solar IPH systems (3,4,5,6,7). Each industry is defined by a four-digit SIC classification.

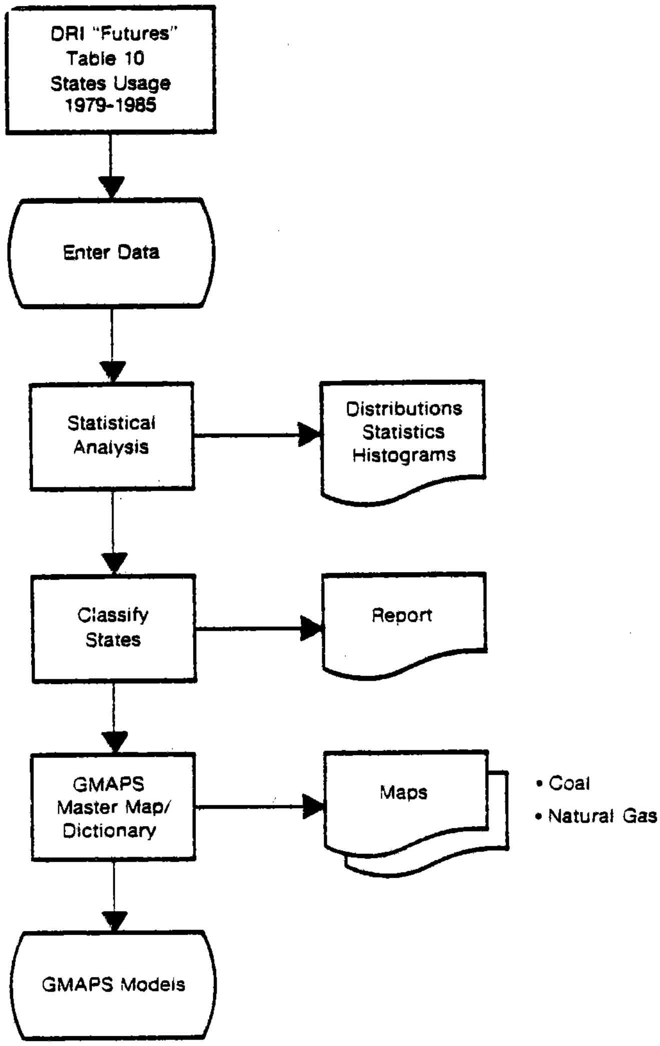


Figure 3-7. Methodology for Computing Petroleum, Natural Gas, and Coal Use (Market Shares)

These studies and subsequent analyses by SERI staff defined charcteristic temperature ranges as follows for each industry group criteria:

- Industries characterized by heat requirements of less than 100°C (212°F);
- Industries characterized by heat requirements varying from 100°C to 177°F (212°F to 350°F); and
- Industries characterized by heat requirements in the range of 177°C to 288°C (350°F to 550°F).

The selected 81 industries represent only potential candidate industries for solar IPH. There are many approximations and assumptions inherent within the selection. Each installation must be examined separately, even within a single four-digit SIC industry. Differences in details of plant design, processes used, or actual production methods may greatly influence the feasibility of solar IPH. Furthermore, many other factors such as management attitudes, financial conditions, age of boilers, and available land/roof area can affect the economics of solar IPH, or the feasibility of installing solar IPH at any given plant.

3.3.2 Analysis of Manufacturing Industries Locations

Seventy-six of the four-digit SIC codes define industries in the manufacturing sector (the remaining five are in the minerals sector). The most recent plant location data available on magnetic tape from the Bureau of Census are the 1972 Census of Manufacturers (28). These tape data contain unpublished information; namely, the distribution of plants by county and by relative size for each four-digit SIC code. Because of data confidentiality limitations, no other information is available at this level of detail.

The basic steps in analyzing these data are shown in Figure 3-8. Before the maps were analyzed, a number of data files were produced. First, the 76 desired four-digit codes were extracted from the entire suite of such codes. Second, a file of plant frequencies by state for each SIC code was developed (Appendix D-2). A similar file giving frequencies by county within each state was also prepared.

Because it was desirable to account for differences in plant size, the concept of "standard plant equivalents" was developed. Each of the seven plant size ranges is defined by an employment range. The median plant of each range was considered a representative average. The size range is 1 to 19 employees; thus, a median value of 10 was selected for this range.

A plant employing 10 people is defined as the "standard plant equivalent". Thus, a plant employing 50 people would be 5 standard plant equivalents. By this definition, each employment size range was converted to standard plant equivalents. By multiplying the number of plants in each size range by the appropriate equivalency factor and summing the results, the number of standard plant equivalents occurring in each county was determined.

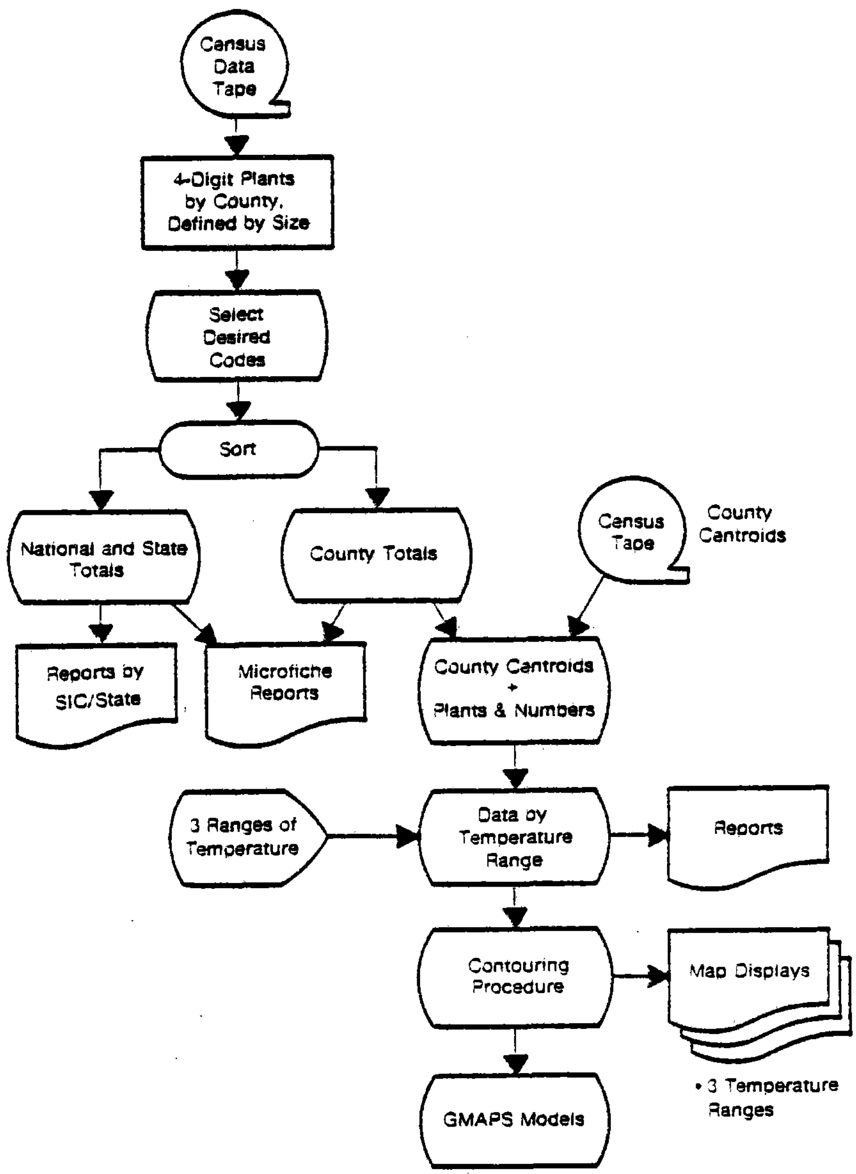


Figure 3-8. **Methodology for Computing Industrial Plant Distributions for 81 Industries by 4-Digit SIC and by County**

To produce map displays, the total number of standard plant equivalents within each county for each SIC code were categorized to the proper temperature range and summed to produce three totals for each county. These include the number of plants categorized as using heat below 100°C, those using heat in the range of 100°C to 177°C, and those requiring heat above 177°C. This file was combined with another file containing the latitude/longitude values of each county centroid and was submitted to the contouring procedures.

3.3.3 Energy Consumption Patterns for the Manufacturing Industries

Energy use estimates were obtained from 1976 Bureau of Census Data (27). National use statistics for each four-digit SIC code were available, describing the use of coal, natural gas, and oil (both residual and distillate). These values were converted to Btu equivalents by applying the recommended conversion factors given in the reports. The energy data were selected from 1976 because they were the most recent available and more nearly reflected post-1973 oil embargo economics.

The energy use analysis process is shown in Figure 3-9. The procedure parallels that applied to the analysis of plant distribution. By totaling the number of standard plant equivalents nationally for each SIC code, it was possible to equitably allocate the national energy consumption figures for that SIC code to each county (or state) by using the proportions of the standard plant equivalents.

Once the energy allocations were made for each SIC code to all counties, these energy use values were combined into the three derived temperature ranges. These values were then merged with the country latitude/longitude centroid data and submitted to the contouring process. Results were contour maps and GMAPS files showing energy use levels for the groups of four-digit SIC codes falling within each temperature range. These maps and models form an important component in analyzing the user demand component of the project. Maps 16, 17, and 18 show the energy patterns for these three temperature ranges. In most cases for all three maps, energy consumption is concentrated in metropolitan areas of the far West, Great Lakes, far East, and the Gulf coast. Some areas of the Central Midwest also have large energy demand concentrations.

3.3.4 Analysis of Regional Growth Patterns for Manufacturing Industries

The variations in the rate of expansion of manufacturing industries from one region to another can affect the demand for solar IPH. In those regions where growth is more rapid, larger numbers of new plants, as well as expansions to existing facilities, are likely. New plants will probably be more amenable to solar IPH installations, since the design and financing incorporate solar requirements more easily. Also, new construction can include ample space for solar collector systems.

A number of data sources were reviewed to analyze regional growth patterns. In the absence of any superior source, the Bureau of Census data in the Annual Survey of Manufacturers Report Series (8) were used. The time period chosen

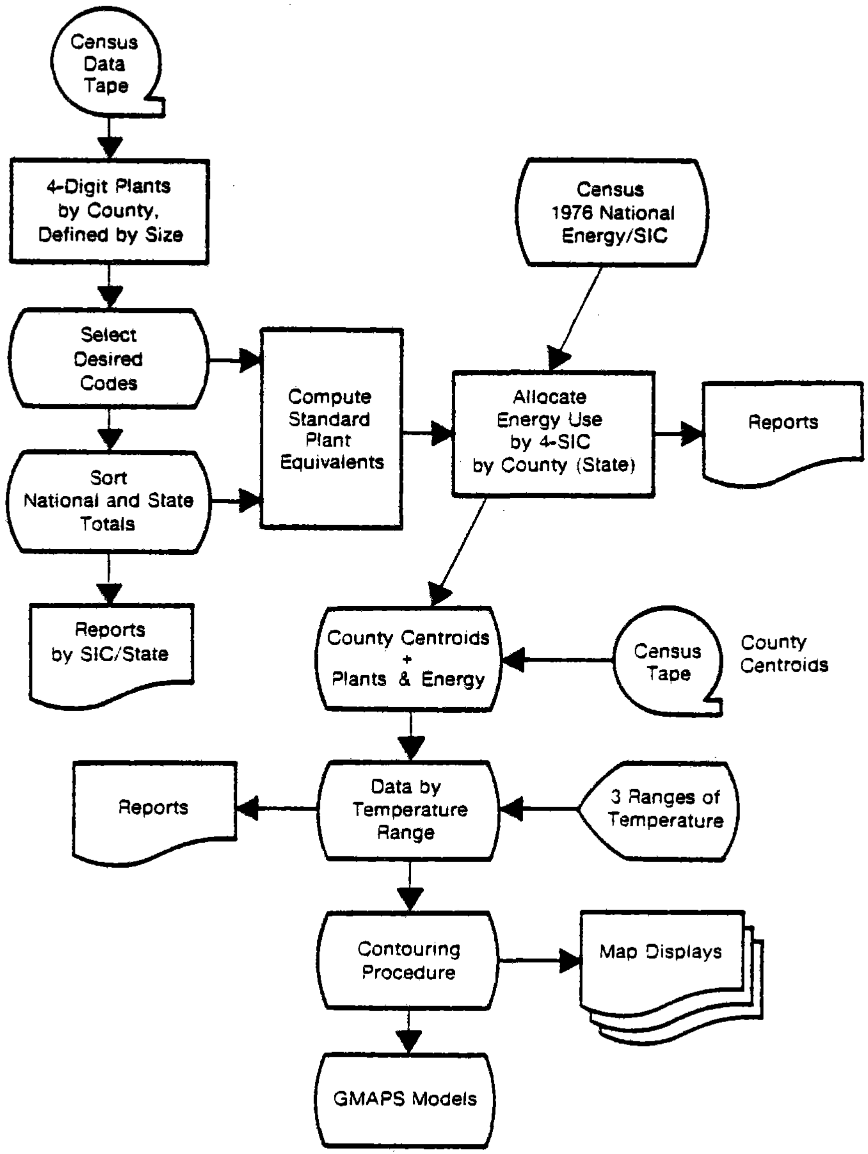


Figure 3-9. Methodology for Computing Distribution of Energy Consumption by 4-Digit SIC and by County

was 1970-76, 1976 being the most recent data available. This period includes a recession and the oil embargo of 1973.

Regional growth of manufacturing was measured by analyzing the annual expenditures for new plants and equipment, gross book values of capital assets, annual construction expenditures, and employment levels. These data were extracted for each state. For reasons explained in Appendix D.4, the ratios of construction expenditures to employment levels (i.e., the construction expenditures per worker) were eventually selected as the proxy for regional growth. These ratios were used to establish relative state rankings employing the GMAPS Master Map/Dictionary data entry option. The resulting map is shown as Map 19. Generally, the West and South show high industrial growth for the 1970-76 period. The specific states with the highest growth are Florida, Oklahoma, New Mexico, Arizona, Nevada, Utah, Colorado, Wyoming, North Dakota, and South Dakota.

3.3.5 Analysis of the Candidate Minerals Industries

Five of the 81 industries in this solar IPH study belong to the Minerals industries grouping according to the SIC classifications. These five industries are:

- SIC 1021 - Copper Ores,
- SIC 1211 - Bituminous Coal and Lignite,
- SIC 1474 - Potash, Soda, and Borate Minerals,
- SIC 1475 - Phosphate Rock, and
- SIC 1477 - Sulfur.

Because there are many fewer plants and the plants are often concentrated into small geographic areas, these five industries differ from the 76 manufacturing industries studied in this project. Such charcteristics raise data confidentiality problems for the Bureau of the Census. Accordingly, to gather the information on the geographical distribution of energy demand for these industries, supplementary information was secured to support the Bureau of Census statistics.

A slightly different "customized" approach was developed for each industry, depending on available data. Basically, a geographical distribution of either employment or production was determined, and this was used to allocate the national energy consumption figures for that industry; the actual procedures are described in Appendix D-5.

These procedures have several weaknesses which are unavoidable with the available data sources. First, data are broken down only to state levels (rather than to the county as was done for the manufacturing industries). However, in some cases, it was possible to plot these industries at the center of their concentration within a state, rather than at the state centroid. Second, only 33 of the 48 states contained any of these five industries, and several of these 33 states had low levels of activity. Third, the energy consumption figures comprised total energy usage, including vehicle fuels for trucks in many operations, and so embrace many applications for which solar energy cannot be used. Although this is a limitation in the calculation of energy consumption for the manufacturers also, the nature of energy use by the minerals industries tends to aggravate this problem.

Whenever possible, statistics of employment or production and of energy usage were confined to those parts of the process where solar IPH might be employed, rather than using the entire suite of activities contained within a single 4-digit SIC code.

The chief sources of data for the minerals sector were the 1976 Census of Mineral Industries (29) a U.S. Bureau of Mines report, "Mineral Facts and Problems" (30), and a report entitled "Energy Use in Mining" (31). Four of the five minerals industries (SIC codes 1021, 1474, 1475, 1476) fell within the temperature range 100°C - 177°C, and the fifth (SIC code 1211) belonged to the below 100°C range. Accordingly, two map displays were prepared for the minerals industries, one for each temperature grouping (Maps 20 and 21), and these were subsequently combined with the appropriate manufacturing industries temperature groupings as shown in Figure 4-1. Map 20 shows energy consumption concentrations for the bituminous coal industry (low temperature - below 100°C). This map indicates that West Virginia, Ohio, Pennsylvania, Illinois, northwest New York, and Wyoming are the dominant energy consuming states for the bituminous coal industry. Map 21 indicates energy consumption concentrations for the copper, sulfur, potash, and phosphate industries (intermediate temperature - 100°C-288°C). The primary states identified are Florida, Louisiana, Texas, New Mexico, Arizona, southern California, southern Colorado, southern Nevada, Utah, Montana, and Michigan.

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SECTION 4.0

COMPOSITE MAPPING FOR GEOGRAPHIC MARKET ANALYSIS

4.1 MODEL DESIGN

The concepts underlying the model design have been discussed in Section 2.4. Figure 2-3 presents them diagrammatically, and Table 3-1 lists them topically. Three broad data categories combine to form this market analysis;

- solar supply data,
- competitive fuels data, and
- industrial demand data.

Section 3.0 and associated Appendices B through D describe the sources of information for the various baseline data components forming these broad categories.

Figure 4-1 shows the logical framework of the model design developed to satisfy the concepts. A total of 21 baseline components were mapped ("baseline maps") to use in this model design. The baseline maps are shown on the left side of Figure 4-1.

These baseline maps were created by the techniques and from the sources described in Section 3.0. The initial products were GMAPS computer map files in symbolic formats. This means that the conditions within each map were delineated by character codes, without any intrinsic value necessarily attached to each code. In many cases, the codes corresponded to rankings produced by contouring or statistical analysis of input data; valuation was relatively straightforward. However, this was not universally true. Furthermore, each map generally had a large number of symbolic condition codes, some of which were combined for later analysis. Consequently, the research carefully assessed each baseline map file and then developed appropriate valuation schemes for each map.

Each map was given a five-character computer code-name. These have been used in Figure 4-1. Table 4-1 gives these code-names and describes each map. GMAPS produces "composite maps" by combining existing maps to define intermediate or final model components; these are also named by these five-character code names. For simplicity, these have been used in Figure 4-1. Three baseline maps (CAIR2, CSHAR, and GSHAR) were used twice in the model, but were not valued exactly the same for each use.

Copies of the baseline maps, reproduced at the end of this report, were prepared on the line-printer as gray-tone displays and then were photographically reduced to report page size. To retain clarity, these displays have generally been restricted to four or five shades by combining categories before displaying them. The actual data analysis levels were more numerous, however, so that much finer definition is retained within the model sequence.

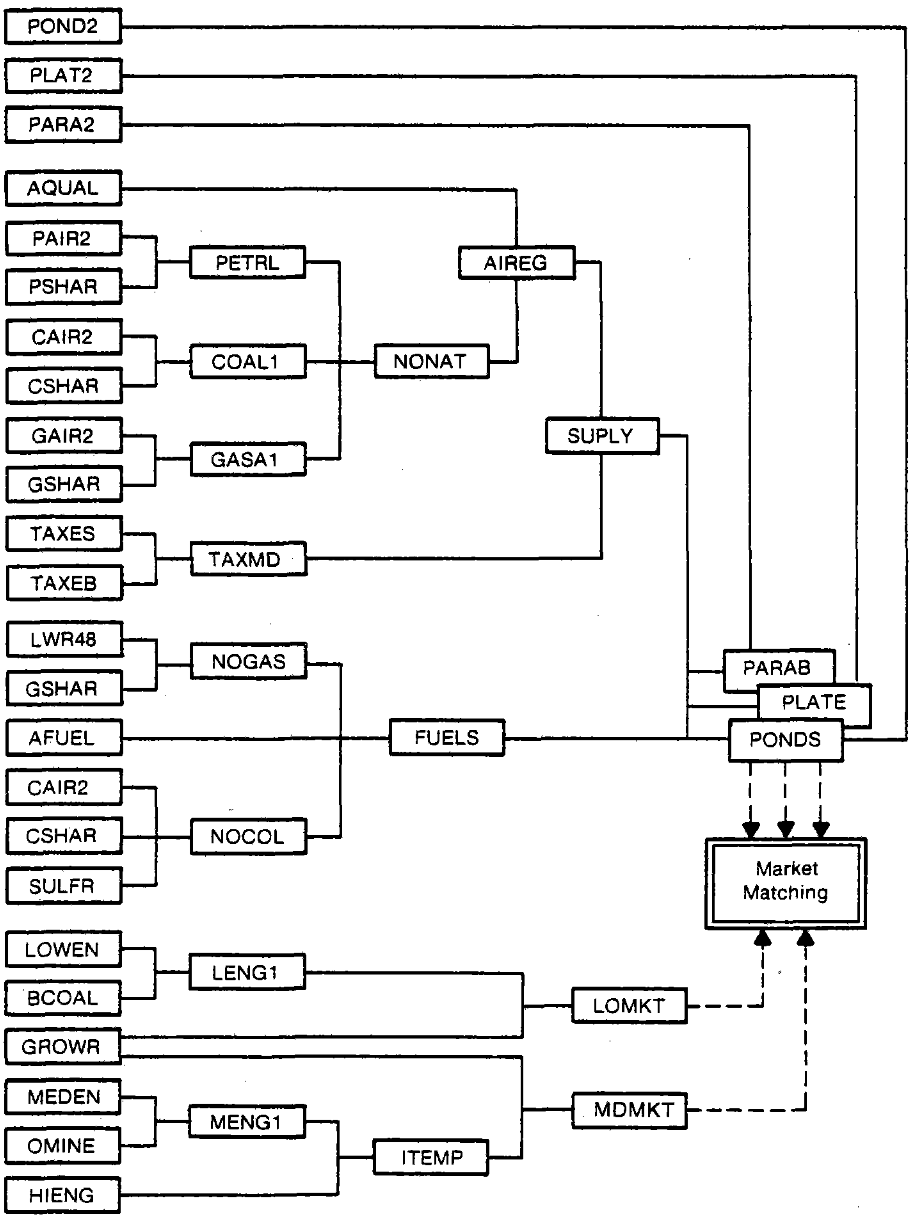

Figure 4-1. Geographic Market Analysis Model Flowchart

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TABLE 4-1

GMAPS MAPS USED IN MODEL ANALYSIS

A. BASELINE MAPS

Map* Number	GMAPS Code Name	Map Topic
1	POND2	Solar pond annual average thermal outputs
2	PLAT2	Flat-plate annual average thermal outputs
3	PARA2	Parabolic trough annual average thermal outputs
4	CAIR2	Non-attainment status indices for coal
5	PAIR2	Non-attainment status indices for oil
6	GAIR2	Non-attainment status indices for natural gas
7	AQUAL	Class I PSD air restrictions
8	TAXES	Solar income tax incentives for a small business
9	TAXEB	Solar income tax incentives for a large business
10	AFUEL	Weighted average costs for conventional fuels
11	PSHAR	Oil market shares
12	CSHAR	Coal market shares
13	GSHAR	Natural gas market shares
14	LWR48	Percent natural gas supplied from "Lower-48" sources
15	SULFR	1985 state sulfur emission standards
16	LOWEN	Regional energy demands for temperatures below 100°C
17	MEDEN	Regional energy demands for temperatures 100°C to 177°C
18	HIENG	Regional energy demands for temperatures 177°C to 288°C
19	GROWR	Regional growth of industrial activity
20	BCOAL	Energy demand by the bituminous coal industry
21	OMINE	Energy demand by the copper, sulfur, potash, and phosphate industries

B. COMPOSITE MAPS

Map* Number	GMAPS Code Name	Map Topic
22	PETRL	Oil use non-attainment constraint ratings
23	COAL1	Coal use non-attainment constraint ratings
24	GASA1	Natural gas use non-attainment constraint ratings
25	NONAT	Non-attainment air quality incentives for solar IPH
26	AIREG	Combined air quality incentives for solar IPH
27	TAXMD	Combined solar tax incentives
28	SUPLY	Environmental and tax incentives for solar IPH
29	NOGAS	Areas where industry is most dependent on imported gas
30	NOCOL	Areas of unlikely coal use
31	FUELS	Fuel incentives for solar IPH
32	LENG1	Low temperature demand-growth energy demand
33	LOMKT	Low temperature market areas
34	MENG1	Energy demands for 100°C to 177°C range
35	ITEMP	Energy demands for 100°C to 288°C range
36	MDMKT	Intermediate temperature demand-growth market areas
37	PONDS	Solar ponds solar attractiveness index
38	PLATE	Flat plate solar attractiveness index
39	PARAB	Parabolic trough solar attractiveness index

As shown in Figure 4-1, the model design consists of these seven stages:

- Analyzing the solar energy supply capabilities for three collector systems, culminating in the models POND2, PLAT2, and PARA2.

- Analyzing the supply incentives to solar IPH, culminating in the model SUPLY.

- Analyzing the economics of competing fuels, culminating in the model FUELS.

- Combining the SUPLY and FUELS models with one of the solar energy supply models to produce three different solar IPH attractiveness models (PONDS, PLATE, and PARAB); one model for each collector system.

- Developing two market demand models, one for the lowest temperature demands in the range below 100°C (LOMKT), and one for the intermediate temperature range between 100°C and 288°C (MDMKT).

- Market matching appropriate technologies with market demand models. Because of obvious constraints of the collector systems, the PONDS and PLATE attractiveness models were matched to the lowest temperature (LOMKT) market demand model, while the PARAB model was matched to the intermediate temperature (MDMKT) market demand model.

- The results of market matching allowed for comparisons of the attractiveness of various market areas. By changing certain model weightings, sensitivity analyses on these comparisons could be performed.

4.1.1 Solar Energy Supply

This stage in the model analysis is straightforward. It involved the creation of contour maps of solar collector output values based on SERI supplied estimates at over 300 specified locations. Three baseline models were produced (POND2, PLAT2, and PARA2) and valued, one for each of the specified collector systems.

4.1.2 Supply Incentives

This stage culiminated in the production of a model named SUPLY. By analyzing environmental incentives (air pollution regulations) the model AIREG was produced, while tax incentives analysis produced the model TAXMD. These were combined to produce SUPLY.

The air regulations analysis involved several intermediate stages. First, the potential difficulty of operating a conventionally fueled plant was evaluated for each fuel (oil, coal, and natural gas) separately. In each case, the non-attainment rating for that fuel (models PAIR2, CAIR2, and GAIR2) was combined with a state market shares model for that fuel (PSHAR, CSHAR, and GSHAR), assuming that the difficulties were compounded in areas of higher use or higher levels of non-attainment, and that the worst situations for conventional fuels occurred where these conditions coincided.

The non-attainment incentives were combined for all fuels in the NONAT model, which was then combined with model AQUAL to include the effects of the Class I PSD areas. Assuming that both non-attainment constraints and PSD constraints are equally advantageous to solar IPH, these two models were combined equally to produce the AIREG model.

4.1.3 Economics of Competing Fuels

This stage culminated in the construction of the FUELS model. It is based on the premise that areas having high potential for natural gas shortages, exhibiting high prices for the presently used mix of fuels, or having legislative or economic constraints acting against the use of coal, are areas which are potentially attractive to solar IPH use. All three of these factors were modeled.

The potential for natural gas shortages was analyzed by combining natural gas market shares (GSHAR) with data concerning what proportion of the natural gas used comes from domestic, "Lower-48" sources. It is based on the premise that the likelihood of shortages and economic disruption increases as the dependency on natural gas increases, and is compounded when larger proportions of such gas are derived from non-domestic sources.

The analysis of fuel prices is based on a state-by-state weighted average price for all fuels, adjusted for the price and market share of each fuel and estimated for 1985. It results in the AFUEL model.

Since coal represents an important competitor to solar IPH use, an analysis to locate where coal use is unlikely was undertaken. It is based on three premises: first, where coal is not used presently, its future use is also unlikely; second, where present air pollution causes difficulties for coal combustion, increased coal use is unlikely; and third, those states having the most restrictive sulfur emissions standards are less likely to undergo increased coal use. These factors were combined to form the NOCOL model, which was then combined with the AFUEL and NOGAS models to produce the FUELS model.

4.1.4 Demand Models

Two demand models were developed based primarily on the energy consumption patterns of industries having heat requirements in the low (below 100°C) and intermediate (100°C to 288°C) temperature ranges. In each case, manufacturing SIC codes had to be combined first with some minerals industry SIC codes. Furthermore, the initial breakdown of the intermediate range included a break point at 177°C; these two groups had to be merged.

Industrial growth patterns help to define market areas. States experiencing rapid industrial growth represent an important potential market factor, since new construction is often more amenable to the use of solar collectors. Accordingly, each demand model included an adjustment for industrial growth which is the GROWR model. As described in Section 3.3.4 and Appendix D.4, the industrial growth model was based on annual capital expenditures per worker on a state-by-state basis.

4.2 MARKET MATCHING

Completion of the project required the definition of market regions, followed by an analysis of these regions as described conceptually in Section 2.5.

4.2.1 Definition of the Market Regions

The user demand models LOMKT and MDMKT each contained a complex pattern of larger and smaller, but more or less isolated, clusters (see Maps 33 and 36). All areas having values of five or greater (on the 0-9 scale) were selected as defining potential markets and these patterns were then analyzed and manually grouped into ten regions. Boundaries were drawn where the patterns indicated natural separations. This method corresponds to the method of defining natural market groupings defined in Section 2.5.1.

Review of these market regions, particularly their relationship to state and regional boundaries, suggested that such groupings would be difficult to use administratively since they tended to impinge on several standard administrative regions. Also, the pattern of these irregular regions seemed likely to skew some statistical analyses and make comparisons among regions more difficult.

Accordingly, regions that were used were standard administrative units. The DRI studies had been based on 13 regions, as defined in Table 4-2. These correspond to the standard economic reporting regions used by the Bureau of the Census in its economic studies, with those regions having numerical qualifiers (e.g., Mountain 1, 2, and 3) being subdivisions of the census regions. Because these DRI regions offered reasonable detail, standardization, and continuity with other models and studies, they were selected for the market matching analysis.

4.2.2 Statistical Calculations

The definitions of the 13 DRI regions were entered into the GMAPS data base through the Master Map/Dictionary option. These regions were selected because they are subdivisions of Census Regime, and all competitive fuels data of this study are already aggregated to these regions. Each region had a unique letter code. GMAPS has the ability to produce statistical cross-tabulations between pairs of maps. These contain, in matrix form, the frequencies of occurrence (in numbers of cells) of all combinations of conditions on the two maps.

By using this capability, it was possible to determine the frequency distributions for all map units on any map model for each DRI region, through comparison of the appropriate map model with the DRI regions map model. Since the maps being analyzed always contained numerical values in the range 0-9, it was possible to compare regions in terms of the percentage of their areas falling within each numerical range and so produce a summary distribution of these values.

TABLE 4-2

DRI DEMAND REGIONS

Region Name	States
New England	MA, ME, VT, RI, NH, CT
Middle Atlantic	PA, NJ, NY
South Atlantic	DE, MD, DC, VA, WV, GA, FL, SC, NC
East North Central	OH, WI, IN, MI, IL
East South Central 1	KY, TN
East South Central 2	AL, MS
West North Central	KS, NE, ND, SD, MN, IA, MO
West South Central 1	OK
West South Central 2	TX, AR, LA
Mountain 1	NM
Mountain 2	MT, CO, WY, ID, UT
Mountain 3	NV, AZ
Pacific	CA, OR, WA, AK, HI

Further processing of these distributions allowed for their characterization by statistical values representing such properties as average values, maxima, minima, or ranges. For this study, zero values did not exist within the United States, and thus did not occur within any of the DRI regions. Thus, a weighted average was computed as one comparison statistic, the average being weighted by the area (number of cells) occurring in each numerical range between 1 and 9.

A second important statistic was a measure of the maximum value occurring within each region. Two regions might have similar averages, such as 5.8 and 5.6. One of these regions might be almost uniform, containing values in the range of 4 to 6, while the other region might have a small portion of its area with much higher values representing more desirable conditions, perhaps even a few nines. Analysis of the regions in terms of their maxima, as well as their weighted averages, was thus deemed significant in evaluating market potentials.

The maximum statistical computation had to reflect the value of the maximum value observed on a thematic map model within a region and the frequency of such a maximum. If two regions each have the maximum value of 8, but one has five cells labelled 8 while the other has several hundred such cells, they should not be ranked equally. The region with the larger area containing values of 8 should retain a larger maximum value statistic than the other region. Both regions, on the other hand, should have a maximum less than 9.0, since a third region with even a single cell valued nine is marginally better than either of the first two.

Based on these premises, the computation of maximum value statistics was defined. These maximum value statistics would contain the integer value corresponding to the highest value found on any cell within the region, and these integer values would be modified by a decimal fraction representing the areal frequency of such maximum values. This areal frequency fraction was computed by comparing the area occupied by maximum value cells to 11 percent of the regional area, but if this ratio exceeded a value of 0.98, then the fraction was set to 0.98. The logic of this concept is based on the need to develop a fractional range roughly from zero to one, and on the fact that a uniform distribution of all values in the range 1-9 should give about 11 percent of the area to each level.

Using these procedures, maximum value statistics for each region would theoretically range from 1.01 to 9.98, and weighted average statistics would range from 1.00 to 9.00. In actuality, the observed ranges are smaller than this, as would be expected.

These maximum and average statistical values were computed for all 13 DRI regions for the following map models:

- the three solar system energy output models (POND2, PLAT2, AND PARA2),
- the environmental and tax incentives model (SUPLY),
- the economic incentives model (FUELS),

- the user demand models (LOMKT and MDMKT), and

- the final solar attractivenes index models (PONDS, PLATE and PARAB).

4.2.3 Analytical Methods

These maximum and average statistical values for each thematic map and region formed the basis of the market ranking computations. The selected themes represented both the overall solar IPH attractiveness indices for each system and their principal factor components, as well as the user demand concentrations for the low temperature and medium temperature industrial groups.

Thus, it was possible to compute a market regional ranking using the vectorial computations defined conceptually in Section 2.5.2, and to perform sensitivity analyses by adjusting the importance of the component factors through the use of multipliers to adjust their scales, as defined in Section 2.5.3. Both two- and four-dimensional analyses were undertaken. In each case, the appropriate statistic (maximum or average value) for each region formed a coordinate along a component or factor axis (see Figure 2-5).

The two-dimensional analyses compared the final solar attractiveness index models for each collector system (PONDS-Map 37, PLATE-Map 38, AND PARAB-Map 39) with the appropriate user demand models representing the low and medium temperature users (LOMKT-Map 33 and MDMKT-Map 36). The four-dimensional analyses allowed for the division of the final solar attractiveness index models into their three primary components, and thus the comparison of these components to the appropriate user demand models. For each analysis, the following components of the attractiveness index model were used:

- the solar system energy output, measured by the POND2, PLAT2, OR PARA2 models,

- the environmental and tax incentives for solar IPH, measured by model SUPLY, and

- the economic incentives for solar IPH, measured by model FUELS.

4.3 SENSITIVITY ANALYSES

Two forms of sensitivity analysis made up the final stage in the model building and analysis. The principal form involved the weighting of certain factors in the four-dimensional market matching analysis and recalculation of the vector ranks as described conceptually in Section 2.5.2. Weighting of the two factor model components was also tried, but caused little relative change in the regional rankings, which remained similar to the unweighted ranks of the four-dimensional analyses. Accordingly, these two-dimensional studies are not further reported on. The four-dimensional analyses were reanalyzed with all factors weighted equally (unity) and then with each factor in turn doubled and quadrupled, a total of 9 analyses for each combination of factors.

These analyses were repeated using both the arithmetic average values and the maximum values for each region. The numerical rankings obtained by these analyses are summarized in Appendix H. In some cases, the vector lengths for two or more regions are almost the same; consequently, the numerical rankings may reflect small differences. In order to account for such conditions, the data were re-evaluated and each region placed in one of four categories labeled A through D. The boundaries between categories were selected to reflect the more significant differences between the regional vector values; accordingly, those regions having the same letter code can be considered substantially equal. In order to prevent undue bias in selecting these category boundaries, the separation between B and C categories occurs, as much as possible, at values about half the maximum vector length. Thus, the A and B categories represent the upper half of the range of market strength, while the C and D categories represent the lower half of the range.

Tables 4-3 and 4-4 summarize these categorized rankings of the market regions for the average and maximum values statistics, respectively. Examination of these tables reveals how the regions respond to increases in each component factor. Some regions are relatively insensitive to such changes, while other regions change their ranking (either upward or downward) by one or several categories. This form of sensitivity analysis is discussed further in Section 5.0.

Other forms of sensitivity analysis are possible. New models of one or several components can be built using alternate data sources or the same data sources but different assumptions. These can be analyzed using the same conceptual framework and the results compared with the existing models. This was done to a limited extent in this project. Different assumptions were made regarding the level and method of calculating the tax incentives, yielding slightly different state rankings. Analyses also were made using 1976 fuels price data from the Census of Manufacturers, and using projected 1985 fuel prices according to the methods defined in Appendix C, Section C.2.2. In both cases, comparisons of the final market rankings produced by these different assumptions showed them to be in close agreement, with no differences which could be judged significant.

4.4 RESULTS OF ANALYSIS

Analysis of the solar IPH marketing attractiveness on a regional basis, utilizing the thirteen DRI standard reporting regions, reveals a number of interactions among the physical, legal, and economic incentives controlling these markets. Some of these patterns reflect what is obvious to many observers of economic trends; nonetheless, the magnitudes of the trends are not obvious, but the emergence of the trends lends credence to the overall methodology.

Based on the criteria used in this study, the most attractive solar IPH markets occur in the southwest and west, while the least attractive markets occur in the upper plains states and the central and southern Appalachian regions. These trends are readily understood when insolation rates and available tax and environmental incentives are considered, along with economic characteristics of the regions, sources, availability, and prices of conventional fuels.

TABLE 4-3. CATEGORIZED RANKINGS OF THE MARKET REGIONS BASED ON AVERAGE VALUES

	FOUR-FACTOR ANALYSIS WEIGHTINGS														
Solar Collector Output	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1
Environmental and Tax Incentives	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1
Competitive Fuels Incentives	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1
User Demands	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
REGIONS	SOLAR PONDS					FLAT PLATES					PARABOLIC TROUGHS				
NEW ENGLAND	B+	D+	B	A+	B	B+	D	B	A+	B	B	C	B	A+	B
MID ATLANTIC	B	D	C+	A−	C+	B	D−	C+	B+	C+	B	D	C	A	B
SOUTH ATLANTIC	C+	B−	C−	B−	B	B−	C	C	B−	B	C	C	C	B	C
EAST NORTH CENTRAL	C−	D−	C	B	C	C+	D	C	B	C−	C	D	C	B	C
EAST SOUTH CENTRAL 1	D−	C+	D−	D−	D−	D−	D+	D	D−	D−	D−	D	D	D−	D−
EAST SOUTH CENTRAL 2	D+	B	D	D	D	D	C+	D−	D	D	D	C	D−	D	D
WEST NORTH CENTRAL	D	C	D	D+	C	C	C−	D+	D+	C−	D	C	D	C	C
WEST SOUTH CENTRAL 1	B	B	B+	C	B+	B	B	B+	C	B+	B	B	B	B	B
WEST SOUTH CENTRAL 2	B−	B+	D+	D+	B	B	B	D+	D+	B	C	B	D	C	B
MOUNTAIN 1	A−	A+	B−	B+	A	A−	A	B	B	A	A	A	B	B	A
MOUNTAIN 2	C	B−	C+	C	B	B	B−	C+	C+	B	B	B	C	B	B
MOUNTAIN 3	A+	A	A	B	A+	A+	A+	A	B	A+	A+	A+	A	B	A+
PACIFIC (EX. ALASKA, HAWAII)	A	B	A+	A	A−	A	B+	A+	A	A−	A−	B	A+	A	A

TABLE 4-4. CATEGORIZED RANKINGS OF THE MARKET REGIONS BASED ON MAXIMUM VALUES

	FOUR-FACTOR ANALYSIS WEIGHTINGS														
Solar Collector Output	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1
Environmental and Tax Incentives	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1
Competitive Fuels Incentives	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1
User Demands	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4

REGIONS	SOLAR PONDS					FLAT PLATES					PARABOLIC TROUGHS				
NEW ENGLAND	B	D	B	A	C+	B	D	B	A	C+	B	D+	B+	A	C
MID ATLANTIC	C-	D	C	B+	D	D+	D	C	B+	D-	C-	D-	C	B+	D+
SOUTH ATLANTIC	B	B	C	B	B+	B	C+	C+	B	B+	C+	C	C	B	B
EAST NORTH CENTRAL	C	D+	B-	B	C	C	C-	B-	B-	C	C	C-	B	B	C
EAST SOUTH CENTRAL 1	D	C-	D	D	D	D-	C-	D-	D-	C	D-	D	D-	D-	D-
EAST SOUTH CENTRAL 2	D	C	D	D	D	D	C	D	D	C	D+	C	D	D+	C
WEST NORTH CENTRAL	C+	C	C	B	C	C+	C+	C	B	C	C+	B	C	B	C
WEST SOUTH CENTRAL 1	B	B	B	C	B	B	B	B	C	B	B-	B	B+	C	B
WEST SOUTH CENTRAL 2	B	B+	D+	C	B	B	A-	D+	C	B	B	B+	C-	B	B
MOUNTAIN 1	A-	A-	C	B-	A	A-	A	C	C+	A	B+	A-	C	C+	A+
MOUNTAIN 2	C+	B	C	C	B	C+	B	C	C	B	B	B+	C	C	B
MOUNTAIN 3	A	A+	A	B-	A+	A	A+	A	C+	A	A	A+	A	C+	B+
PACIFIC (EX. ALASKA, HAWAII)	A+	A+	A+	A+	A	A+	A+	A+	A+	A	A+	A+	A+	A+	A+

In the west and southwest, insolation is high, tax and environmental incentives are common, the areas show positive growth trends, and conventional fuels come from foreign sources to varying degrees. Such combinations of factors place the Pacific, Mountain 1, and Mountain 3 regions into the top category. In contrast, the east coast regions form a much less attractive market. In New England and the Mid-Atlantic regions, insolation is weak and there is a lack of industrial growth and tax incentives. In the South Atlantic, the demand remains relatively weak, although the solar energy component increases. In all these regions, their dependency on high priced, imported fuels is the dominant factor in raising their market rankings.

The northern mountain states (Mountain 2) and the southern plains states (West South Central 1 and 2) form markets of similar strength to the east coast, but for different reasons. In these areas, domestic conventional fuels are readily available at lower than national prices. This serves to reduce the ranking of otherwise good areas. The northern mountain states have lower solar values because of latitude, but tend to have positive environmental incentives and one state (Utah) has tax incentives. In the south, these factors are reversed, with solar insolation gains being offset by fewer tax and environmental incentives. All these areas are marked by industrial growth. A strengthening of tax and environmental incentives, or a weakening of the availability of domestic conventional fuels, would increase the solar IPH market attractions for these regions.

The Great Lakes area (East North Central) shows still lower market rank because it is characterized by relatively weak insolation, lack of industrial growth, and a lack of tax and environmental incentives. The area's dependency on relatively expensive conventional fuels, some from foreign sources, and its large industrial base represent the chief factors in favor of solar applications.

The remaining areas of the country represent the least attractive market areas for solar IPH. These are the northern plains states (West North Central) and the southern Appalachian regions (East South Central 1 and 2). The dominantly rural character and low insolation values of the northern plains, coupled with a lack of tax or environmental incentives, make the region a relatively weak market area. The southern Appalachian region forms a weak market for another suite of reasons. Kentucky and Tennessee have no tax or environmental incentives, lack of industrial growth, but have abundant conventional fuels. Further to the south, insolation improvements are largely or entirely counteracted by a lack of suitable demand, continued availability of inexpensive conventional domestic fuels and a lack of tax and environmental incentives.

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SECTION 5.0

CONCLUSIONS

The market suitability analysis method used in this study was successful in generating useful market data and in identifying geographic areas with characteristics favorable to solar IPH systems. There are a number of conclusions of this research which relate to the data base and analysis, the market matching of composite suitability maps, and the sensitivity analysis.

5.1 DATA BASE AND ANALYSIS

The data assessed and individual maps produced have resulted in five separate conclusions. These are discussed according to solar collector output, air quality regulations, state tax incentives, competitive fuels, and industrial demand and growth.

5.1.1 Solar Collectors Output

Although the output maps for various collectors are generally predictable, some differences in output were unexpected. The geographic distribution of performance differed between ponds and flat plates, with ponds showing a stronger latitude variation effect, despite the reliance of both collector systems on total solar radiation. This variance is probably due to the required horizontal orientation of ponds; flat-plate collectors can be tilted to maximize annual performance.

5.1.2 Air Quality Regulations

Prevention of Significant Deterioration (PSD) areas constrain the location of conventional energy systems for industry near national parks and wilderness areas. These areas exist in the United States primarily in the far west but also in the mid-south, Florida, North, and Northeast. Non-attainment of primary and secondary National Ambient Air Quality Standards (NAAQS) are greatest in metropolitan areas primarily in California, the Great Lakes Region, the Northeast, Florida, Texas, Louisiana, Missouri, Nebraska, Utah, and several other parts of the south.

5.1.3 State Tax Incentives

The analysis of state tax incentives for solar IPH showed that the magnitude varied significantly between the 14 states that offer income tax incentives. Income tax credits are more effective than income tax deductions. It also showed that the percent of credit allowed in states is not likely to result in an equal reduction in costs for the solar IPH system. This is because of the low income tax rates at the state level, concomitant carry forward and discounted value of the state credit, and the limitation in some states of the maximum dollar credit allowed or number of years of carry forward.

Consistently, the three states with the most substantial solar IPH income tax incentives are Arizona, Oregon, and California.

5.1.4 Competitive Fuels

The availability and cost of conventional fuels is an important issue to industrial decision-makers. Fuel availability is a complex and uncertain issue, but it seems logical that those areas where domestically produced fuels predominate have a greater supply security than those areas which have a greater dependence on imported gas and oil. The areas having the greatest anticipated dependence on imported fuels in 1985 are along the west and east coasts and bordering the Great Lakes. Regarding fuel prices, the New England states, Oregon, South Dakota, and North Carolina showed the highest costs. Since coal poses the most difficult economic competition for solar IPH systems, a number of states have been projected by DRI (18,19) to be primary coal users by industry in 1985. These states are Pennsylvania, Virginia, West Virginia, Ohio, Wisconsin, Indiana, Michigan, South Dakota, Missouri, Tennessee, Wyoming, and Utah.

5.1.5 Industrial Energy Consumption and Growth

User demand and industrial growth areas were important considerations of this research. In most cases, for the process heat temperatures included in this study, energy consumption is concentrated in or near metropolitan areas of the Far West, Great Lakes, and the east and Gulf coasts. Some areas of the central Midwest also have large energy demand concentrations. High industrial growth for the 1970-76 period has occurred throughout the West and South, most significantly in the states of Florida, Oklahoma, New Mexico, Arizona, Nevada, Utah, Colorado, Wyoming, North Dakota, and South Dakota.

5.2 MARKET MATCHING OF COMPOSITE SUITABILITY MAPS

The market matching of composite suitability maps for thirteen regions provides conclusions which can assist in targeting solar IPH marketing efforts. Based on the equal weighting of all analysis criteria as used in this study, the regions of the United States can be ranked in four categories which show the most and least desirable geographical markets. Thus, category A represents the most promising regions for low (below 100°C) and intermediate (100°C to 288°C) temperature solar IPH technologies, while category D lists regions with qualities least desirable for marketing solar IPH systems. It should be re-emphasized that these conclusions are based solely on the market data used in this study. It is entirely possible that factors apparent at the plant site, such as available land area, an inefficient conventional energy system or process, and favorable attitudes among the senior plant executive officers, can combine to create viable solar IPH installations in regions with market analysis characteristics that are less favorable. With the above caveats, Table 5.1 lists, by these four categories, the low temperature (below 100°C) and intermediate temperature (100°C to 288°C) rankings for each region.

TABLE 5.1

CATEGORIZATION OF MARKET REGIONS

LOW TEMPERATURE MARKETS (BELOW 100°C)

Category A: Mountain 3, Pacific, Mountain 1

Category B: New England, Mid Atlantic+, West South Central 1, West South Central Central 2

Category C: South Atlantic*, Mountain 2, East North Central

Category D: West North Central*, East South Central 2, East South Central 1

INTERMEDIATE TEMPERATURE MARKETS (100°C TO 288°C)

Category A: Mountain 3, Pacific, Mountain 1

Category B: Mountain 2, New England, Mid Atlantic+, West South Central 1

Category C: South Atlantic, East North Central, West South Central 2*

Category D: West North Central*, East South Central 2, East South Central 1

NOTE: For definition of states within each region, see Table 4.2

*Includes significant non-uniformity in region. When maximum values of data are considered, its rank will improve by one category.

+Includes significant non-uniformity in region. When maximum values of data are considered, its rank decreases by one category.

5.3 SENSITIVITY ANALYSIS

Since the importance of the mapping criteria used in this study all vary depending on the values of the industrial decision-maker, a sensitivity analysis was successfully completed for all thirteen regions. Overall, the classification of 13 regions in the four categories listed in Table 5.1 were only mildly sensitive to a sequential change in the weight of each of the four main composites (i.e., solar system output, environmental and tax incentives, competitive fuels incentives, and user demand) by a factor of two. As expected, changes were more pronounced when a weight of four was assigned to each composite while holding the remaining three composites to weights of one. The analysis showed that sensitivity varied significantly depending on the region. Some regions are consistently strong or consistently weak for all composites. These regions showed that repeated rankings with a weight of four assigned separately to each composite did not change its rank of category by more than one. These relatively insensitive regions are Pacific, Mountain 2, West South Central 1, West North Central, East South Central 1, East North Central, and South Atlantic. Thus, the equal weighting classification of these regions in the four categories above are more certain for the criteria used in this study than other regions.

Other regions showed greater sensitivity to repeated rankings with a weight of four. These regions showed a change in rank by two categories (for example, from Category A to Category C, or vice versa) at least once during the sensitivity runs. These regions are Mountain 1, Mountain 3, and East South Central 2. The analysis showed Mountain 1 to be most sensitive negatively in rank to environmental and tax incentives, and to competitive fuels incentives for solar IPH in the low temperature analysis of maximum values. The Mountain 3 region showed that the relative security and low price of conventional fuels adversely affected rank consistently when the competitive fuels composite was given a weight of four. Finally, a significant improvement in rank for East South Central 2 resulted for low temperature markets in solar ponds because of the large improvement in annual output in southern latitudes.

Several regions showed the highest sensitivity. These regions had a change in rank of category from weakest to strongest and vice versa (e.g., from Category A to Category D). New England, Mid Atlantic, and West South Central 2 all have the highest sensitivity and, therefore, the equal weighting classification of these regions are least certain. Both New England and Mid Atlantic regions showed negative sensitivity in rank consistently when annual solar collector output data is weighted by a factor of four. Conversely, a significant improvement in ranking resulted when the competitive fuels composite was weighted by a factor of four, obviously because of the heavy reliance of industry in these regions on expensive fuels such as oil and increased reliance on imported gas. As expected, West South Central 2 showed consistently improved rankings when solar collector output is heavily weighted. A significant decrease in rank also resulted because of a lack of tax and environmental incentives for solar IPH, and due to the secure supplies of low priced domestic conventional fuels in the region.

Some conclusions are appropriate regarding the relevance of this analysis for future years. Clearly, there are some evaluation criteria in the study, such as environmental regulations and solar IPH tax incentives, that are easiest and more likely to change in the future. Others, including fuel prices and reliance on imported fuels, may change but are less likely to cause rapid change. Finally, the criteria least likely to change in the future are annual output of collectors, location of industrial demand, and industrial growth areas. Consequently, the authors recommend that the data and analysis of this study be updated every few years if the results are to maintain validity. Additional recommendations for refining this study are to:

- Investigate delivered energy costs as a common denominator for many criteria used in this study;
- Explore the use of opinions of industrial decisionmakers to weight the importance or to value the cost of different criteria used in the study;
- Expand the study to include higher temperature solar thermal systems (e.g., central receiver and dish technology) matched to high temperature industrial demands.

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COMPUTER MAPS USED IN THE ANALYSIS

A. Baseline Maps

Map* Number	Map Topic
1	Solar pond annual average thermal outputs
2	Flat-plate annual average thermal outputs
3	Parabolic trough annual average thermal outputs
4	Non-attainment status indices for coal
5	Non-attainment status indices for oil
6	Non-attainment status indices for natural gas
7	Class I PSD air restrictions
8	Solar income tax incentives for a small business
9	Solar income tax incentives for a large business
10	Weighted average costs for conventional fuels
11	Oil market shares
12	Coal market shares
13	Natural gas market shares
14	Percent natural gas supplied from "Lower-48" sources
15	1985 state sulfur emission standards
16	Regional energy demands for temperatures below 100°C
17	Regional energy demands for temperatures 100°C to 177°C
18	Regional energy demands for temperatures 177°C to 288°C
19	Regional growth of industrial activity
20	Energy demand by the bituminous coal industry
21	Energy demand by the copper, sulfur, potash, and phosphate industries

B. Composite Maps

Map* Number	Map Topic
22	Oil use non-attainment constraint ratings
23	Coal use non-attainment constraint ratings
24	Natural gas use non-attainment constraint ratings
25	Non-attainment air quality incentives for solar IPH
26	Combined air quality incentives for solar IPH
27	Combined solar tax incentives
28	Environmental and tax incentives for solar IPH
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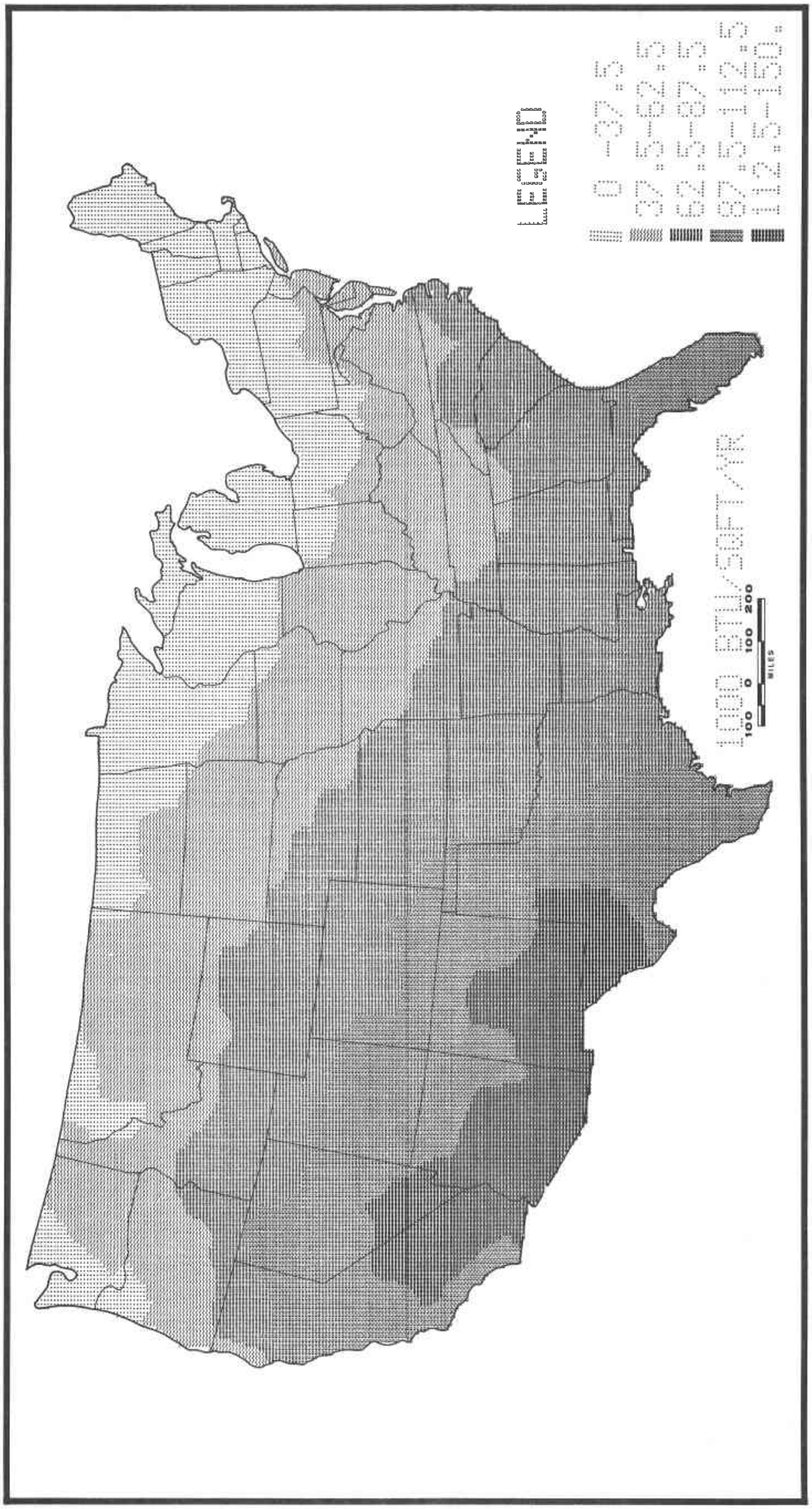
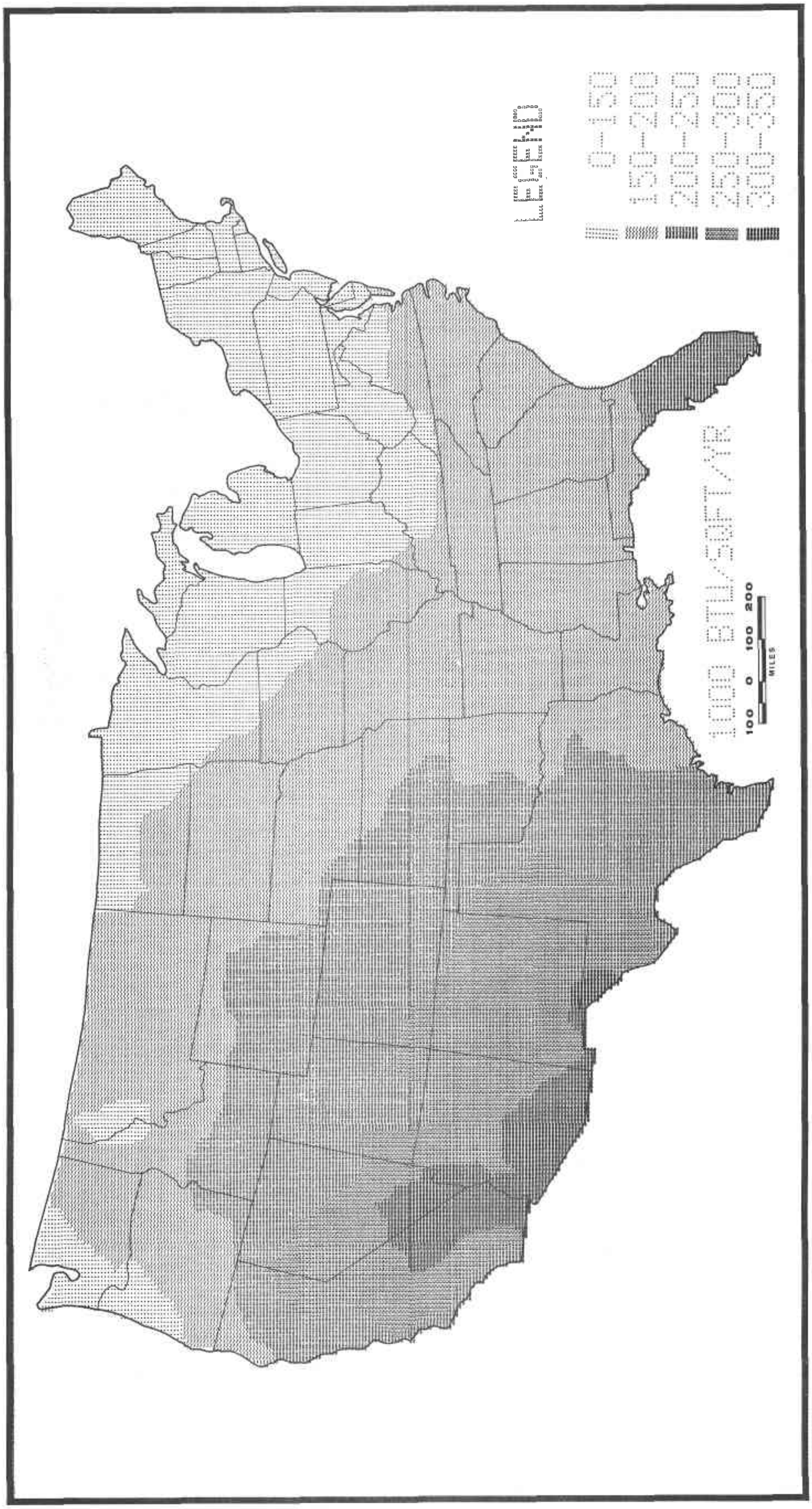
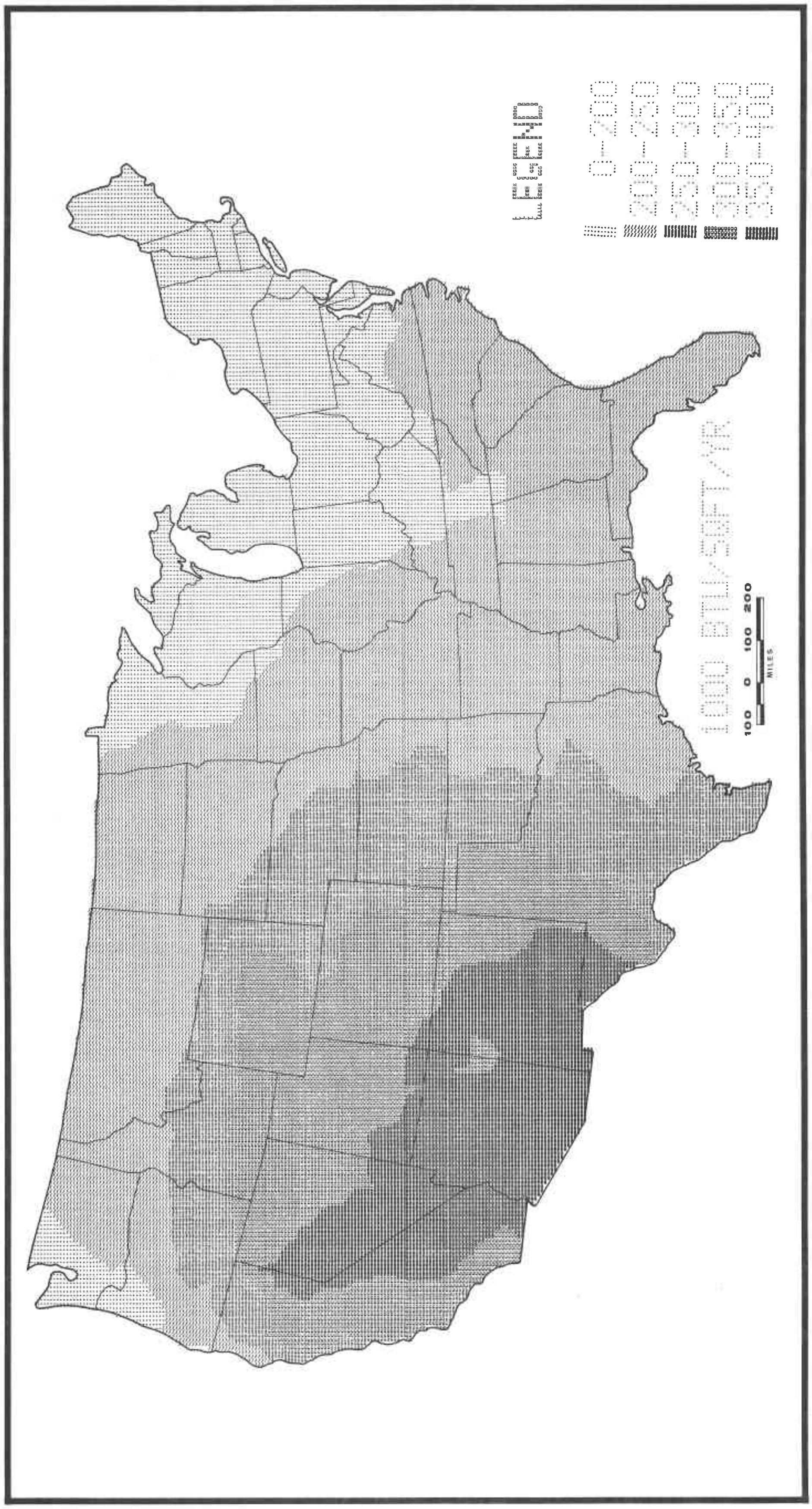


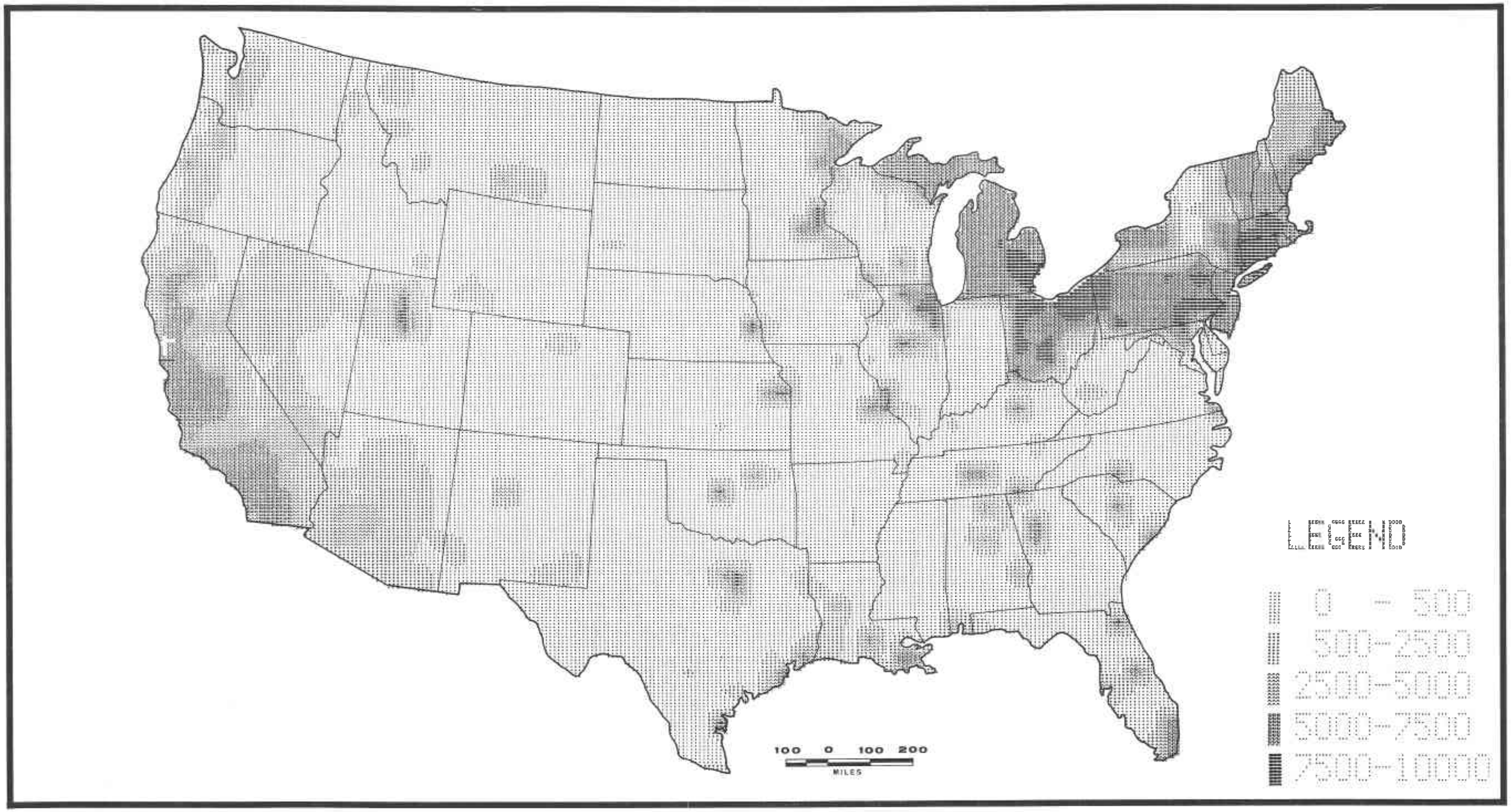
MAP 1 — SOLAR POND ANNUAL AVERAGE THERMAL OUTPUTS



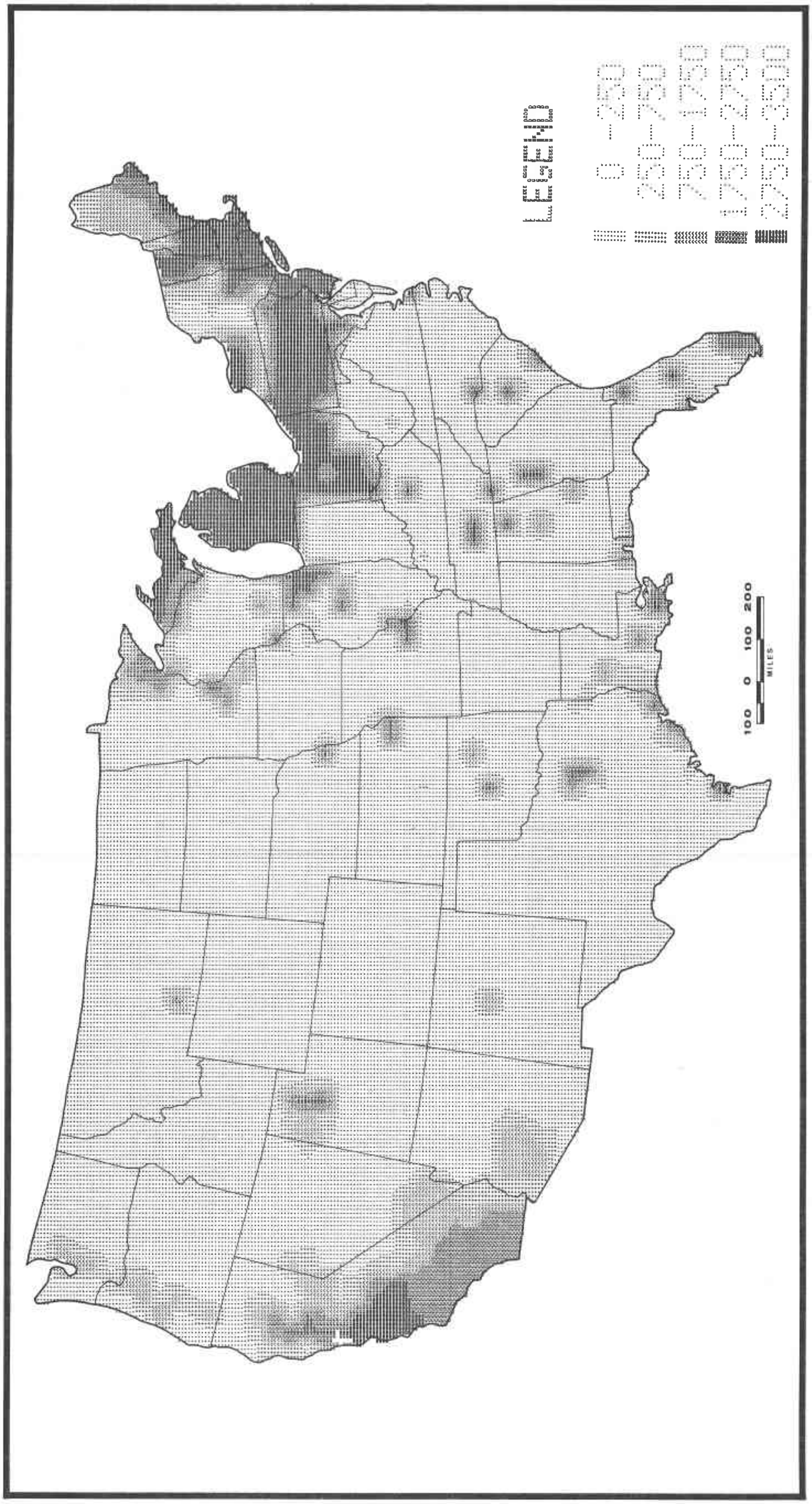
MAP 2 — FLAT-PLATE ANNUAL AVERAGE THERMAL OUTPUTS



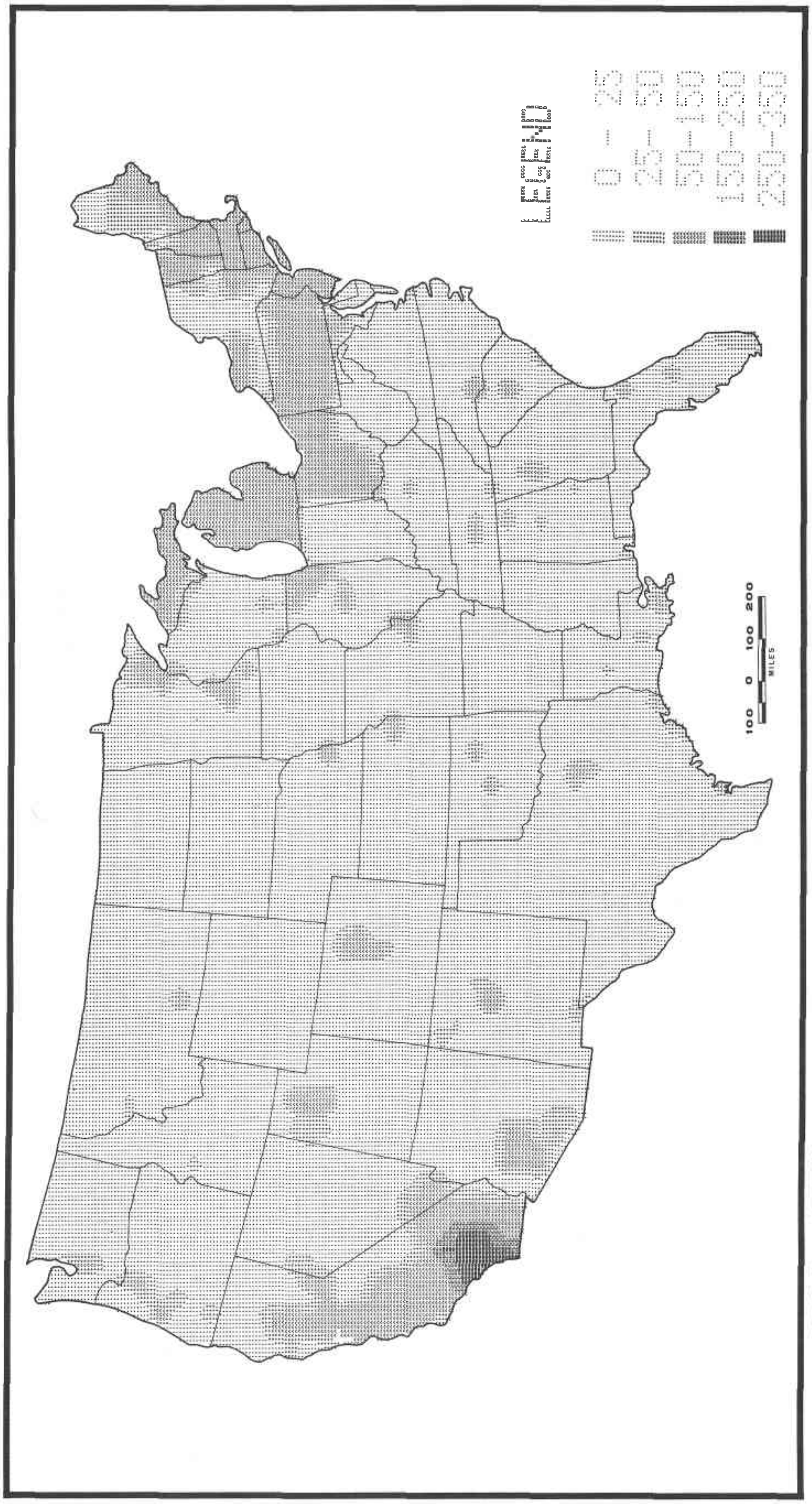
MAP 3 — PARABOLIC TROUGH ANNUAL AVERAGE THERMAL OUTPUTS



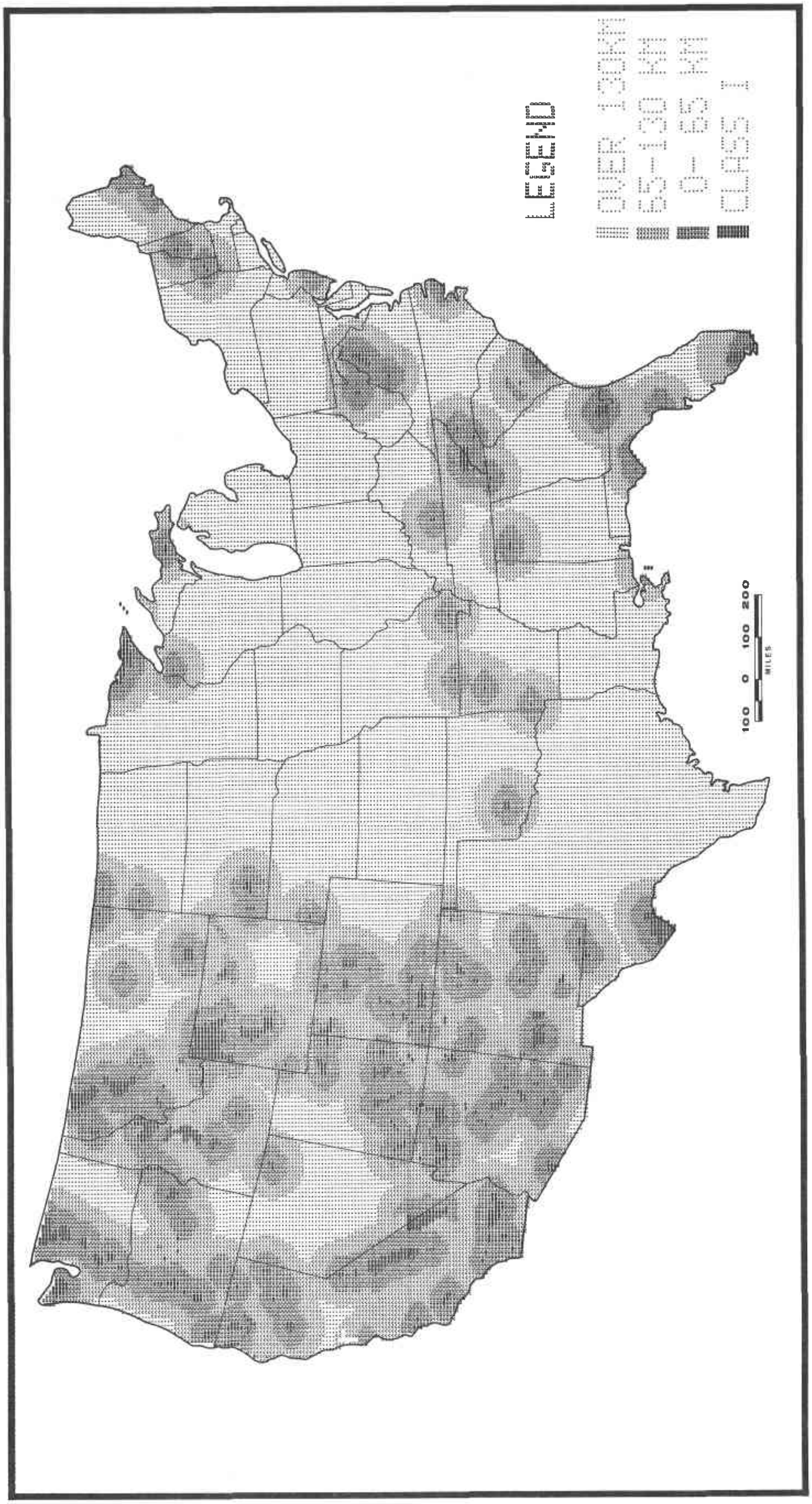
MAP 4 — NON-ATTAINMENT STATUS INDICES FOR COAL



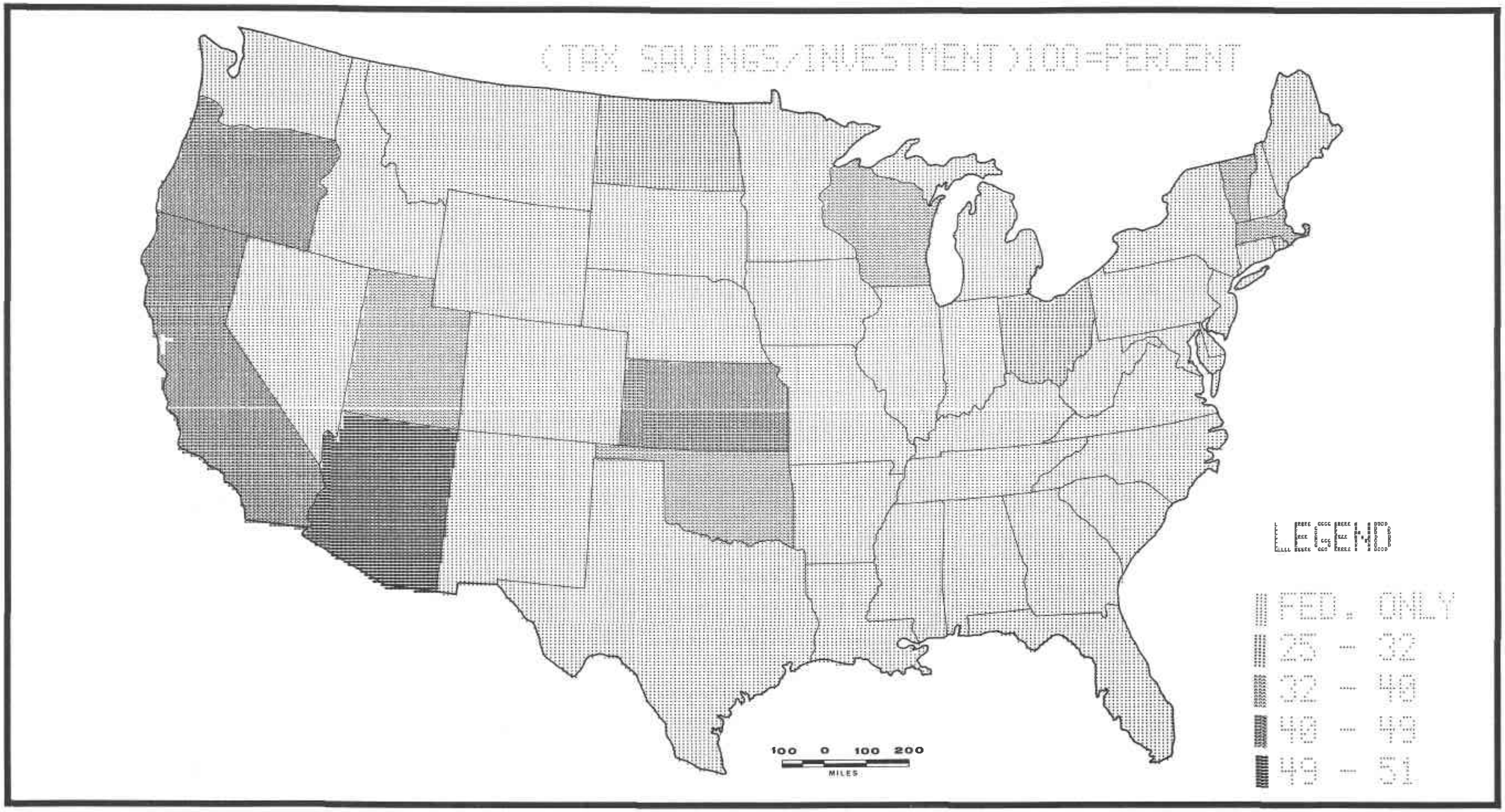
MAP 5 — NON-ATTAINMENT STATUS INDICES FOR OIL



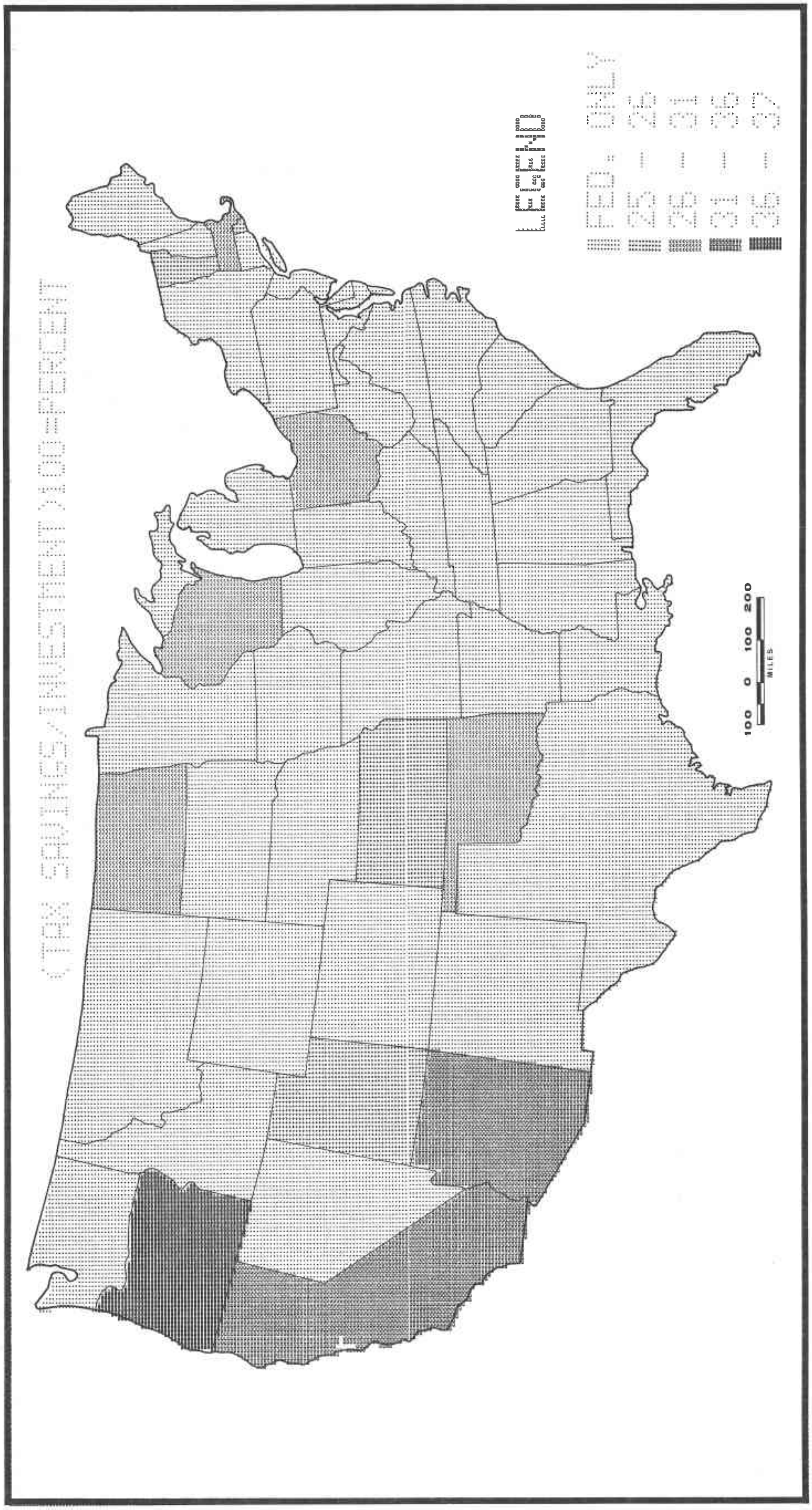
MAP 6 — NON-ATTAINMENT STATUS INDICES FOR NATURAL GAS



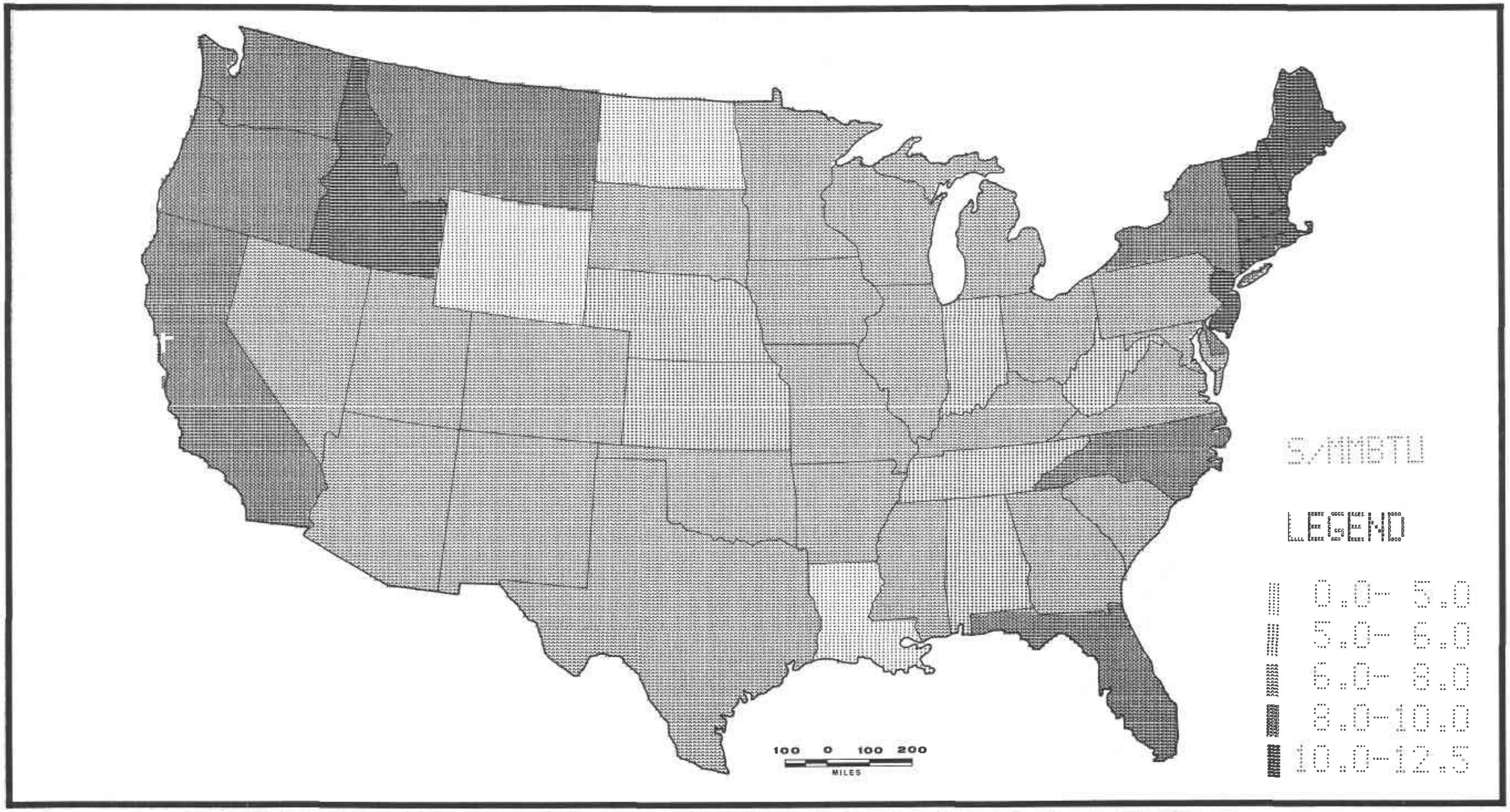
MAP 7 — CLASS I PSD AIR RESTRICTIONS



MAP 8 — SOLAR INCOME TAX INCENTIVES FOR A SMALL BUSINESS



MAP 9 —SOLAR INCOME TAX INCENTIVES FOR A LARGE BUSINESS



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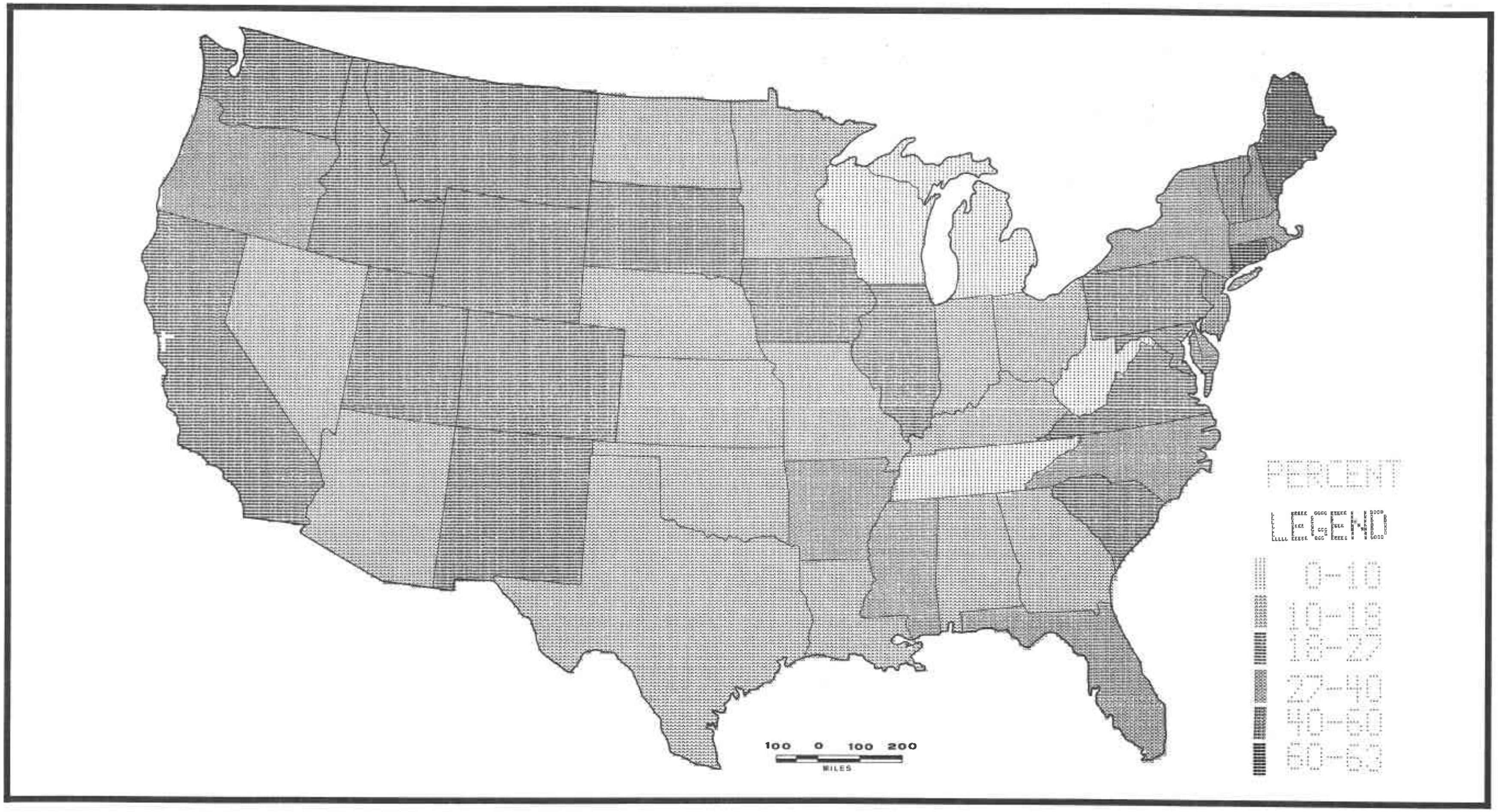
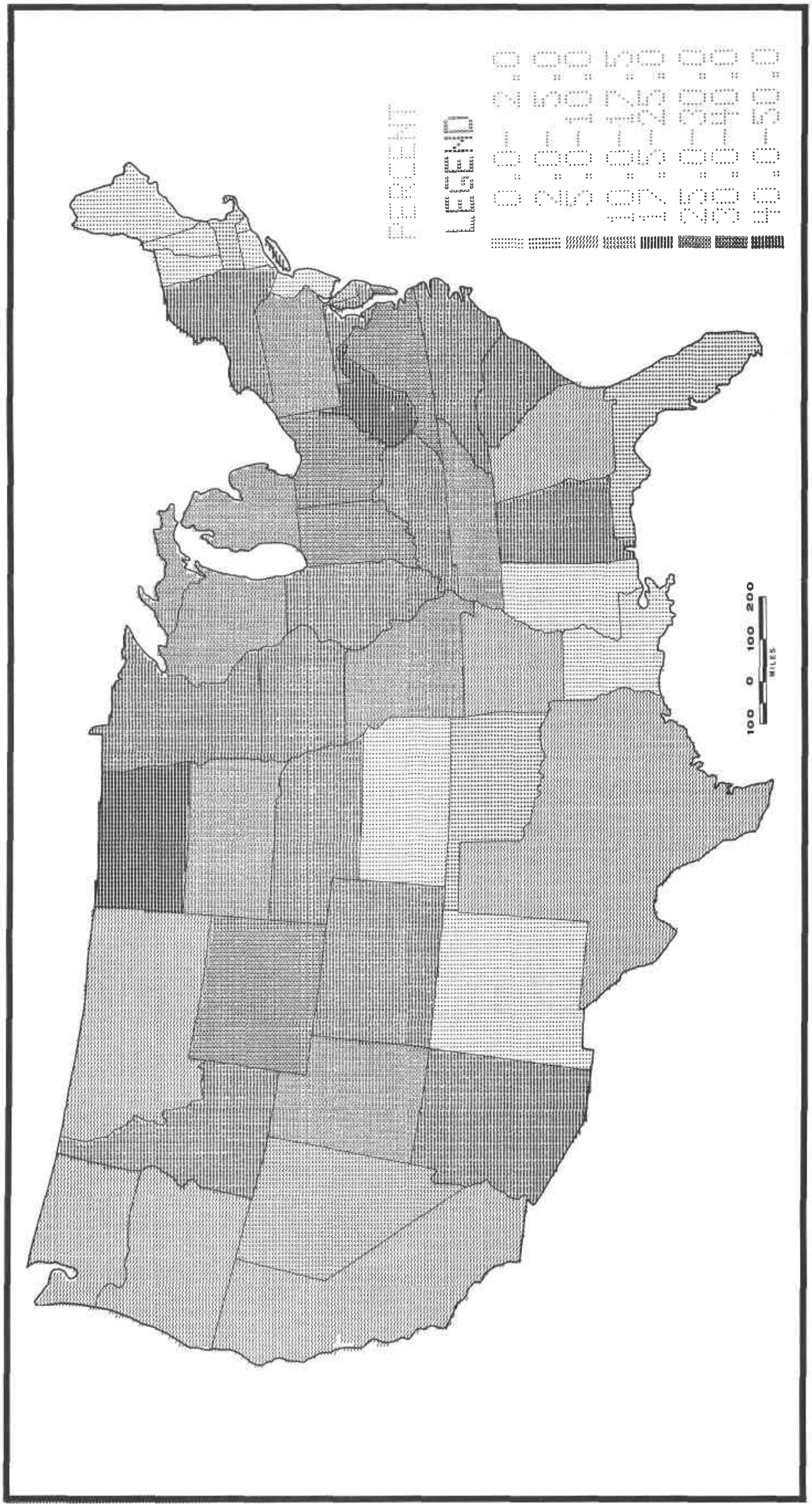
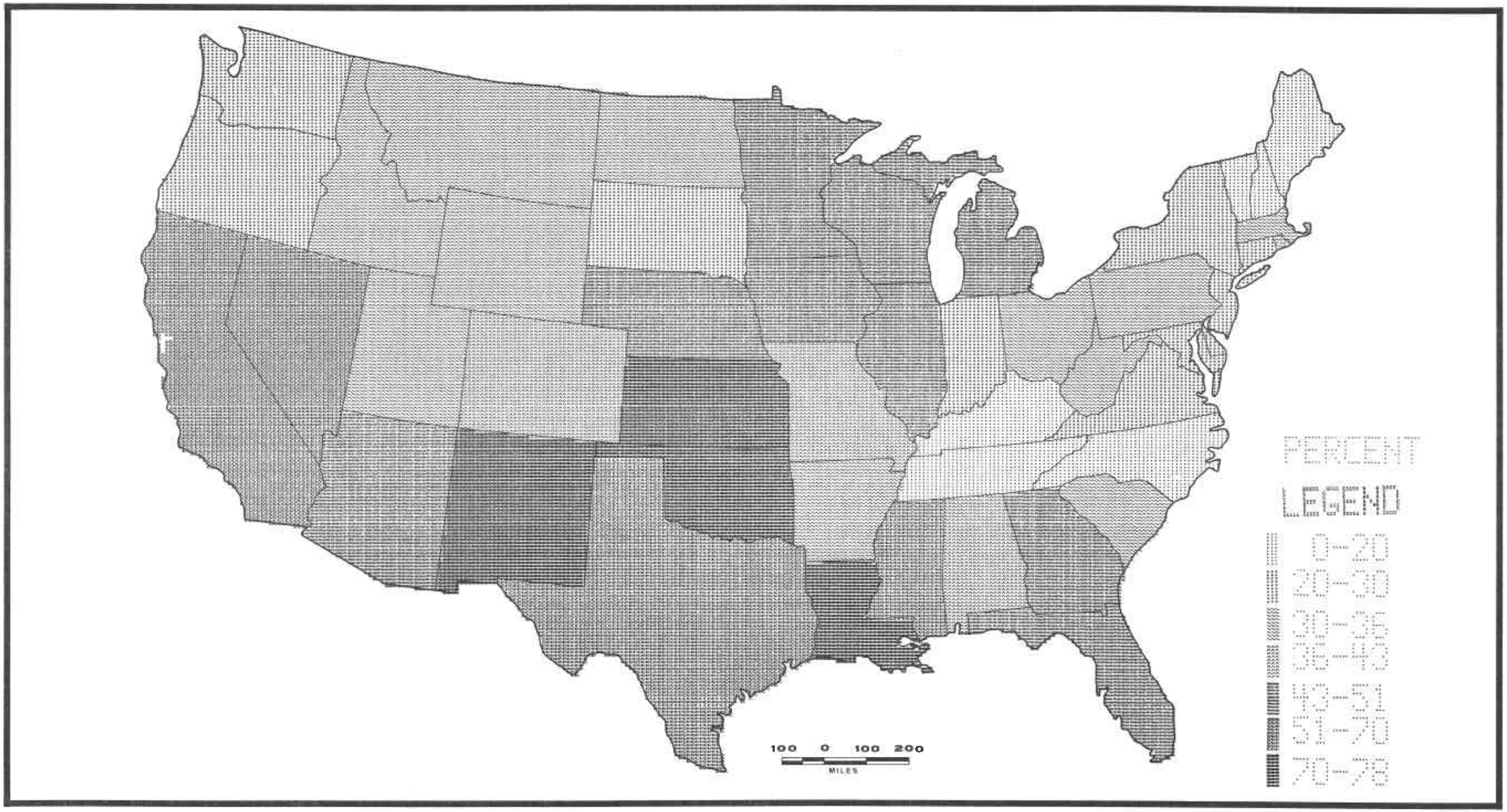


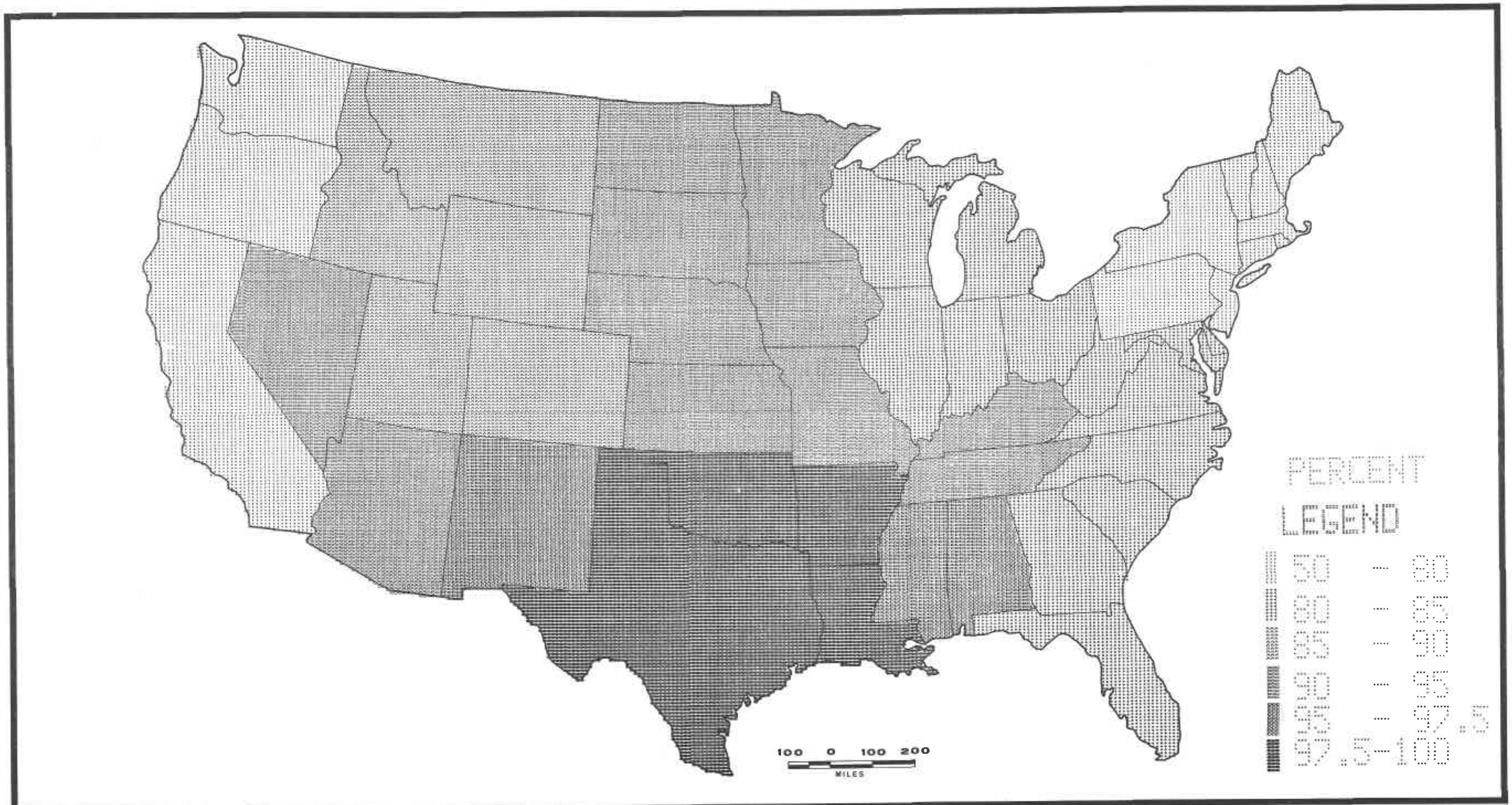
MAP 11 — OIL MARKET SHARES



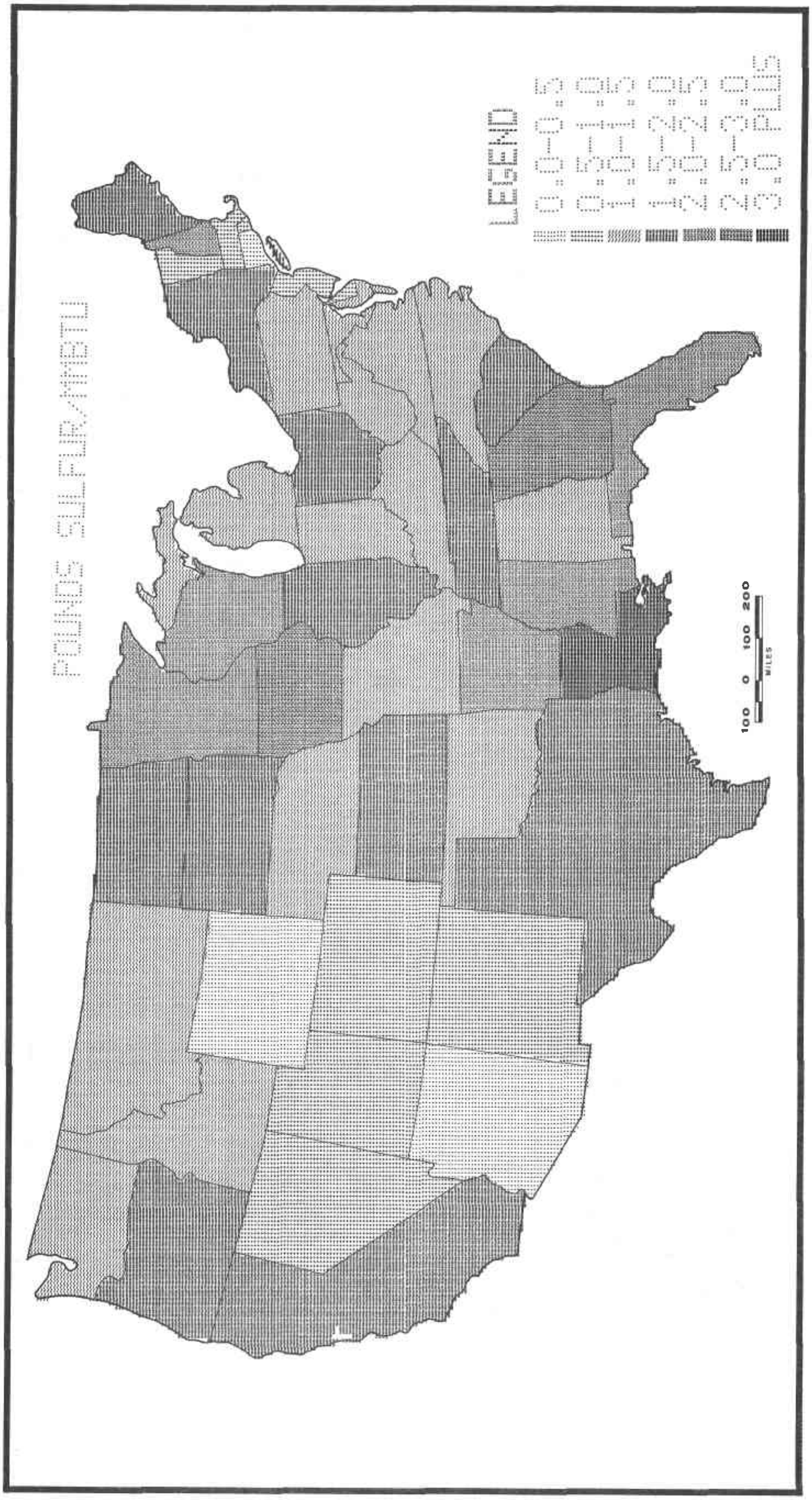
MAP 12 — COAL MARKET SHARES



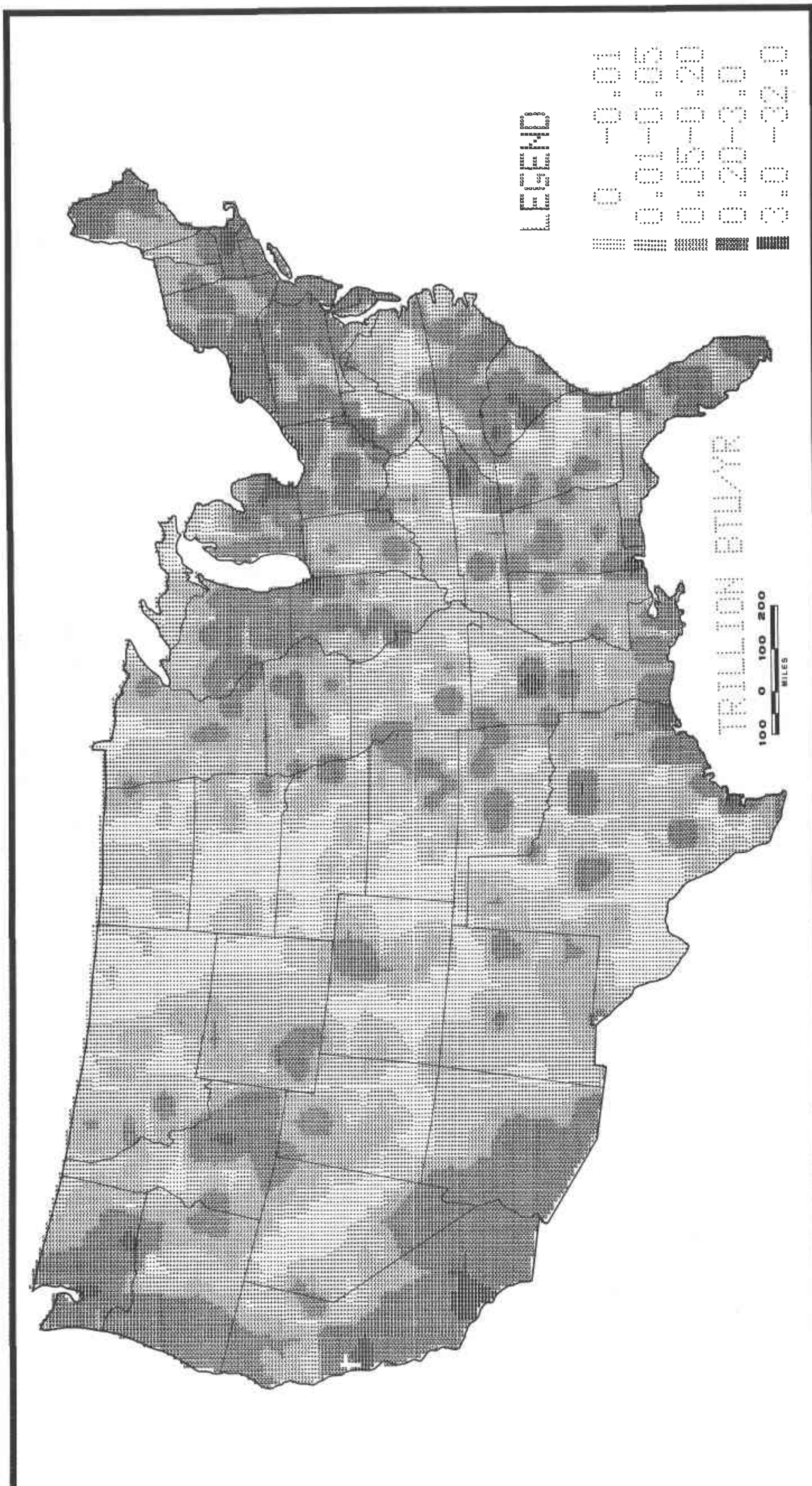
MAP 13 — NATURAL GAS MARKET SHARES



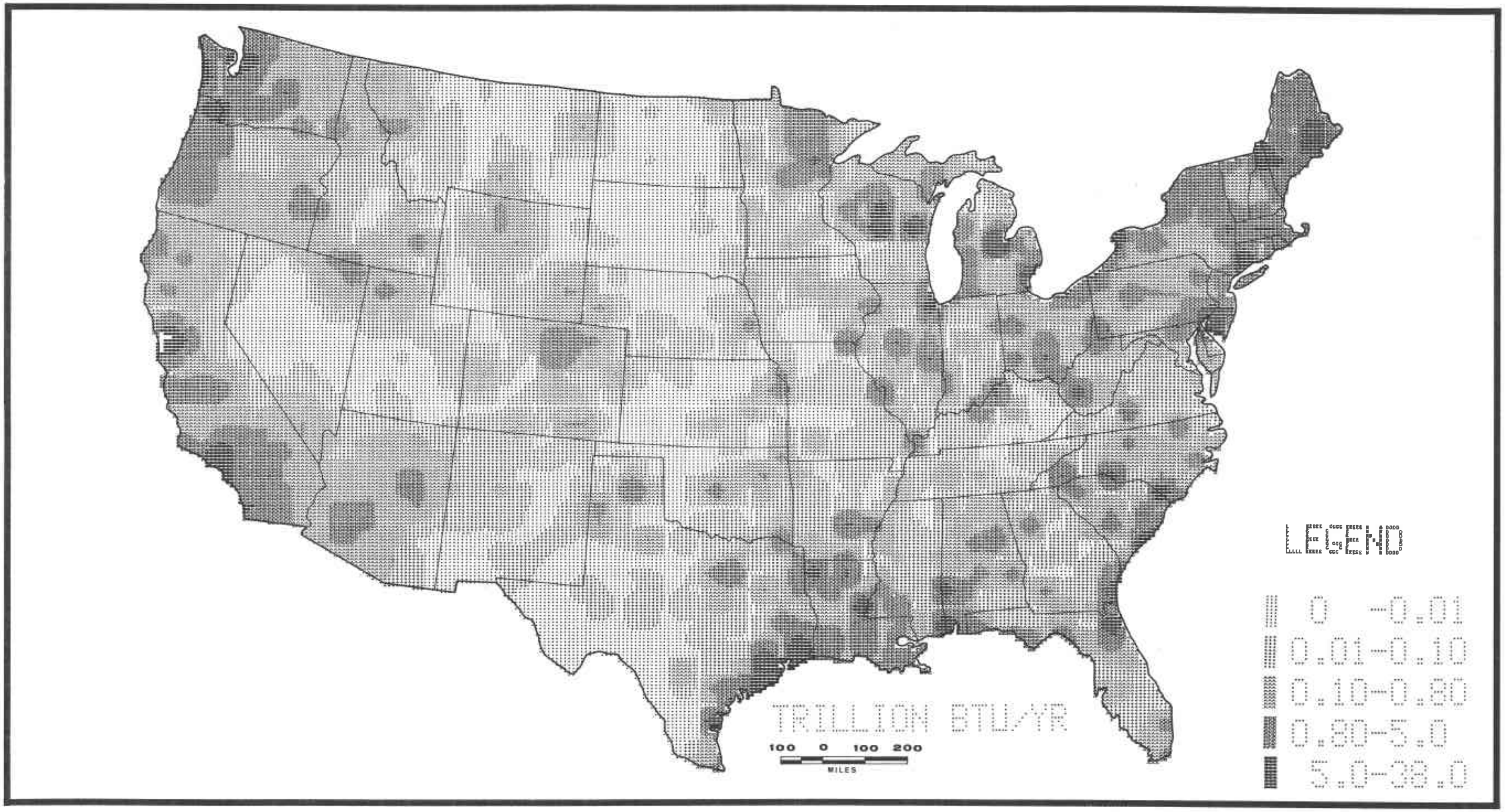
MAP 14 — PERCENT NATURAL GAS SUPPLIED FROM "LOWER-48" SOURCES



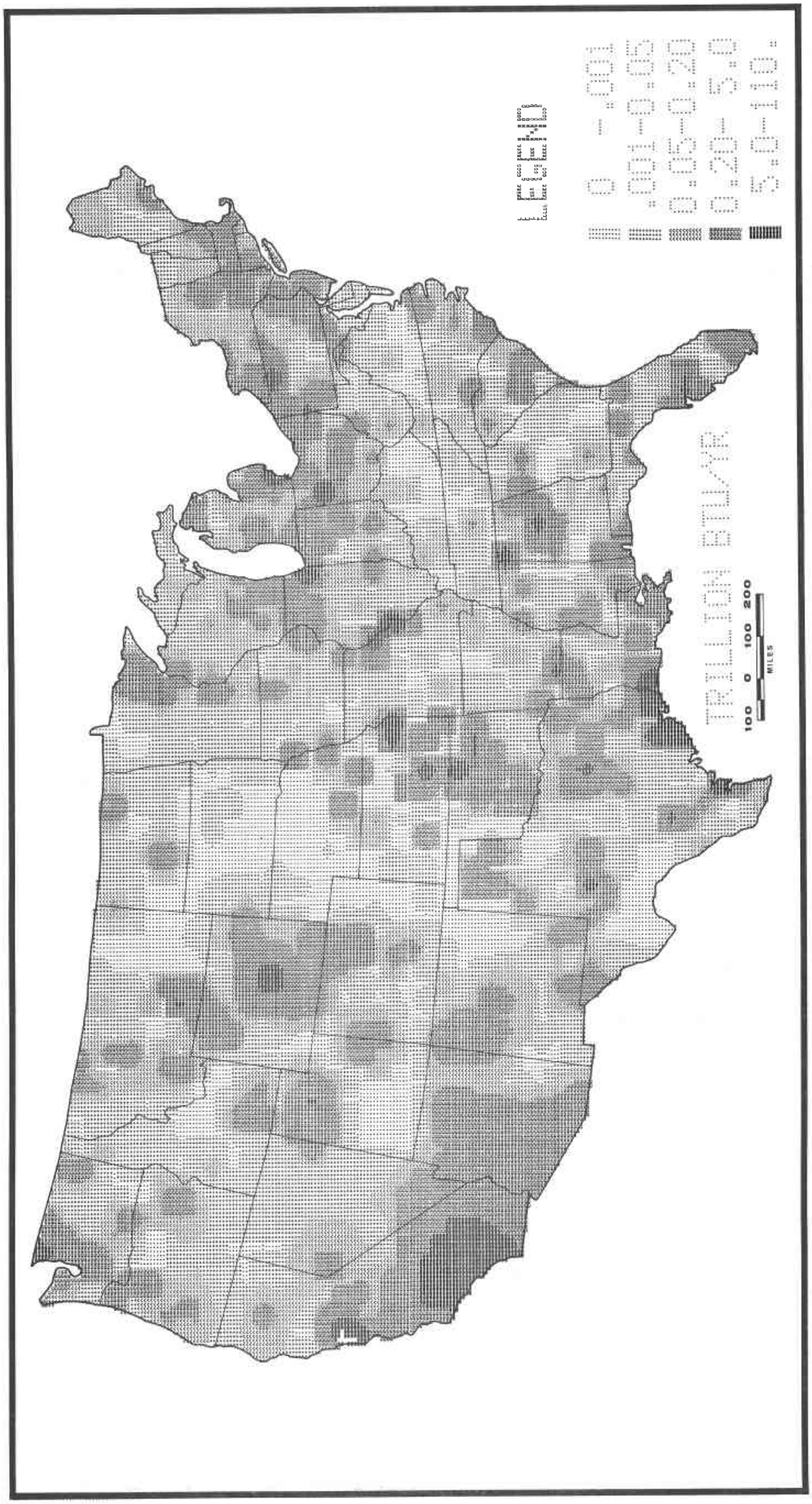
MAP 15 — 1985 STATE SULFUR EMISSION STANDARDS



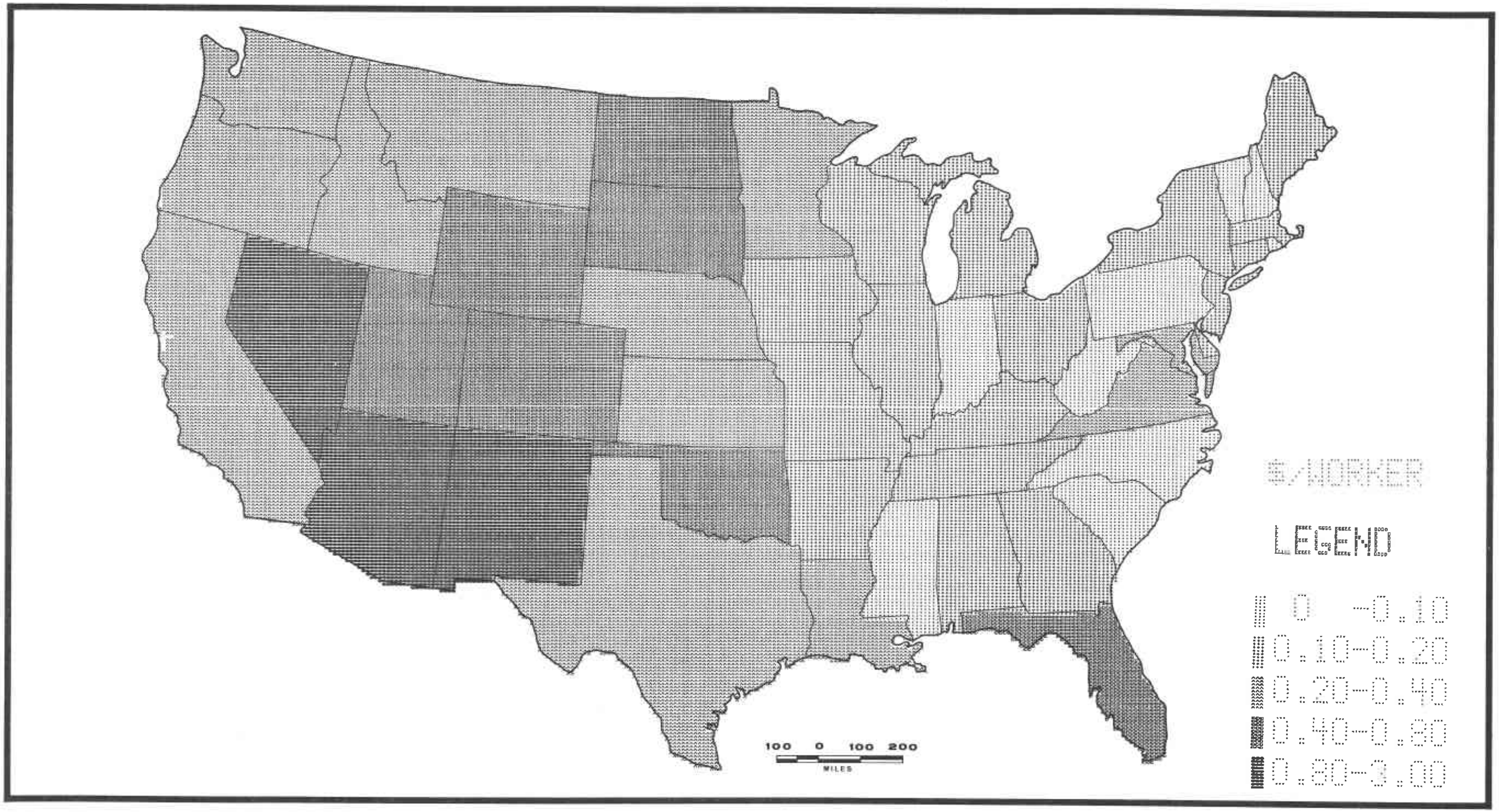
MAP 16 —REGIONAL ENERGY DEMANDS FOR TEMPERATURES BELOW 100°C



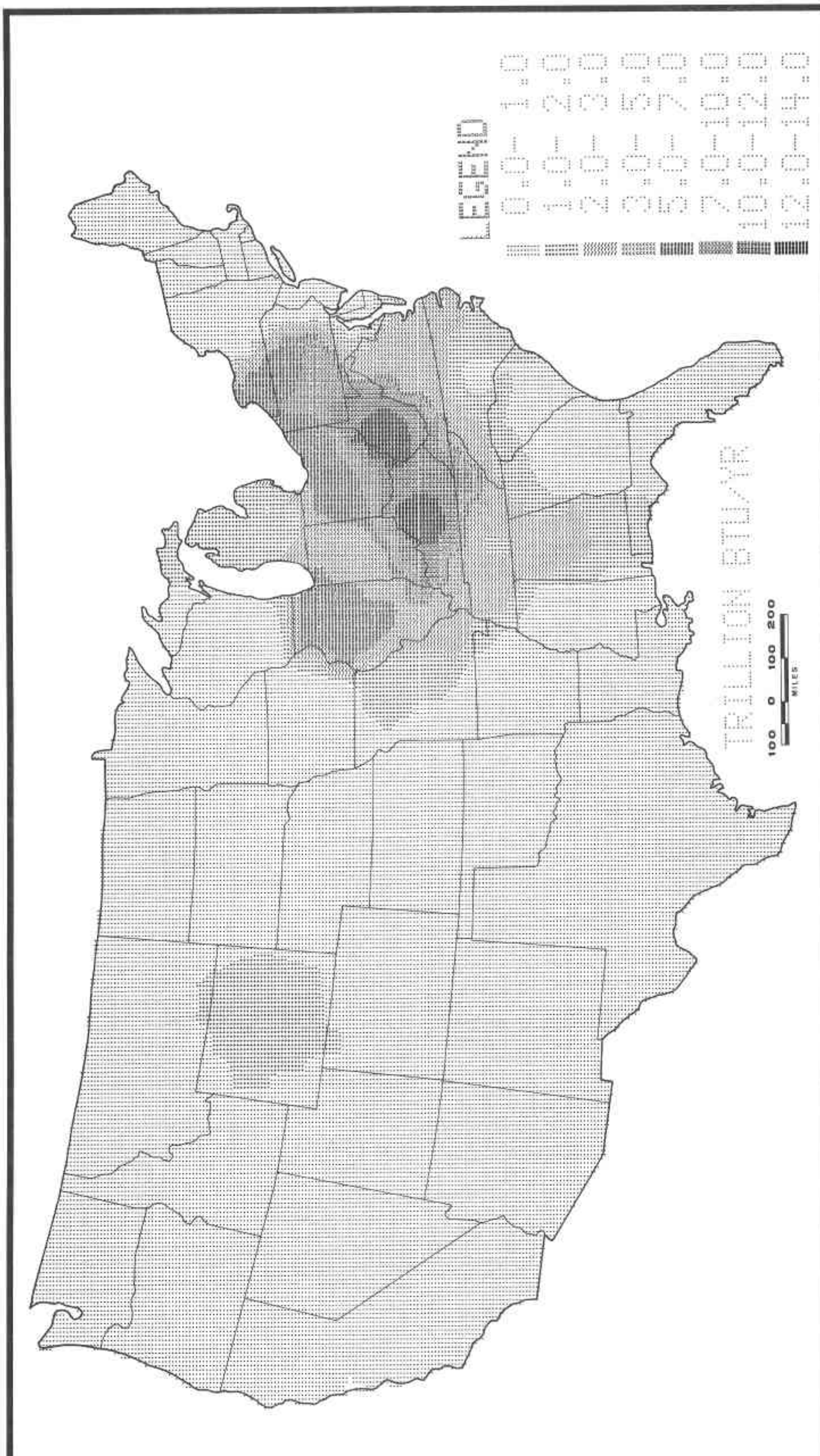
MAP 17 — REGIONAL ENERGY DEMANDS FOR TEMPERATURES 100°C TO 177°C



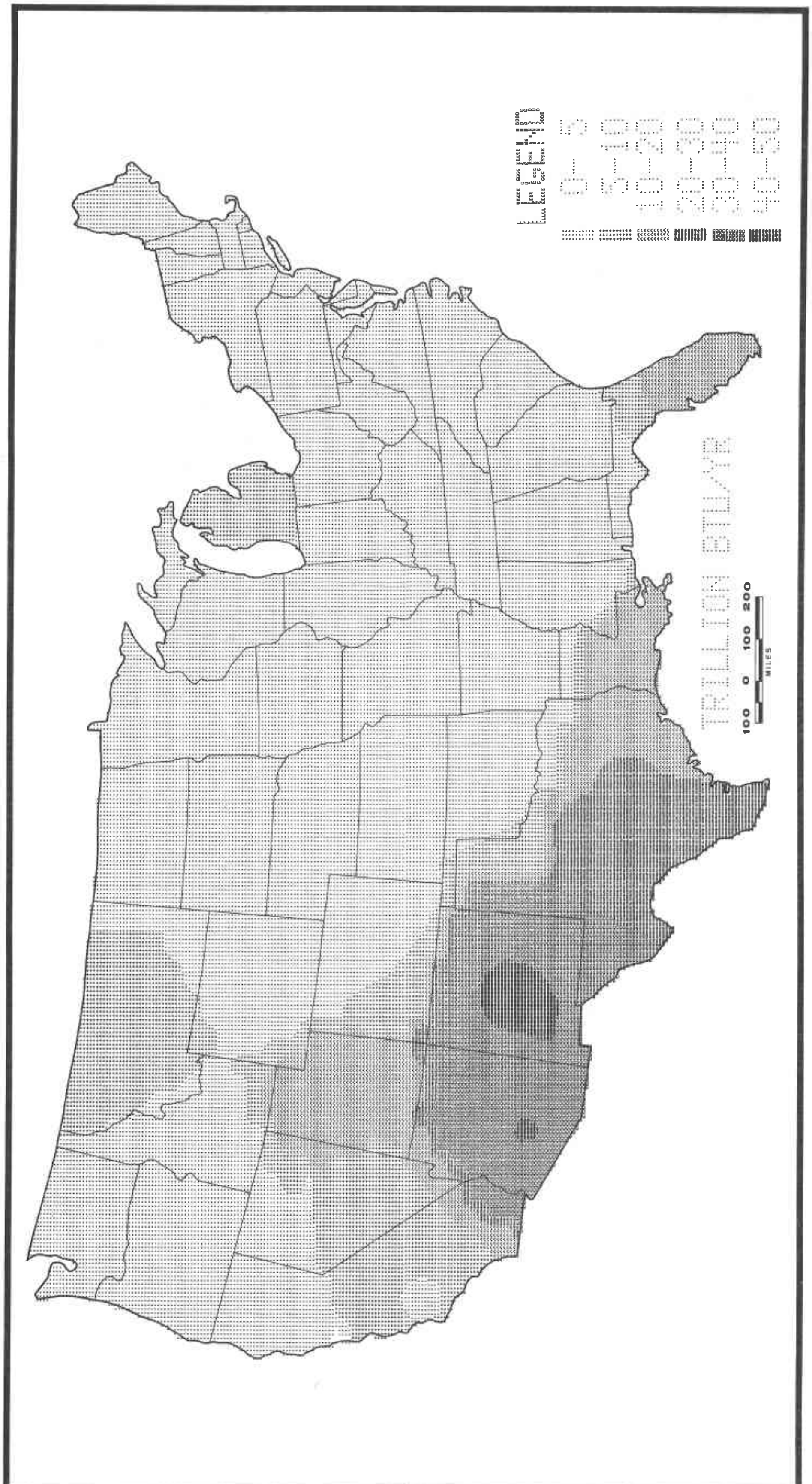
MAP 18 — REGIONAL ENERGY DEMANDS FOR TEMPERATURES 177°C TO 288°C



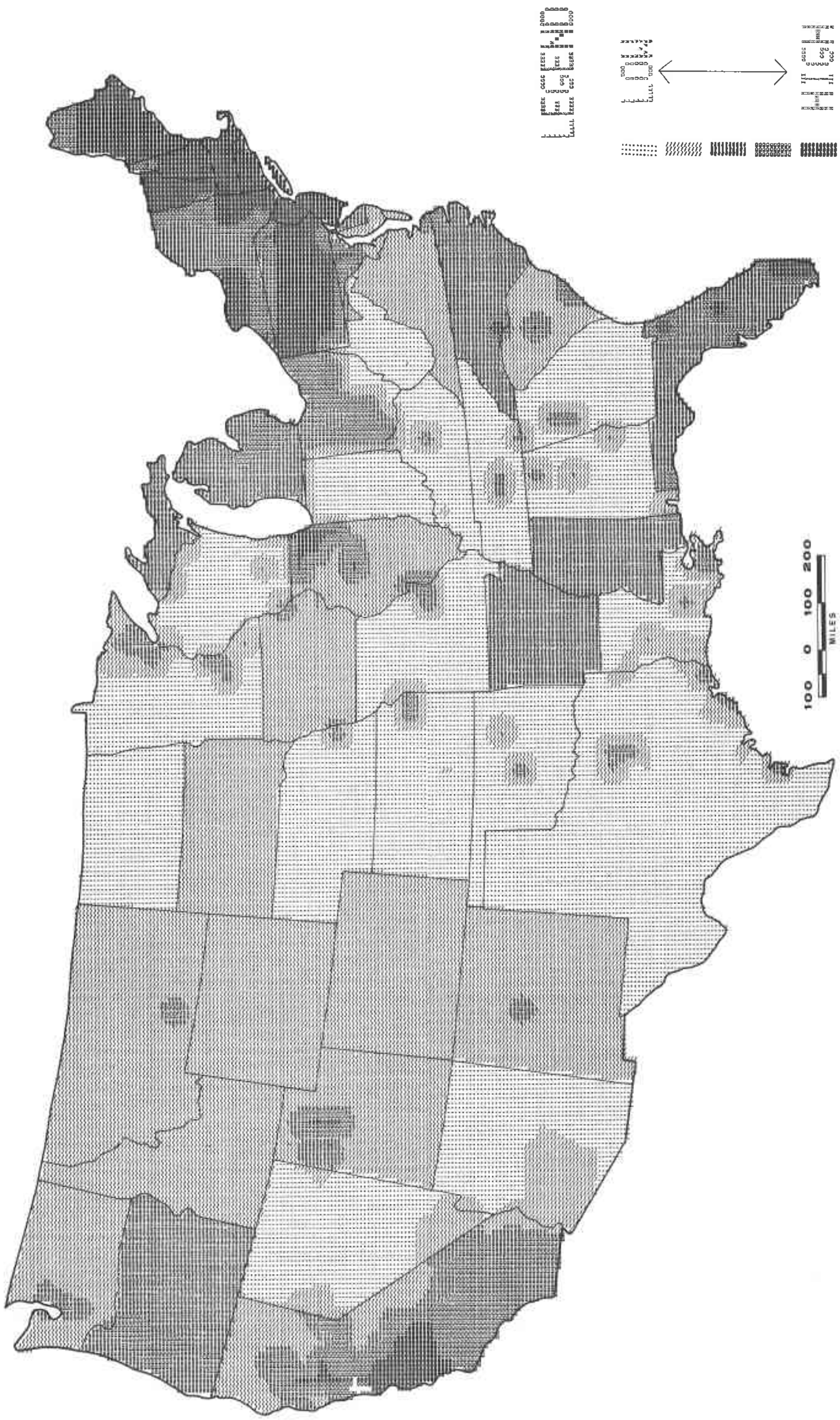
MAP 19 — REGIONAL GROWTH OF INDUSTRIAL ACTIVITY



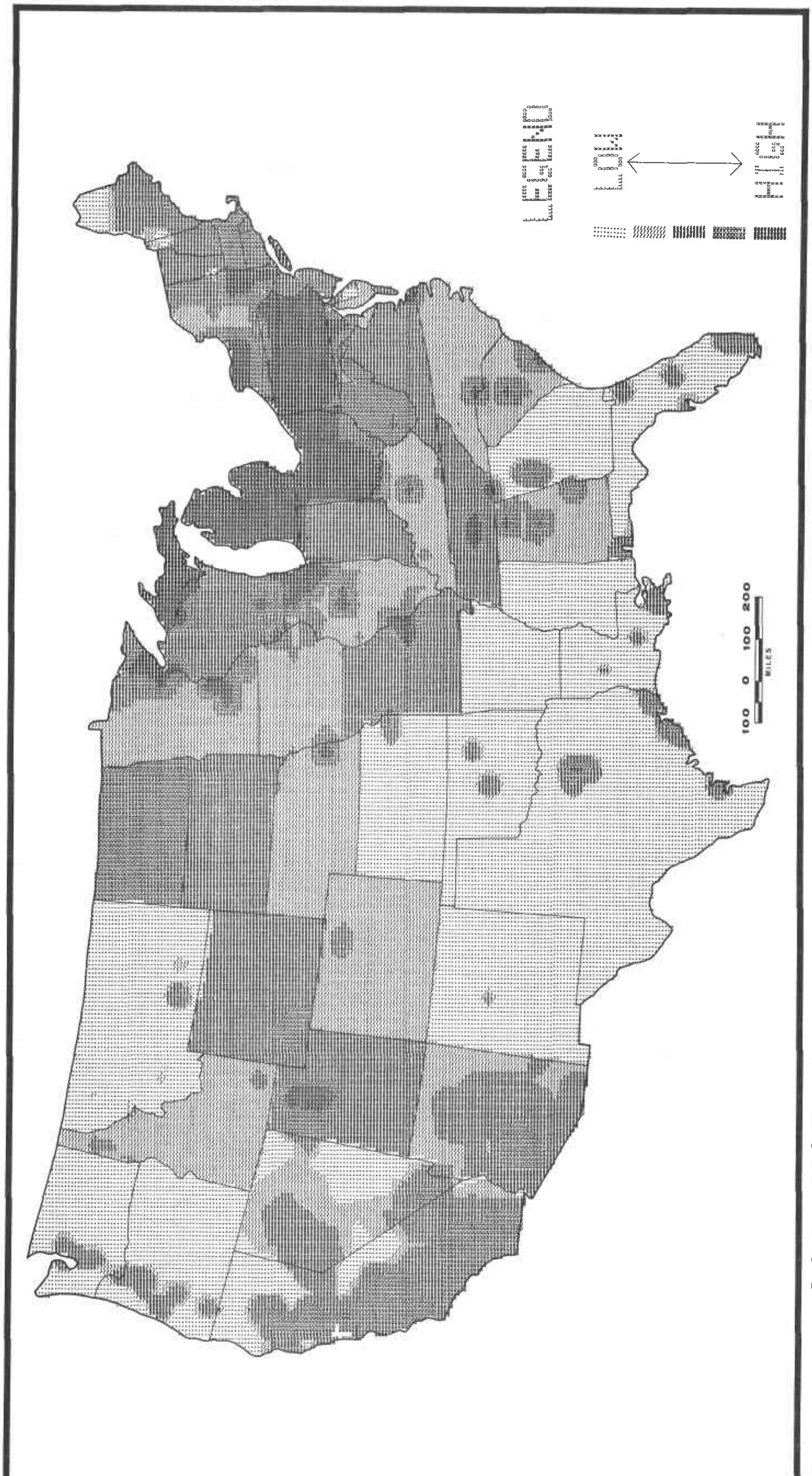
MAP 20 — ENERGY DEMAND BY THE BITUMINOUS COAL INDUSTRY



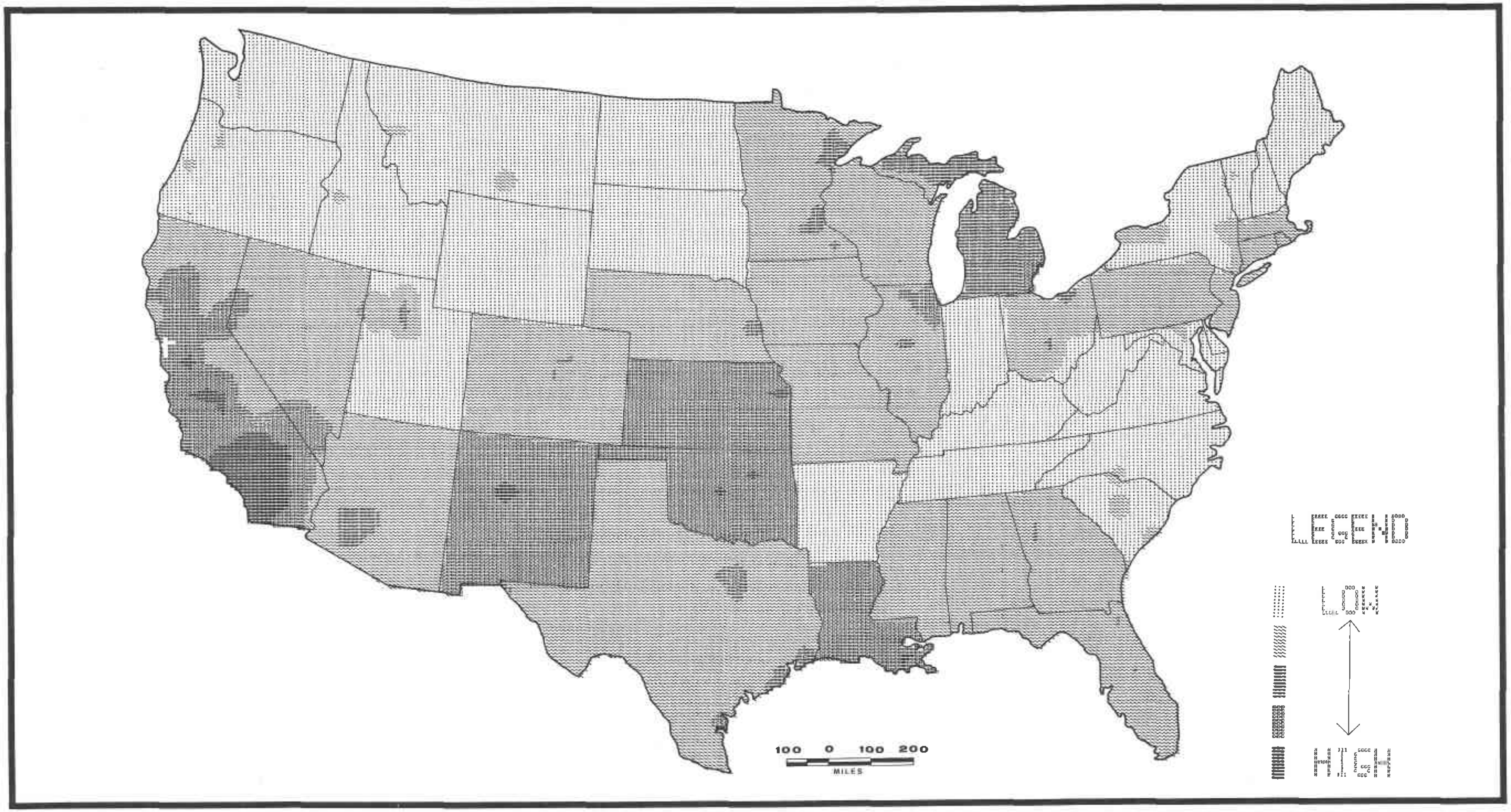
MAP 21 — ENERGY DEMAND BY THE COPPER, SULFUR, POTASH, AND PHOSPHATE INDUSTRIES



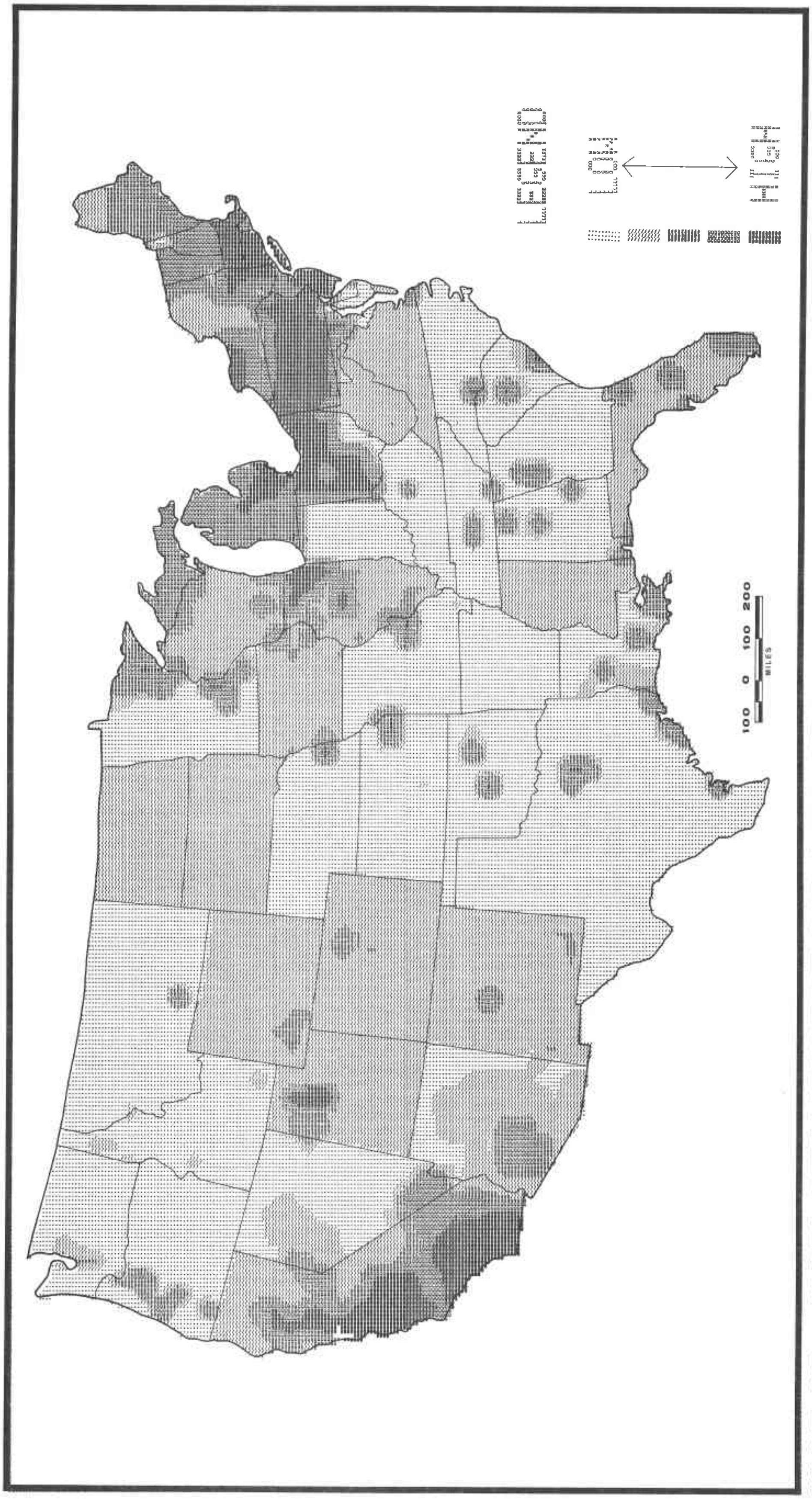
MAP 22 — OIL USE NON-ATTAINMENT CONSTRAINT RATINGS



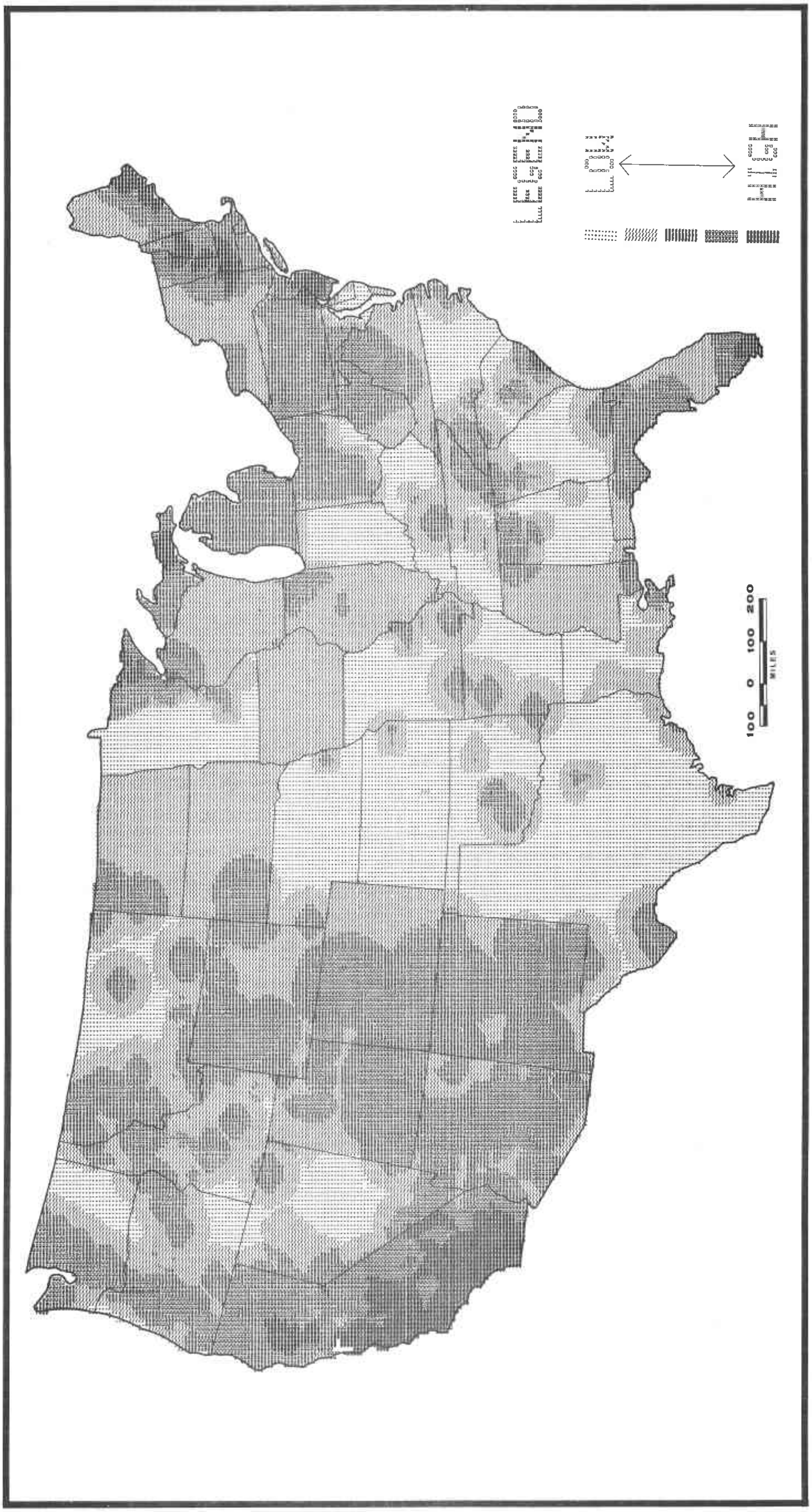
MAP 23 — COAL USE NON-ATTAINMENT CONSTRAINT RATINGS



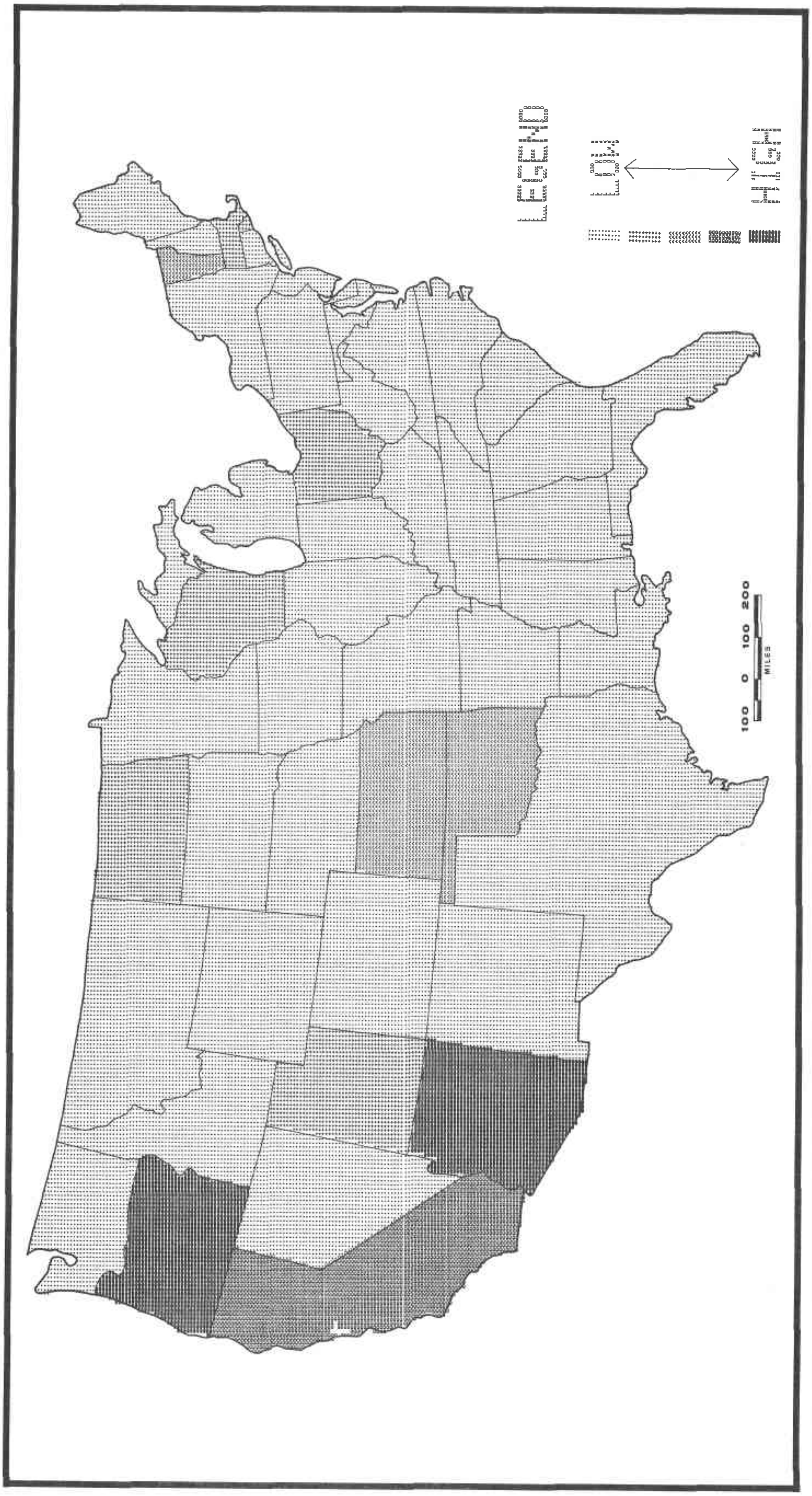
MAP 24 — NATURAL GAS USE NON-ATTAINMENT CONSTRAINT RATINGS



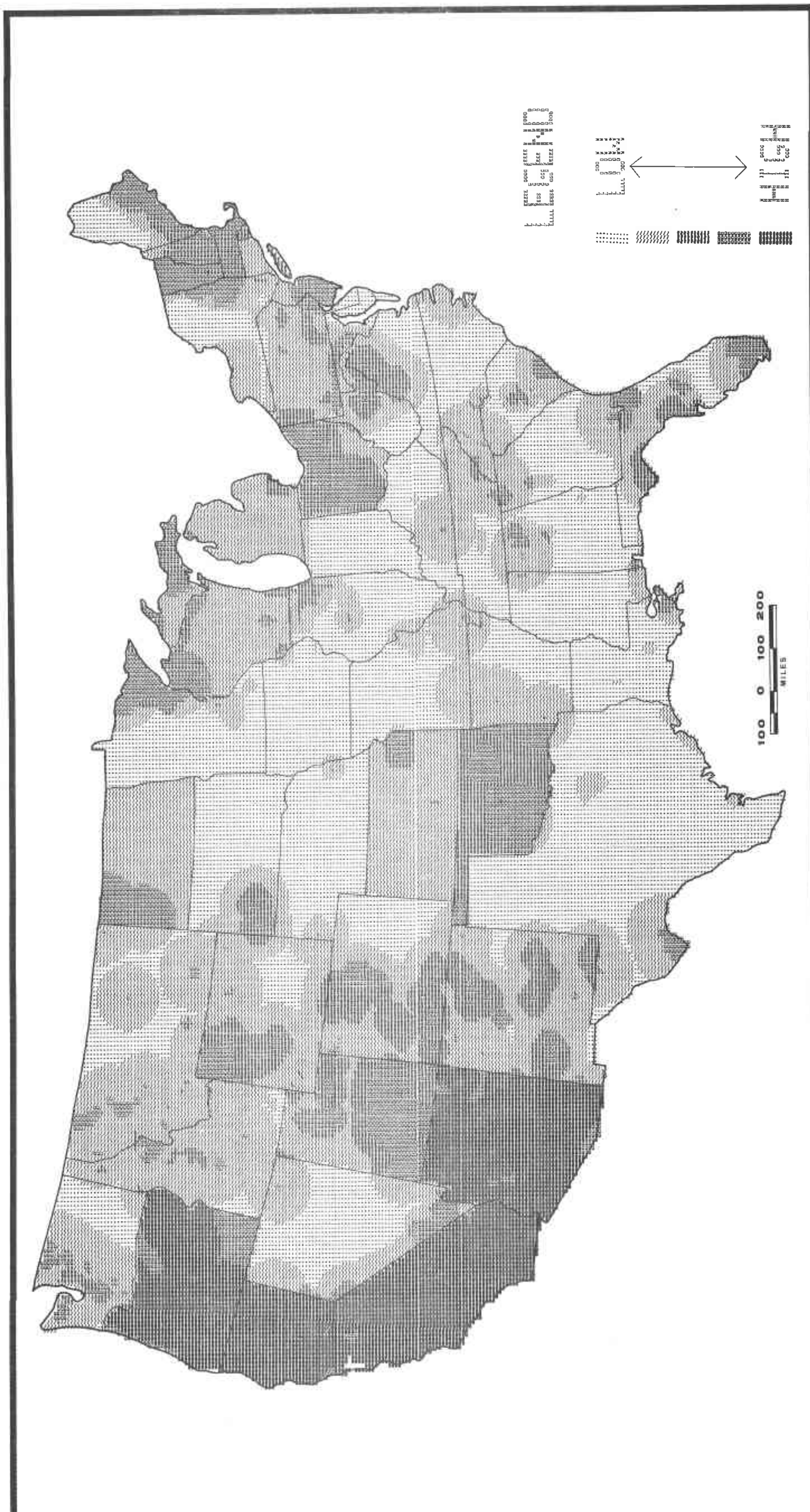
MAP 25 — NON-ATTAINMENT AIR QUALITY INCENTIVES FOR SOLAR IPH



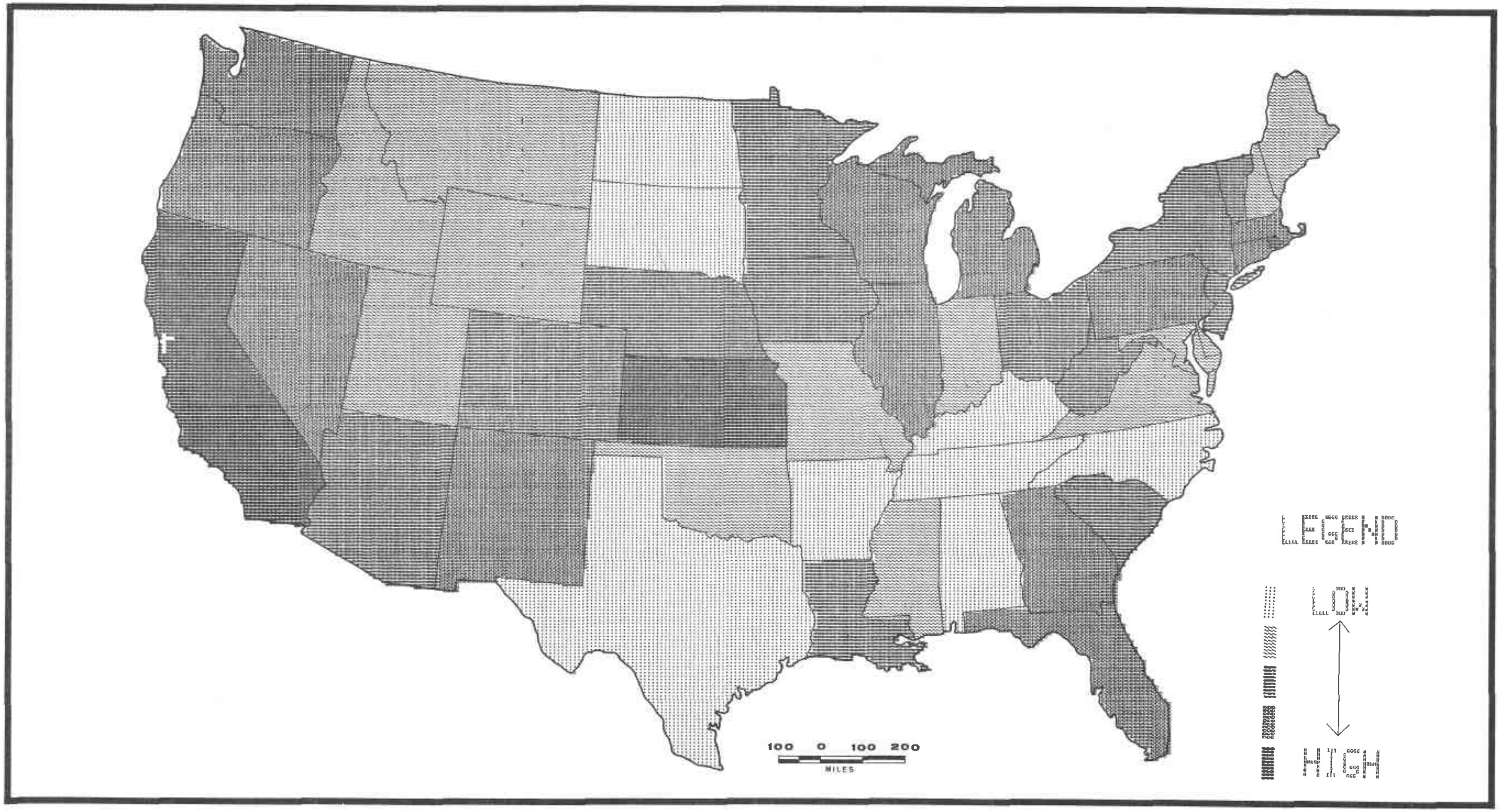
MAP 26 — COMBINED AIR QUALITY INCENTIVES FOR SOLAR IPH



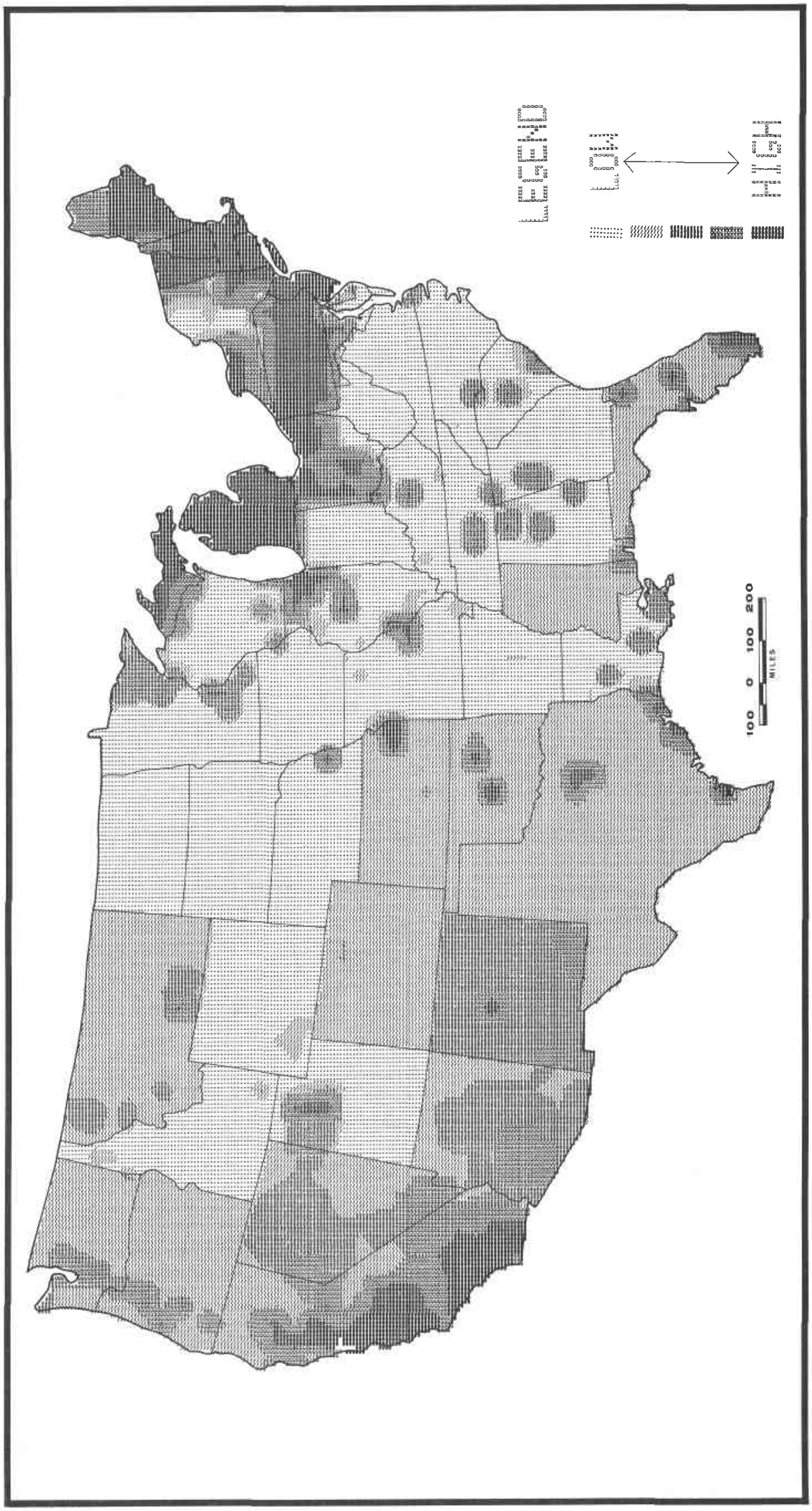
MAP 27 — COMBINED SOLAR TAX INCENTIVES



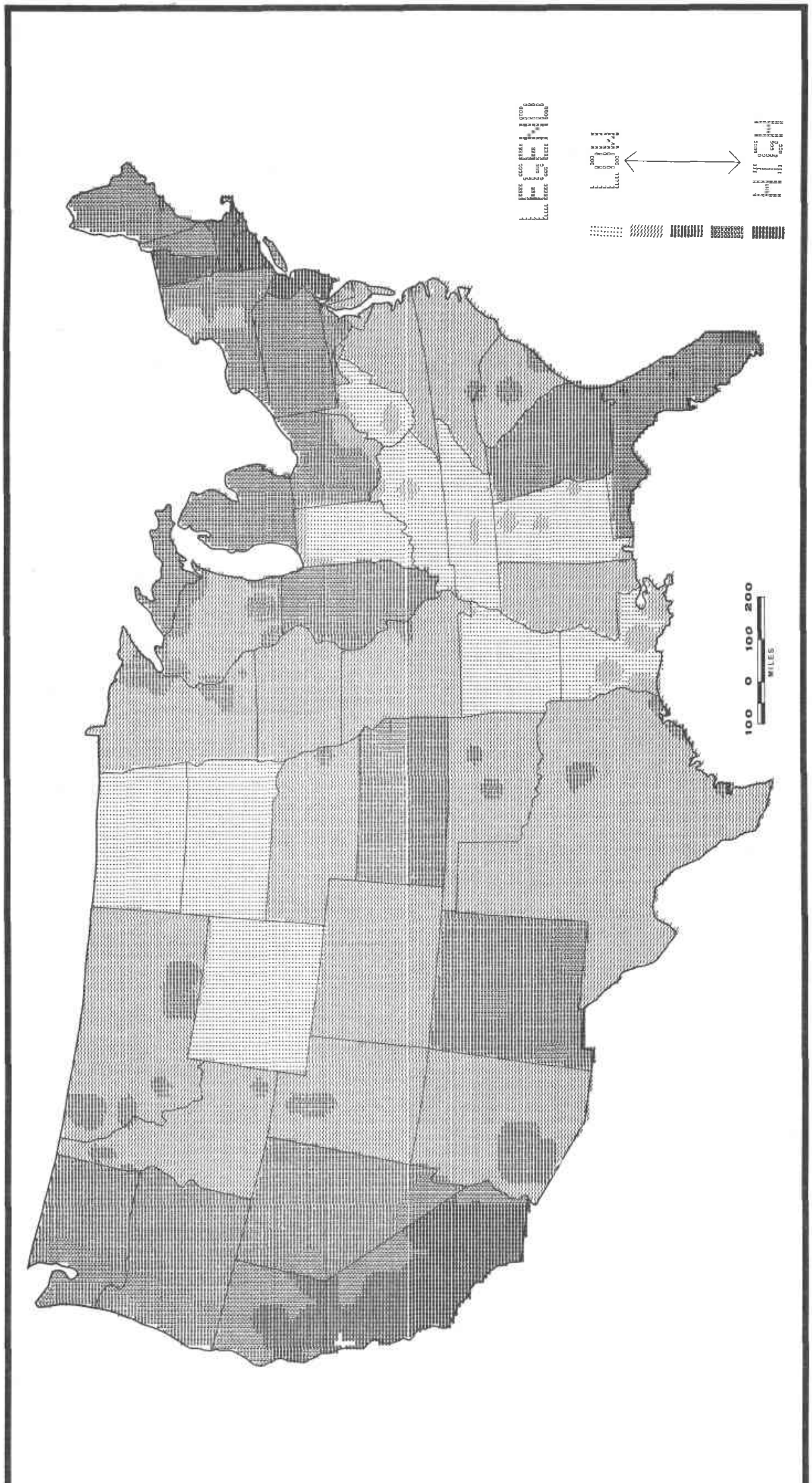
MAP 28 — ENVIRONMENTAL AND TAX INCENTIVES FOR SOLAR IPH



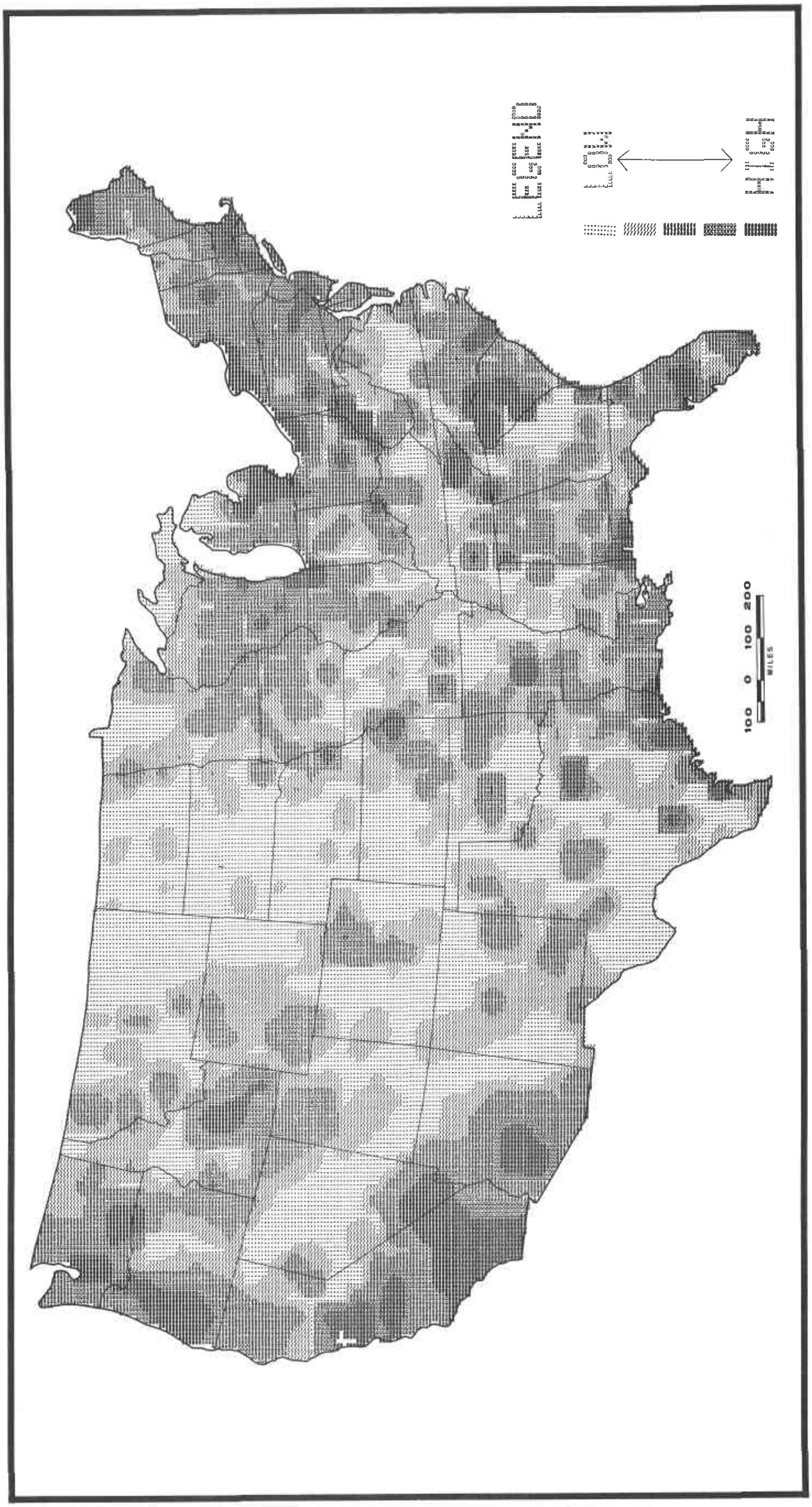
MAP 29 —AREAS WHERE INDUSTRY IS MOST DEPENDENT ON IMPORTED GAS



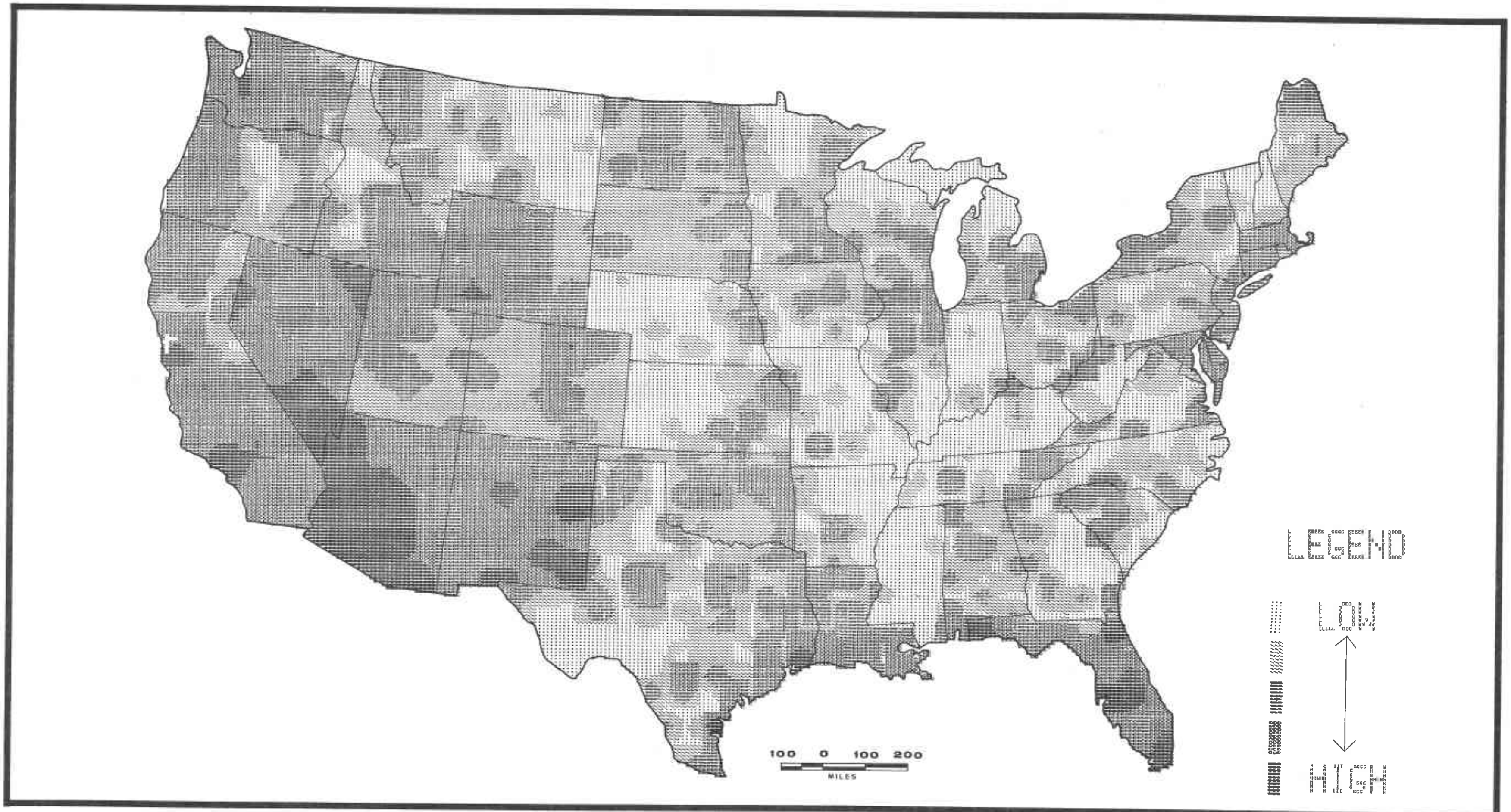
MAP 30 — AREAS OF UNLIKELY COAL USE



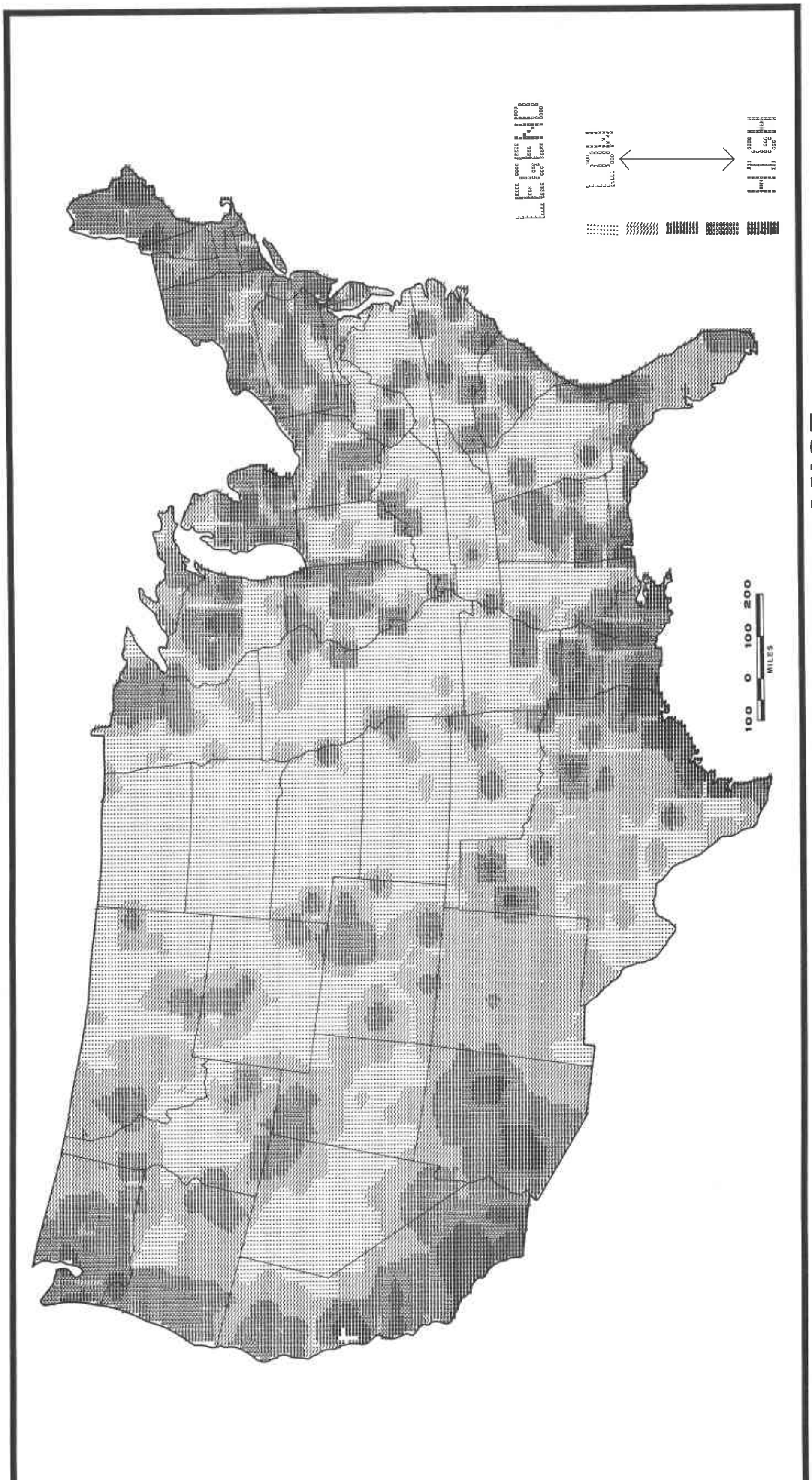
MAP 31 — FUEL INCENTIVES FOR SOLAR IPH



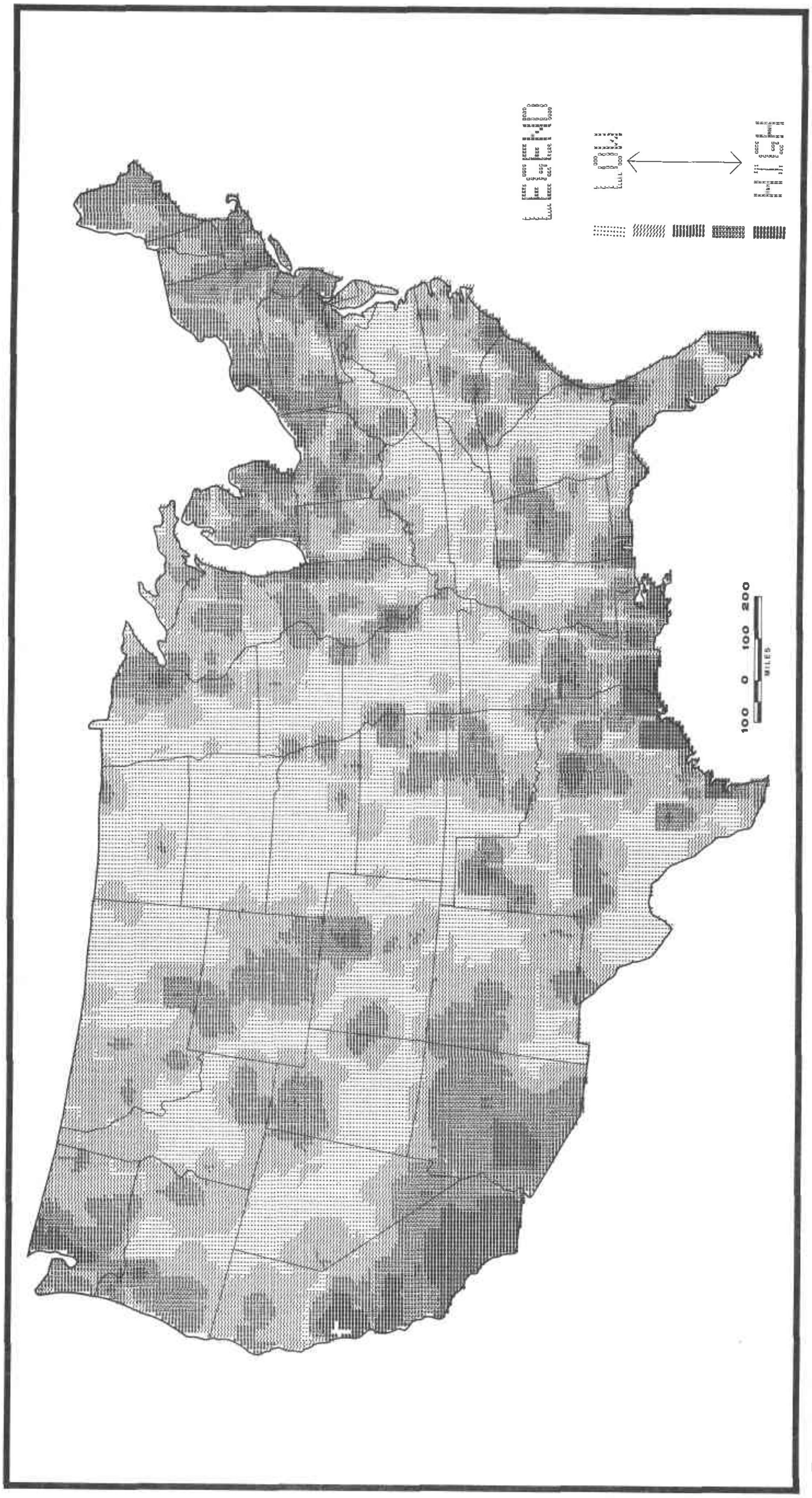
MAP 32 — LOW TEMPERATURE ENERGY DEMANDS



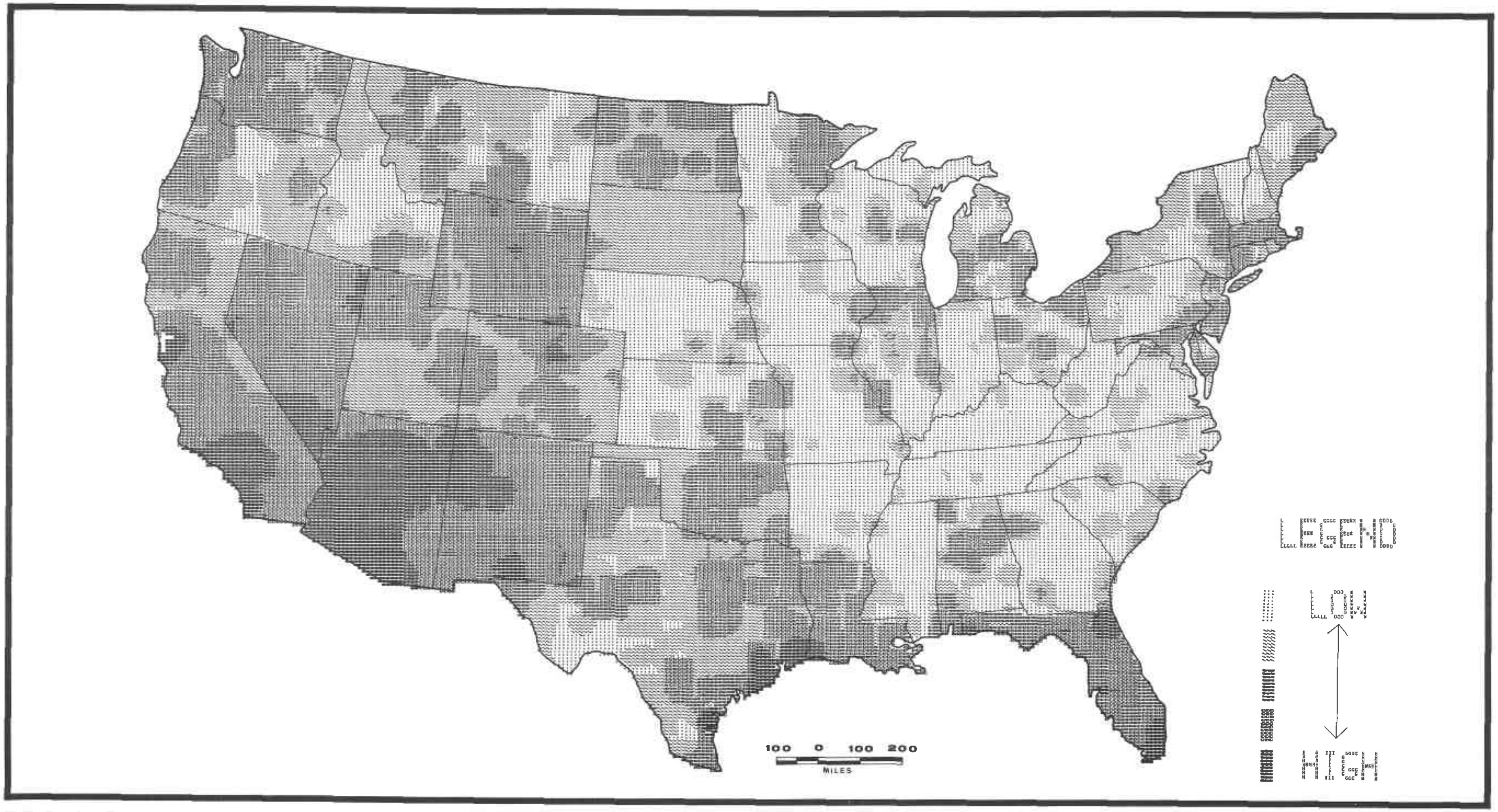
MAP 33 — LOW TEMPERATURE DEMAND-GROWTH MARKET AREAS



MAP 34 — ENERGY DEMANDS FOR 100°C TO 177°C RANGE



MAP 35 — ENERGY DEMANDS FOR 100°C TO 288°C RANGE



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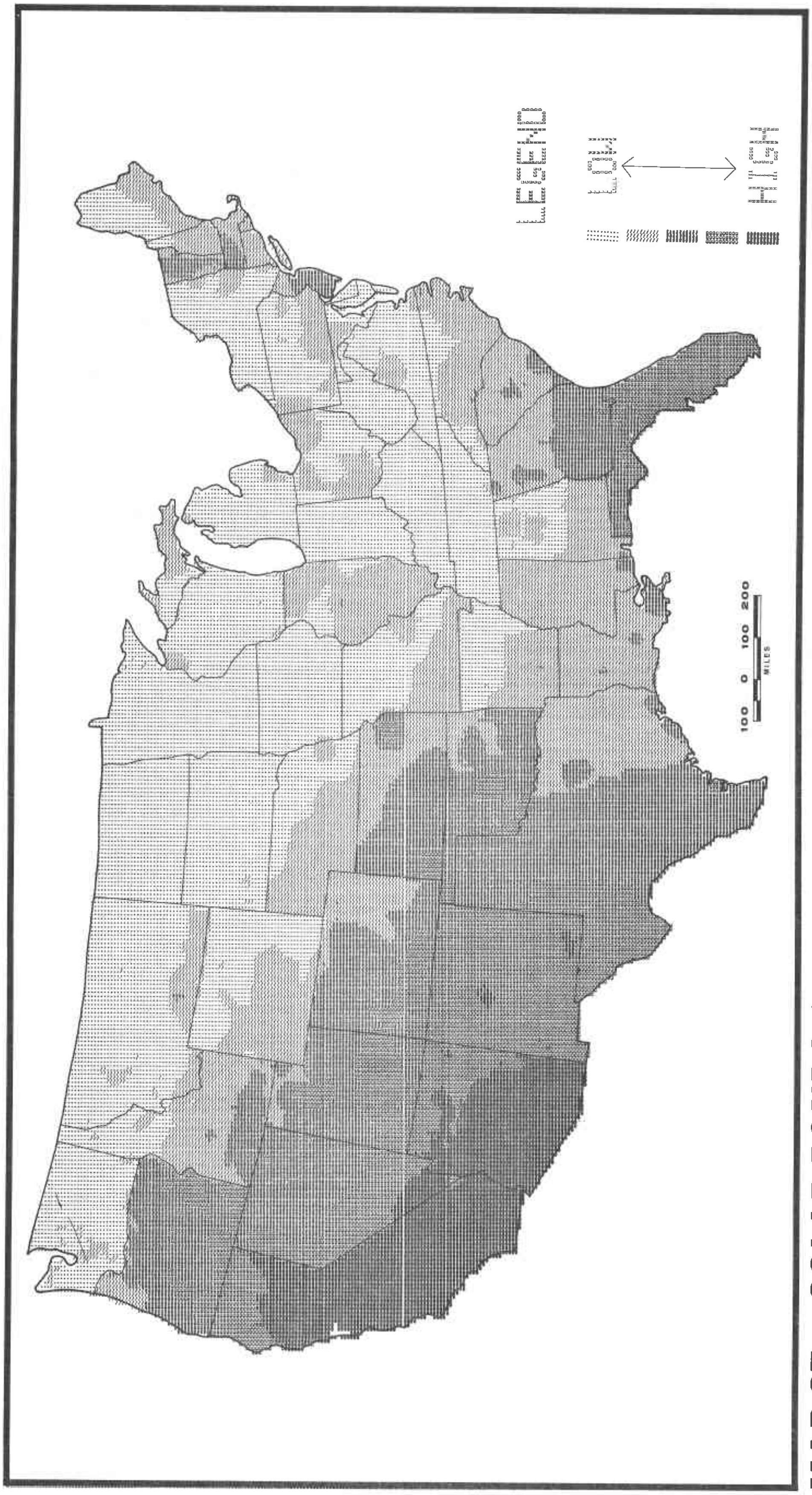
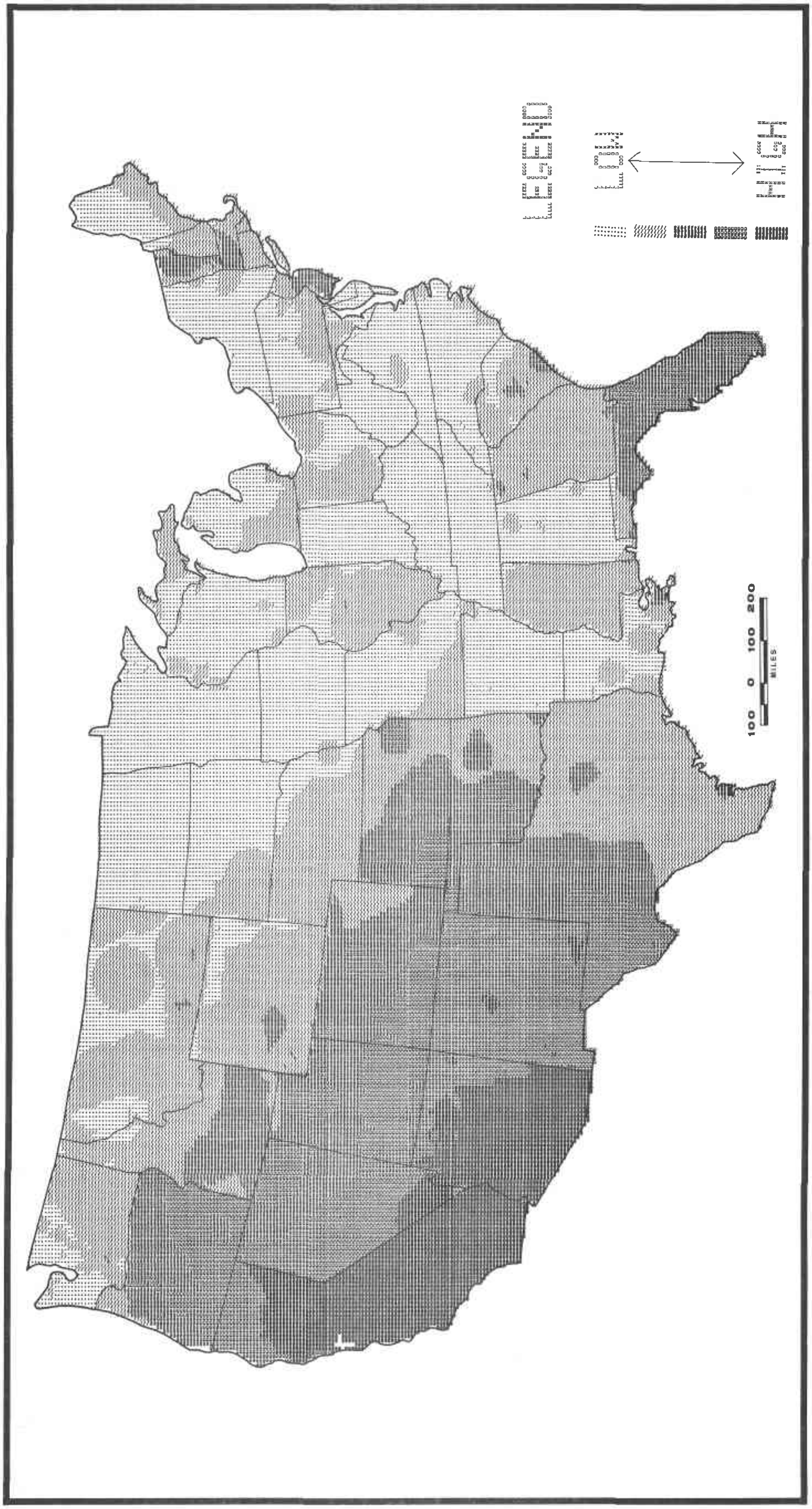
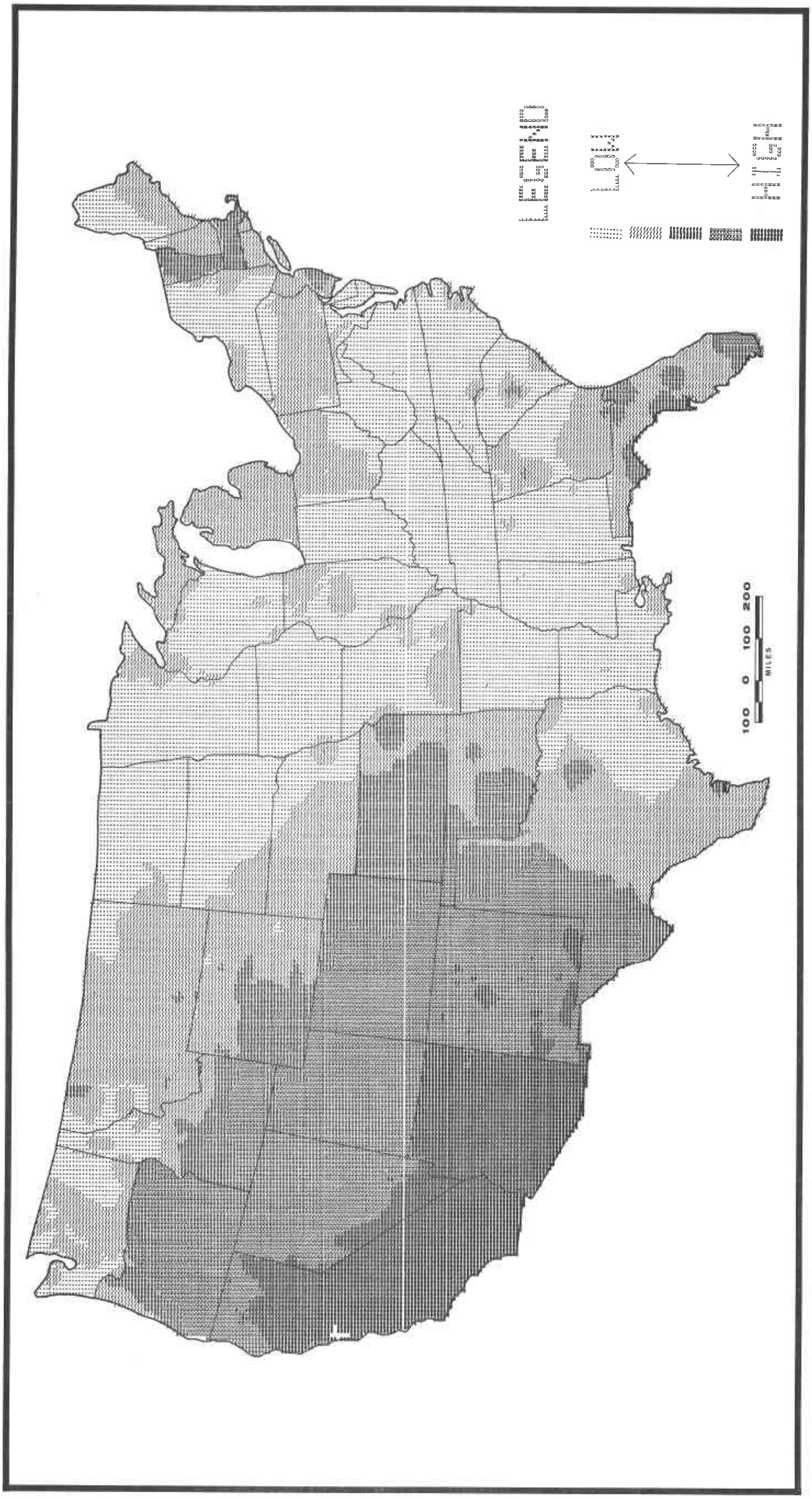


MAP 37 — SOLAR PONDS SOLAR ATTRACTIVENESS INDEX



MAP 38 — FLAT-PLATE SOLAR ATTRACTIVENESS INDEX



MAP 39 — PARABOLIC TROUGH SOLAR ATTRACTIVENESS INDEX

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16. Abstract (Limit: 200 words)
Previous studies of the industrial market for solar energy systems have considered the level of solar radiation as the main determinant of geographic markets in the U.S. This study evaluates geographical markets extensively based on such criteria as output of different types of low- and intermediate-temperature solar thermal collectors, air quality constraints for competitive fuels, state solar tax incentives, fuel costs, low industrial use of coal, high industrial growth areas, and industry energy consuption in different parts of the U.S. Market suitability analysis and mapping techniques, refined in the past 20 years by land use planners, were used to evaluate geographical markets. A computer-aided system, "Generalized Map Analysis Planning System" (GMAPS), performed interactive, cellular, computer mapping, and composite mapping. Results indicate that the U.S. Southwest and West are the most attractive geographical markets for solar IPH, based on an equal weighting of the evaluation criteria. The West North-Central and East South-Central regions appear to have the least attractive markets. Specific areas within states where solar IPH systems have distinct marketing advantages also are apparent from the composite maps. However, when different weights are assigned to the various criteria, the results change significantly for some regions of the country, such as the New England, Mid-Atlantic, and West South-Central 2 regions. The results of this work will become less valid in the future as state incentives for solar IPH, air quality regulations, and the status of competitive fuels all change. Volume I contains study results and maps; Volume II comprises the appendices to the study.

17. Document Analysis

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b. Identifiers/Open-Ended Terms

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