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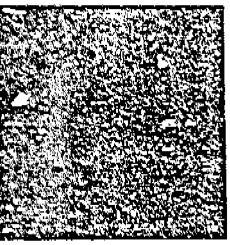

Proceedings: Strategic Benefits of Biomass and Waste Fuels

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Electric Power Research Institute
Palo Alto, California

MUNICIPAL SOLID WASTE EVALUATION: A GEOGRAPHIC INFORMATION SYSTEM MINI-STUDY

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Abstract

This study demonstrates the value of Geographic Information Systems (GIS) to the analysis of renewable energy industries. This work examines the potential uses of municipal solid waste (MSW) for energy purposes in the year 2000, specifically, MSW power and MSW ethanol. The geographic distribution of MSW and existing (and future) MSW combustion capacity were evaluated under several recycling scenarios. In addition, we estimated future capacity potential for both technologies. The impact of the planned growth of the MSW power industry between 1992 and 1995 and the effects of recycling efficiency improvements could significantly change the market for MSW between 1992 and the year 2000. Some of these changes include:

- reduced MSW flows to landfills
- higher competition for MSW between MSW power plants and waste management companies
- lower tipping fees and higher transportation costs
- potential closure of landfills and MSW power plants as a result of changing economic conditions
- limited growth potential for new MSW energy capacity in some regions
- economic opportunities for development of MSW ethanol and MSW power in some regions

Despite these changes, the United States could support between 12 and 80 million tons of new MSW power capacity or between 13 and 35 million tons of MSW ethanol capacity in the year 2000. Based on these results and other opportunities presented by GIS analysis, we have concluded that this GIS tool can greatly enrich the area of renewable energy assessment in the future.

Authors' note: all references to tons in this paper are for 2,000 pound units. To convert to tonnes, multiply by 0.907.

Introduction

The purpose of this work is to demonstrate how GIS enhances analysis. The MSW resource was selected for this study because it is an immediately available, renewable energy resource, and society has a strong desire to find an acceptable use for it to avoid mounting disposal costs and future environmental problems. This social need has manifested itself in attractive tipping fees that have been considered incentives for renewable technology development.

MSW-electric generation is a commercial technology. According to the Environmental Protection Agency (EPA), there are 184 MSW combustion facilities--147 that produce either electricity or steam and another 37 incinerators. Producing ethanol from cellulosic feedstocks is experimental at this time; however, there are two industrial firms working with the National Renewable Energy Laboratory (NREL) to bring this technology to commercial readiness in the near future. The cellulosic fraction of MSW--including paper, some types of packing, cardboard, yard wastes, and urban wood residue--has been proposed as a potential feedstock for initial facilities. The AMOCO CRADA with NREL focuses on this application.

This paper explores four areas in which GIS can expand traditional analysis:

1) Evaluating regional resource characteristics and factors that influence resource estimates
2) Exploring the relationship between the location of renewable energy resources and the projections of renewable energy technology development
3) Examining the impact of local incentives and barriers that can influence future locations of renewable energy developments
4) Evaluating the impact of renewable energy development on other markets, environmental impacts, and regional economic variables.

In addition to these areas, GIS-enhanced analysis opens up the possibility of performing regional analysis that can fortify national projections of renewable energy penetration rates, competitive advantages, environmental impacts, infrastructure requirements, and many other issues that analysts have long been aware of but unable to examine cost-effectively without the appropriate tools.

Background

Traditional analysis has taken a national perspective. Regional opportunities or barriers to development have been overlooked until now. In general, MSW power production has received greater interest than ethanol production from MSW. The common thread in all these analysis is that they start out estimating the resource base using Franklin Associates (EPA) data. They develop estimates of the quantity of the resource that could be used to supply power plants based on various methods of extrapolating historical growth patterns into the future. Differences in the resulting estimates of MSW power potential lie in one of two areas: estimates of per capita MSW generation and estimates of potential resource that can be captured. We are going to apply GIS to the question of how much of this resource can be captured.

According to the most recent Franklin reports, the United States generated 196 million tons of municipal solid waste in 1990; 31.9 million tons were combusted and another 34 million tons were recycled or composted (1). MSW generation is expected to increase to more than 222 million tons per year by 2000, of which only 46.2 million tons are expected to be combusted. Recycling is projected to increase from 17% today to 25% by 1995.

Franklin Associates' estimates of gross MSW generation are based on product-flow analysis. As a result of this particular methodology, these waste estimates are national in scope. They do not reflect regional characteristics such as climate, seasons, purchasing patterns, education, income, and wealth. Franklin Associates provides estimates on the quantity, volume, and types of municipal solid wastes generated, recycled, combusted, and sent to landfills in the United States. There are other site-specific studies on MSW generation or composition which provide wide ranges of estimates; due to their site-specific nature they are not generally appropriate for a national level study (2).

Recovery and recycling are not synonymous because some wastes are generated during the recycling processes that are not accounted for. Wastes from recycling processes are classified as industrial wastes and are not included in estimates of municipal wastes. In addition, some fraction of the material separated for recycling and removed from the waste stream is landfilled for lack of an economic market. Published estimates of this fraction are not available; however, the reader should bear in mind that more MSW may be available under some economic conditions than we accounted for here. In this report we will assume that recovery and recycling are equal.

The MSW stream examined by Franklin is a fraction, albeit a major fraction, of the material that is disposed of in landfills. Subtitle D of the Resource Conservation and Recovery Act deals with wastes other than hazardous wastes. It has been a common practice to dispose of nonhazardous industrial wastes, municipal sludge, automobile salvage wastes, and construction and demolition wastes along with MSW in some Subtitle D landfills. However, only MSW is covered in the Franklin reports. Future analysis of this type should attempt to include these other valuable resources for energy development.

The estimates of combustion demand used by Franklin are national estimates. We have used information provided by the EPA to locate MSW combusters to estimate regional combustion demand.

The EPA provided information on the number, type, location, and capacity of existing MSW combustion facilities (operational and nonoperational) and the planned facilities that are in the conceptual stage (operators have applied for permits, etc.), in the procurement stage, or under construction (3). This planned capacity is projected to be fully operational by 1995. In addition, this report provides information on energy recovery status; e.g., steam, steam/electric, electric, cogeneration, waste incineration, and refuse-derived fuel (RDF) production.

According to this report, there are 184 operating MSW combustors in the United States. The MSW combustion capacity is sufficient to handle 17.9% of the MSW produced in 1991. There were 147 MSW combustors that recover energy. Energy recovery facilities make up the majority of the combustion capacity--94% of the total or 102,755 tons per day. The Government Advisory Associates also list 147 MSW energy recovery facilities operating today in the United States. The operating energy recovery facilities have a combined maximum output of more than 17 million MWh of electricity per year (net energy).

New, more stringent air emission regulations are likely to lead to the closure of a number of older (especially nonenergy recovery) facilities. The 37 nonenergy recovery facilities (incinerators) have a combined capacity of 6,219 tons per day. Because the MSW demands of these facilities are small, their closure will not significantly affect the availability of MSW for future power generation.

Construction of new facilities has slowed recently; there are nine new plants presently under construction. Procurement is under way on 84 additional projects. By 1995, combustion capacity could account for over 30% of the MSW generated in this country, an increase from 40 million tons MSW capacity per year today to 87 million tons per year in 1995.

GIS-Enhanced Analysis

We divided Franklin Associates' estimates of MSW generation and recycling for 1990 and 2000 by United States population for the respective years to generate per capita estimates of MSW (1990 Census). We used the detailed MSW product categories rather than the broad categories to calucate ethanol and Btu conversion efficiencies. Each category of MSW product was examined separately; e.g., its generation per capita and its recycling efficiency.

To test the accuracy of the assumption that MSW per capita correctly projects regional MSW distribution, we examined the locations of existing MSW-combustion plants (Maps 1 and 2). The existing and planned MSW combustion facilities are generally located where high levels of MSW concentration are shown. Therefore, we have some evidence that this method is an acceptable way to estimate where MSW is located and that our projections of where MSW energy facilities could be located are reasonable. Obviously, more site-specific variables have an effect on the location of energy facilities and the distribution of MSW, but if there is a high coincidence between the two, we can assume that these differences probably do not affect the validity of the outcome of this research.

One consideration which is important for developers and which we did not test, is the assumption that MSW composition remains constant across the nation. We recognize that this assumption is probably inaccurate. If further studies of MSW are undertaken, we recommend examining equations that disaggregate the nation by climate, income, and other parameters that affect MSW composition. The problem likely to be encountered is the lack of data. There is very little information available on the types of wastes discarded based on income, climate, industrial activities, and sociological factors. For this reason, this issue has not been resolved in this study, and MSW composition is assumed to be fixed.

The most likely form of bias that could arise from assuming a fixed MSW composition is one of under- or over-estimating the energy output (ethanol or kWh) from MSW energy facilities. Conversion efficiency is a function of either the Btu value of the material or its cellulosic content; therefore, when the composition of MSW changes energy output can change. Sorting and disposal costs will also vary with composition. The effects of various scenarios should be examined at a later date.

For the purposes of this study, we are assuming that all 168 power plants in the planning stages in 1992 are fully operational by 2000. This will increase MSW-power capacity from 4.4 GWe to 10 GWe. Some planned facilities have been recently cancelled, therefore, 168 facilities may not be an accurate figure. Since other facilities could take their place between now and 2000, we feel that this is a reasonable estimate of new capacity additions by 2000. In fact, since it does not include any other capacity additions that could be developed in the intervening years, this estimate may be low. We are also assuming that all MSW power facilities operate at 80% capacity. This assumption is consistent with the assumption used in Franklin Associates' report.

The MSW left over after accounting for composting, recycling, and existing combustion demand is available to support new (e.g., not currently planned) energy facilities. In this work, the combustion demand for MSW is determined by the size of the facility and the capacity factor. We have used the EPA database to locate facilities and represent their capacity as local demands for MSW. Available MSW, net of composting and recycling, is assumed to be directed to the combustion facilities located in the same county. If not enough MSW is available in that county, the county is crosshatched (on maps) and MSW is imported from neighboring counties until combustion demand is met.

We have examined two scenarios for 2000, one in which the recycling efficiency increases from 17% today to 25% by 2000, and one in which the recycling efficiency increases to 50% in the year 2000. We based our projections of recycling efficiency by product from Franklin Associates' projections for recycling by broad categories of products under a scenario for 25% recycling efficiency; however, they did not have a similar scenario for 50% recycling efficiency for the year 2000. We used Franklin Associates' estimates of gross MSW generation by product category for 2000 and multiplied these values by various recycling efficiencies. The maximum recycling efficiency for any product was assumed to be 80%, except for lead-acid batteries, which we assumed were removed from the municipal waste stream through regulation.

Maps 3, 4, and 5 show the differences between gross MSW generation, MSW generation net of recycling and composting, and MSW generation net of composting, recycling, and combustion for 2000 assuming a 25% recycling efficiency. Maps 6 and 7 show the effects of a 50% recycling on available MSW supplies before accounting for combustion demand and after accounting for combustion demand.

Note that the supply of MSW in 2000 is regionally distributed and concentrated in California, Texas, and the Northeastern states (Map 3). The regional location of MSW has implications for analysts who may examine local incentives or barriers that will affect future development of MSW electric or ethanol facilities, or enhance competing uses for MSW such as reycling and pulp demand. This information also indicates where facilities may be concentrated regionally, and may have implications for wheeling or transportation studies.

The most important observation is that areas that may generate large amounts of MSW may not have enough MSW available to support a new energy facility once the diversions from the waste stream have been accounted for. Maps 5 and 7 show large crosshatched areas in the Northeast and other parts of the nation. The difference between the two scenarios is the impact of recycling efficiency on MSW supplies available for energy.

The crosshatched areas cannot support any new energy facilities after the currently planned capacity comes on-line because the MSW demand for combustion is draining the supply of MSW from the surrounding area. If the MSW demand for combustion in one county exceeds the supply in that county, MSW is imported from neighboring counties until the demand is met. *The implication is that all of the MSW produced in the crosshatched areas will be delivered to combustion facilities.* This implication introduces the need to examine the relationship between MSW supplies, waste management companies that operate landfills, and MSW combustion firms.

Is it likely that all MSW produced will be delivered to MSW combustion firms, leaving only the noncombustibles and residues for landfills? How are tipping fees determined and how will this competitive environment affect tipping fees? What are the financial implications for waste management companies and MSW power producers? How will these issues affect the development of the MSW power industry? These questions deserve more attention than a brief research project was designed to provide. We recommend a future study to explore these issues more thoroughly; however, some of the implications are examined here briefly to invite debate and provoke some thought.

Competition for the limited MSW resource will increase in some regions as the projected MSW-combustion companies come on-line between 1992 and 2000. Most MSW combustion firms have to secure long-term contracts for MSW supplies as a requirement to be met prior to obtaining financing and permits. Therefore, we can assume that the MSW power facilities currently in the planning stage today will capture a fraction of the MSW that is currently going to landfills (or would have gone to landfills in the year 2000 in their absence) through long-term contracts.

Between increased MSW combustion demand and recycling efficiency, the flow of MSW to landfills will decline in some regions. The MSW-combustion facilities will produce wastes that will need to be landfilled--noncombustibles from sorting and ash. This stream represents 30% to 50% of the original MSW level. Thus, the flows to landfills may become 30% to 50% of the potential stream in the crosshatched areas in Maps 5 and 7. The composition of the material changes as well, which could have future environmental implications.

A tipping fee can be charged to any person or firm that delivers MSW to the gate of a facility that will dispose of it; this includes MSW combustors and landfills. The tipping fee charged at the gate may not bear any direct relation to disposal costs. Rather, the tipping fee may reflect what the current market will bear, long-term contractual agreements, and other complex multi-firm arrangements. Most MSW is disposed of under long-term contracts that define the tipping fee in advance; this type of tipping fee is not responsive to market conditions. Many firms and municipalities that are responsible for collecting or transporting MSW have long-term contracts with landfills and MSW power facilities.

In this study, we do not attempt to estimate the change in tipping fees caused by the development of the planned MSW power capacity, but recognize the underlying factors that could depress tipping fees. Basic management theory dictates that landfill operators require a minimum revenue stream that covers fixed and operating expenses (e.g., average costs). Revenue is a function of the amount of MSW received and the tipping fee charged at the gate, although revenue can also be generated through other types of fixed fees and licenses.

As the supply of MSW delivered to waste managment companies declines, revenues will fall if tipping fees remain constant under fixed contracts. Depending on the initial level of tipping fees, revenues could fall considerably before they approach the minimum level required to cover costs. If the waste management operators need to maintain a stable cashflow, they will be under pressure to reduce their tipping fees to attract more MSW.

There will be an incentive for waste management companies to "discount" their contracted tipping fees and their gate spot fees. A lower tipping fee will appear attractive to firms disposing MSW and thus attract more MSW. If the supply of MSW is elastic, then a 1% drop in tipping fees will produce more than a 1% increase in MSW deliveries, sufficient to maintain a stable flow of revenue or cashflow.

Recently the Eastern municipal waste industry and waste industry operators have revealed that the MSW industry is subject to the same competitive influences that other industries experience. The recession and continuing slow economic growth have affected consumers' spending patterns; these consumers have been purchasing fewer goods and producing less MSW. The drop in local MSW supplies has caused landfill operators to reduce their tipping fees in an effort to compete for a shrinking pool of MSW. These dynamics support our projection that competition for MSW will cause tipping fees to fall and that the elasticity of MSW supply is greater than one in these regions.

Declining MSW supplies and tipping fees could contribute to the closure of landfills in selected areas. The current threat of landfill closures along the Eastern Seaboard is a result of declining landfill capacity. If the flow of material declines, some landfills could last longer. With less MSW to dispose of, fewer landfills will be needed; this could render the threat of closures moot in some areas. A GIS could be used to evaluate this phenomenon in a more detailed study.

Depressed tipping fees and MSW supplies have implications for future energy developments using MSW feedstocks. Tipping fees are attractive incentives for energy developers, providing a secondary revenue stream to augment energy sales, thereby subsidizing the costs of producing energy. If tipping fees fall, the cost of the energy produced from MSW will increase. Long-term contracts will provide scant protection if the general level of tipping fees fall. A similar phenomenon occurred in the natural gas industry in the 1980s.

MSW will need to be transported from more distant areas to support existing and planned MSW power facilities (compare the locations of existing and planned MSW-combustion facilities in Maps 1 and 2 to the crosshatched areas in Maps 5 and 7). This will cause transportation costs to rise, further eroding the economics of MSW power.

If MSW power is sold under long-term contracts or under contracts which tie the price of energy to local avoided costs, there is a limited opportunity to pass along any increase in cost to the utility or grid. These cost increases may be borne by the investors. A decline in the financial incentives for MSW power production may dampen industrial development. In addition, it will be difficult to pass back these costs to producers of MSW through higher tipping fees, as the general competitive market for MSW will force MSW combusters to keep prices low to ensure an adequate flow of MSW.

To summarize, in a large part of the Northeast and other parts of the country, the development of currently planned MSW power capacity can cause tipping fees to fall, reduce the flow of MSW to landfills, increase the competitive market for MSW, and require MSW to be transported longer distances to fulfill MSW power capacity requirements. These are significant changes compared to the currently situation in the Northeast, where declining landfill capacity and MSW disposal are important local concerns. These results may have significant policy implications that need to be examined in a detailed study.

Moving away from the market issues, we turn to the process of examining how much growth in MSW power capacity is possible (abstracting from the issue of economic viability). Using the information provided in Maps 5 and 7, we developed estimates of where MSW electric and ethanol facilities can be located.

According to NREL Biofuels researchers, 50 million gallons per year is a minimum size facility based on economies of scale in ethanol conversion. This is the capacity used in this report. There have been discussions about the economic viability of smaller facilities but no consensus has been announced yet. Larger facilities reduce the average cost of ethanol produced because capital costs increase at a slower rate than output.

By 2000, an ethanol plant would need 4,650 tons per day (tpd) to produce 50 million gallons per year in the 25% recycling efficiency scenario, increasing to 5,280 tpd in the 50% scenario. This increase is caused by the decline in organic fractions of MSW caused by recycling. MSW combustion facilities were not similarly affected by the changing composition of MSW because plastics recycling has been constrained by the lack of economic incentives. The energy content of MSW slightly increased because a higher fraction of plastics will remain in the waste stream after recycling. Therefore, we examined sites where a 500 tpd MSW power plant (roughly a 15 MWe capacity) could be constructed.

The potential new sites represent locations where enough MSW is generated, after composting, recycling, and existing combustion demands are met, to support new MSW power facilities and MSW ethanol plants. A 30-mile area for MSW power plants and a 50-mile area for MSW ethanol plants were assumed. The larger area for ethanol production was assumed to accommodate the larger feedstock requirements.

The number of potential new facilities that could be supported by MSW supplies that are not dedicated to other uses (recycling, composting, and combustion) declines over time because of increases in recycling efficiency and the impact of combustion capacity in the planning stages today (Table 1). This information is displayed geographically in Maps 8, 9, 10, and 11.

Table 1. New Capacity Projections Using GIS-Enhanced Analysis

Scenario	Ethanol		MSW-Electric	
	Number new facilities (50 mil/gal)	Total new capacity (mil tons)	Number of new facilities (500 tpd)	Total new capacity (mil tons)
1990	51	84	504	116
2000 w/ 25% recycling	20	35	364	79
2000 w/ 50% recycling	7	13	136	34

Part of the reason that the number of potential new energy sites declines between 1990 and 2000 is the impact made by MSW power facilities in the planning stages today. All 168 of these facilities (total capacity of 47 million tons MSW) are assumed to be operational by 2000. The total existing MSW combustion capacity in 2000 is 87.5 million tons per year, with another 79 million tons possible if recycling rates remain low, and only 34 million tons additional capacity if recycling rates are high. Cautious investors may choose to site facilities only where they could be viable under either condition, which could constrain industrial growth to the lower of the two values.

A large proportion of the future MSW power potential is located in California where strict air quality regulations and environmental concerns have prevented any significant development of MSW combustion capacity to date. If this trend continues, the new capacity in California should be subtracted from the total new potential. California could support 48 sites with a combined capacity of 21.7 million tons of MSW. The adjusted U.S. potential could fall to 57 million tons in 2000 for the 25% recycling case and fall to only 12 million tons in the 50% recycling case. Several Eastern states have enacted or are considering enacting legislation to prevent the construction of future MSW combustion facilities. Had this analysis shown potential sites in these states, we could choose to eliminate them on this basis.

The difference between ethanol and MSW-electric capacity potential is the result of the scale of the facilities and feedstock requirements. Because the feedstock requirements for ethanol plants exceed 4500 tpd in 2000, there are very few sites available. If any MSW power facilities are constructed in these areas between 1990 and 2000, fewer sites could be available than indicated here. However, once again, most of these sites are in California, and it is unlikely that California will significantly increase its MSW power capacity in this time frame. Therefore, California may be a promising state for exploring the siting potential for MSW ethanol plants. A second benefit of locating ethanol production in California is that the same air quality regulations that retard MSW combustion capacity encourage the use of oxygenated fuels for transportation. California regulations also require the sale and use of alternative fueled vehicles, such as ethanol vehicles, that could be operated on dedicated ethanol fuel supplies.

Similarly, we could show where ethanol incentives could reduce production costs or where tipping fees are high enough to cover sorting costs (and costs of landfilling non-organic materials). In the same manner, we could show where regional demand for new electric capacity was projected. We could add information on the avoided costs offered in selected utility areas. This information could be used to assess commercial development potential, regional penetration rates, transportation costs, transmission costs, and other issues that have long eluded the analyst. With access to regionally defined data and the models to manipulate them, we could develop sound rationales for regional renewable energy development.

Summary

This report is intended as an exercise to show how GIS can expand the depth of traditional analysis. The ability to consider regional factors, such as state regulations, resource distribution, power demand, regional market prices, and infrastructure provides the analyst with a level of detail that has not been easy to accommodate in the past. This analysis demonstrates the value of GIS as an analytic tool. We believe that this tool will benefit future renewable energy studies.

This analysis also provides a number of interesting insights concerning the potential opportunities and barriers facing MSW combustion and ethanol production, in addition to insights concerning the MSW market and possible environmental and financial implications of MSW combustion development.

- Population location and population density were adequate indicators of where MSW is generated in the United States. The locations of potential energy sites that were projected based on this assumption corresponded to the locations of existing energy sites and energy sites in the planning process.

- If MSW supplies remain static beyond 2000 as a result of waste minimization technologies at the source, recycling, and composting, future MSW power capacity could expand by 34 and 79 million tons per year in addition to the existing and planned capacity (87 million tons). If California continues to resist permitting MSW power facilities, then this potential capacity could be limited to 12 to 57 million tons per year.

- Similarly, there could be between seven and 20 sites available in 2000 for MSW ethanol production if MSW supplies at these sites are unaffected by MSW power demand, as is likely for the California sites.

- The competitive advantage that MSW power has over MSW ethanol is that MSW power is currently commercial. The number of MSW ethanol available sites outside of California could be reduced if any MSW power facilities are located at the same sites.

- The development of the planned MSW power capacity could depress tipping fees in the Eastern Seaboard and other selected locations in the United States. This phenomenon is caused by an increase in recycling efficiency and an increase in competition for a declining supply of MSW between landfill operators and MSW power facilities.

- Some regions could be sending all of the available MSW to combustors, in some cases transporting MSW longer distances to meet MSW-combustor demand for feedstock. This has two effects, an increase in transportation costs and a change in the composition of material delivered to landfills, consisting of noncombustible material and combustion ash.

- Waste management firms may become financially stressed as a result of these changes. Landfill closures could result from the decline in landfill space and from the decline in projected revenues. The threat of landfill closures may become moot if material flows to landfills decline.

- Depressed tipping and increased transportation costs of MSW affect the development of the potential capacity projected in this report. This is one of the many areas of this report that deserves more attention.

In summary, this analysis has shown that the development of MSW power capacity could have unintended regional effects that can be examined through Geographic Information Systems analysis. GIS will be a very powerful tool for future energy analysis.

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List of Figures

Map 1. Existing MSW-Combustion Facilities with MSW net of Composting and Recycling, 1990

Map 2. Planned MSW power Facilities with MSW net of Composting and Recycling, 1990

Map 3. Gross MSW Generation, 2000

Map 4. MSW net of Composting and 25% Recycling, 2000

Map 5. MSW net of Composting, 25% Recycling, and Combustion Demand, 2000

Map 6. MSW net of Composting and 50% Recycling, 2000

Map 7. MSW net of Composting, 50% Recycling, and Combustion Demand, 2000.

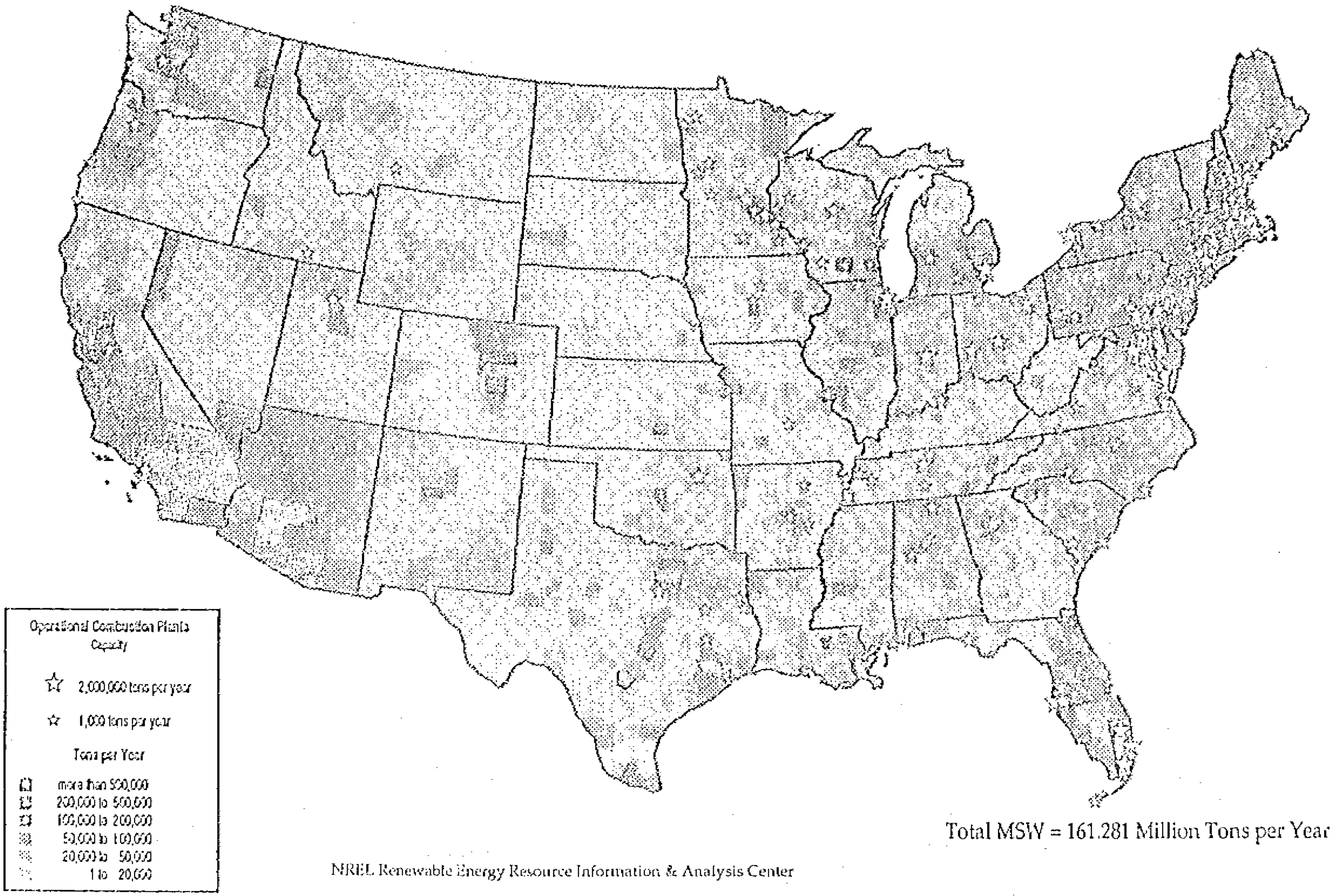
Map 8. Potential MSW power Sites with MSW net of Composting, 25% Recycling, and Existing Combustion, 2000

Map 9. Potential MSW power Sites with MSW net of Composting, 50% Recycling, and Existing Combustion, 2000

Map 10. Potential MSW ethanol Sites with MSW net of Composting, 25% Recycling, and Existing Combustion, 2000

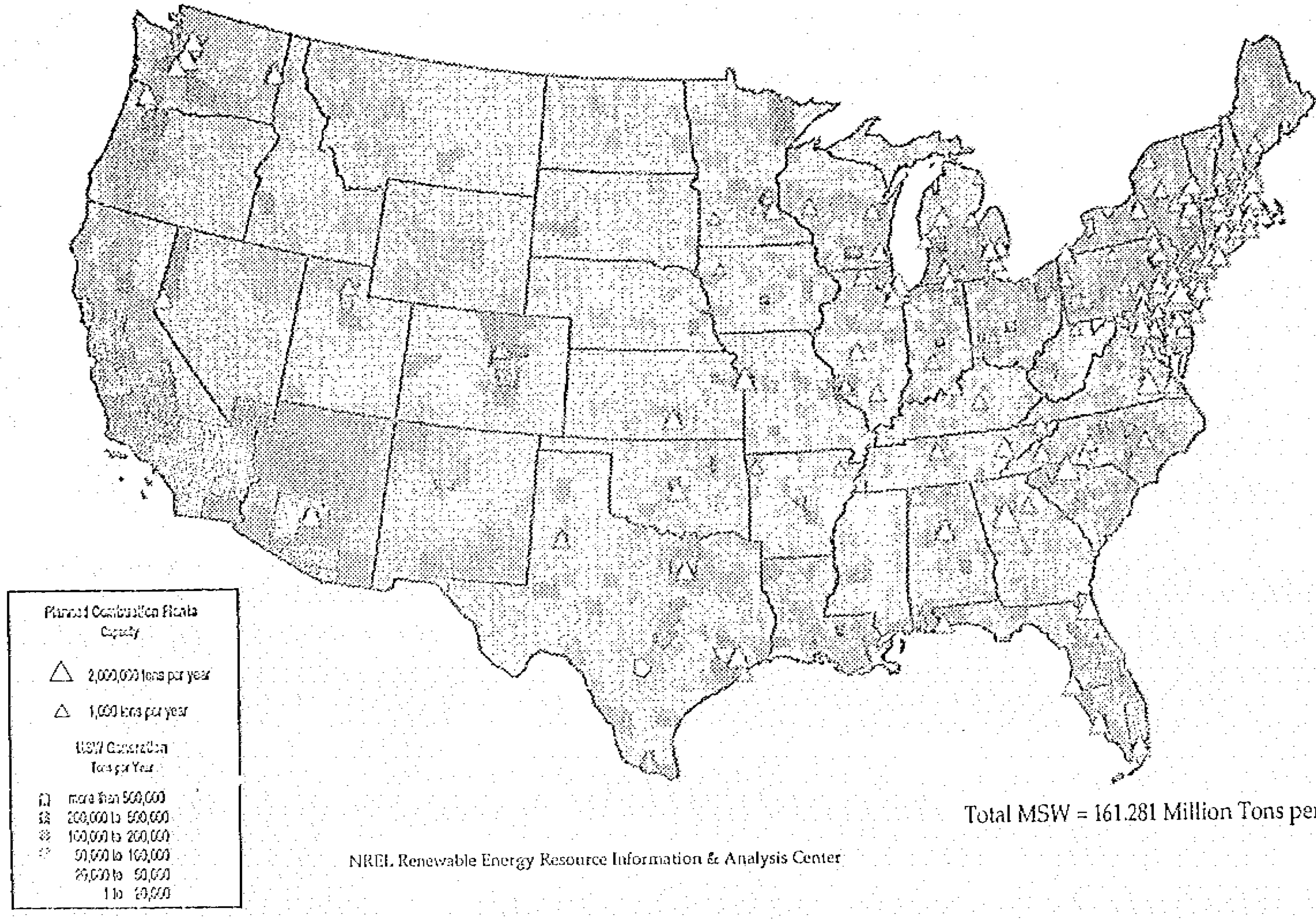
Map 11. Potential MSW ethanol Sites with MSW net of Composting, 50% Recycling, and Existing Combustion, 2000

Map 1
Existing MSW-Combustion Facilities with MSW net of Composting and Recycling, 1990



NREL Renewable Energy Resource Information & Analysis Center

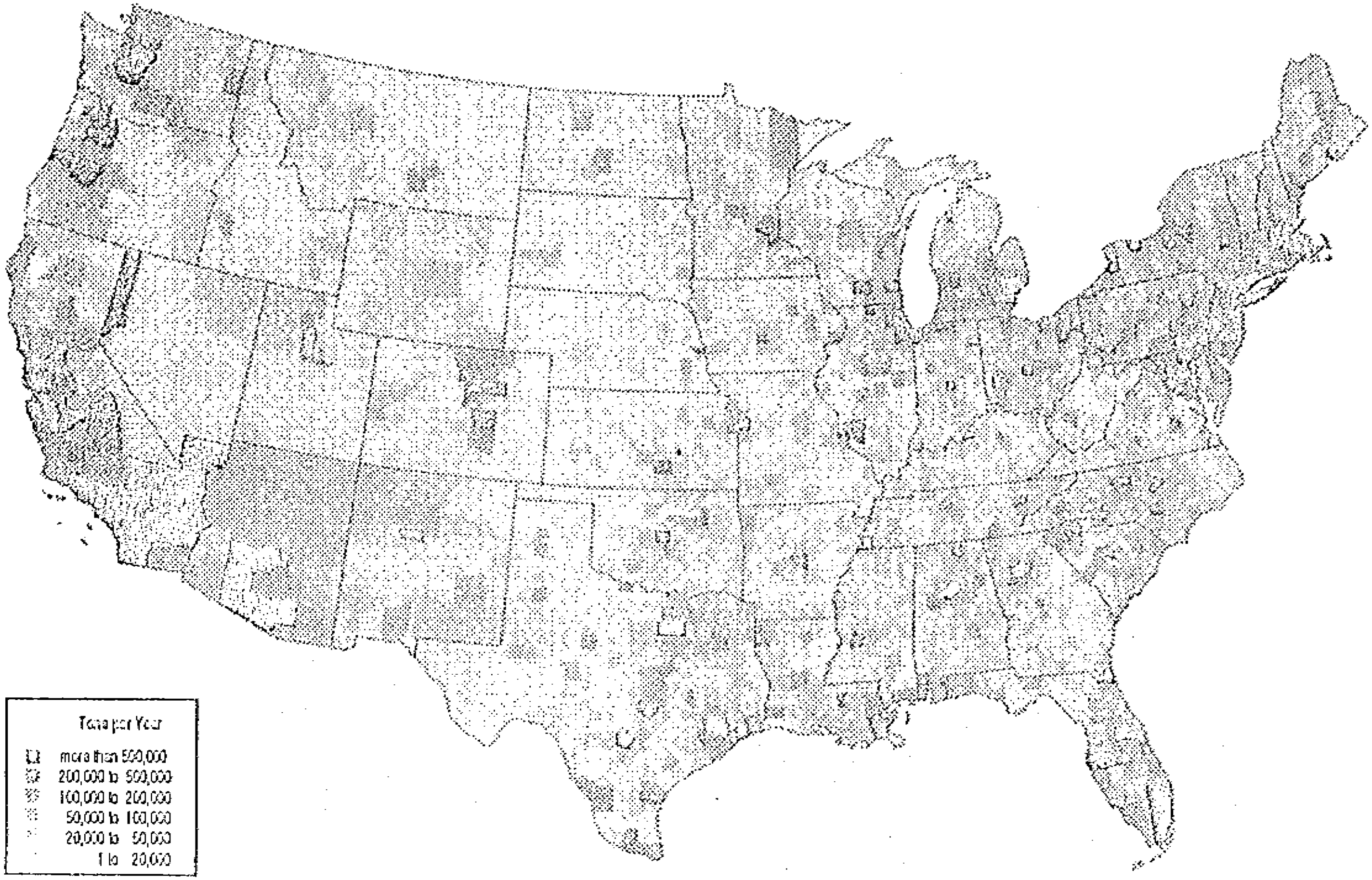
Map 2
Planned MSW-Power Facilities with MSW net of Composting and Recycling, 1990



Total MSW = 161.281 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

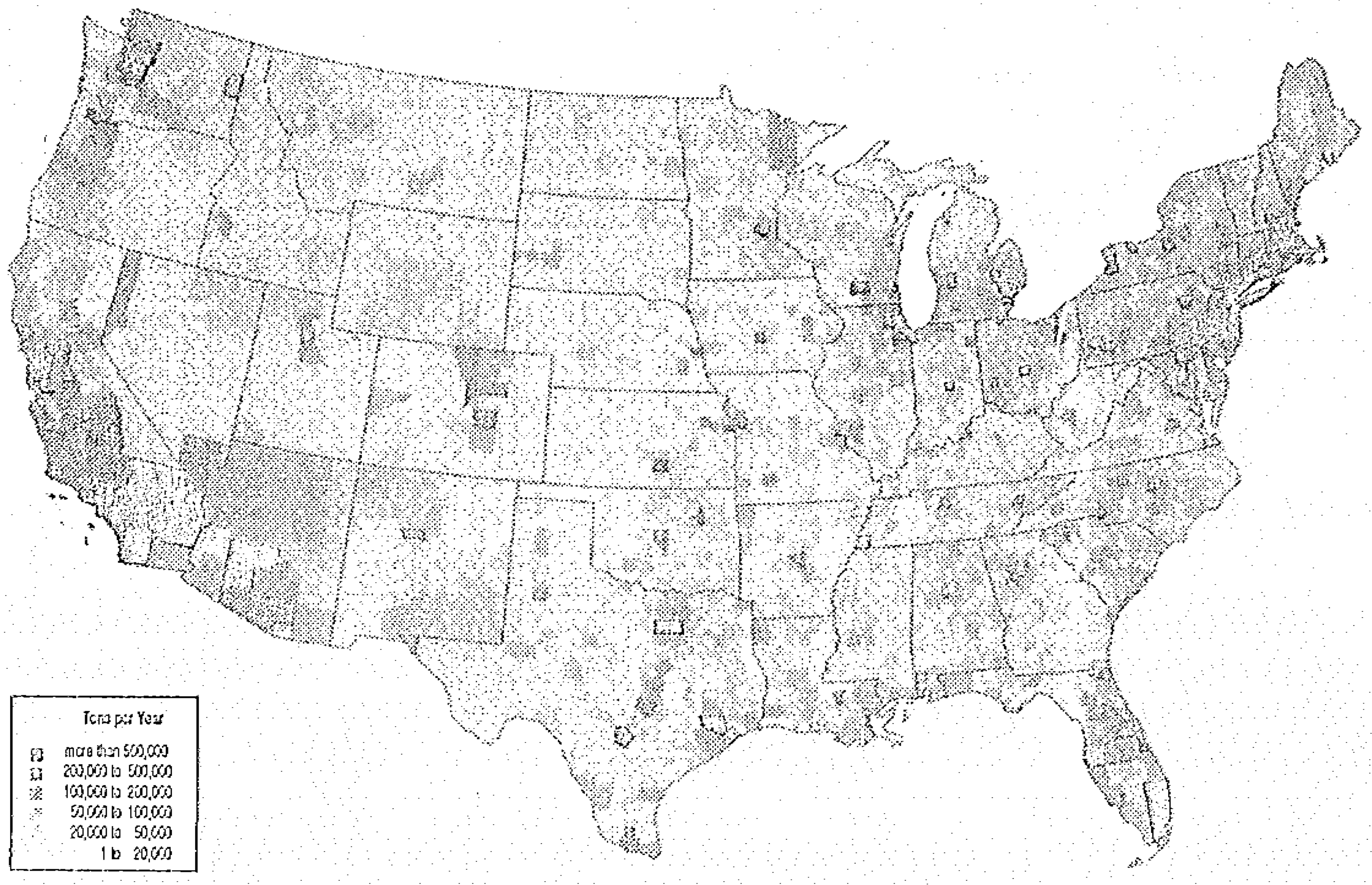
Map 3
Gross MSW Generation, 2000



Total MSW = 220.997 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

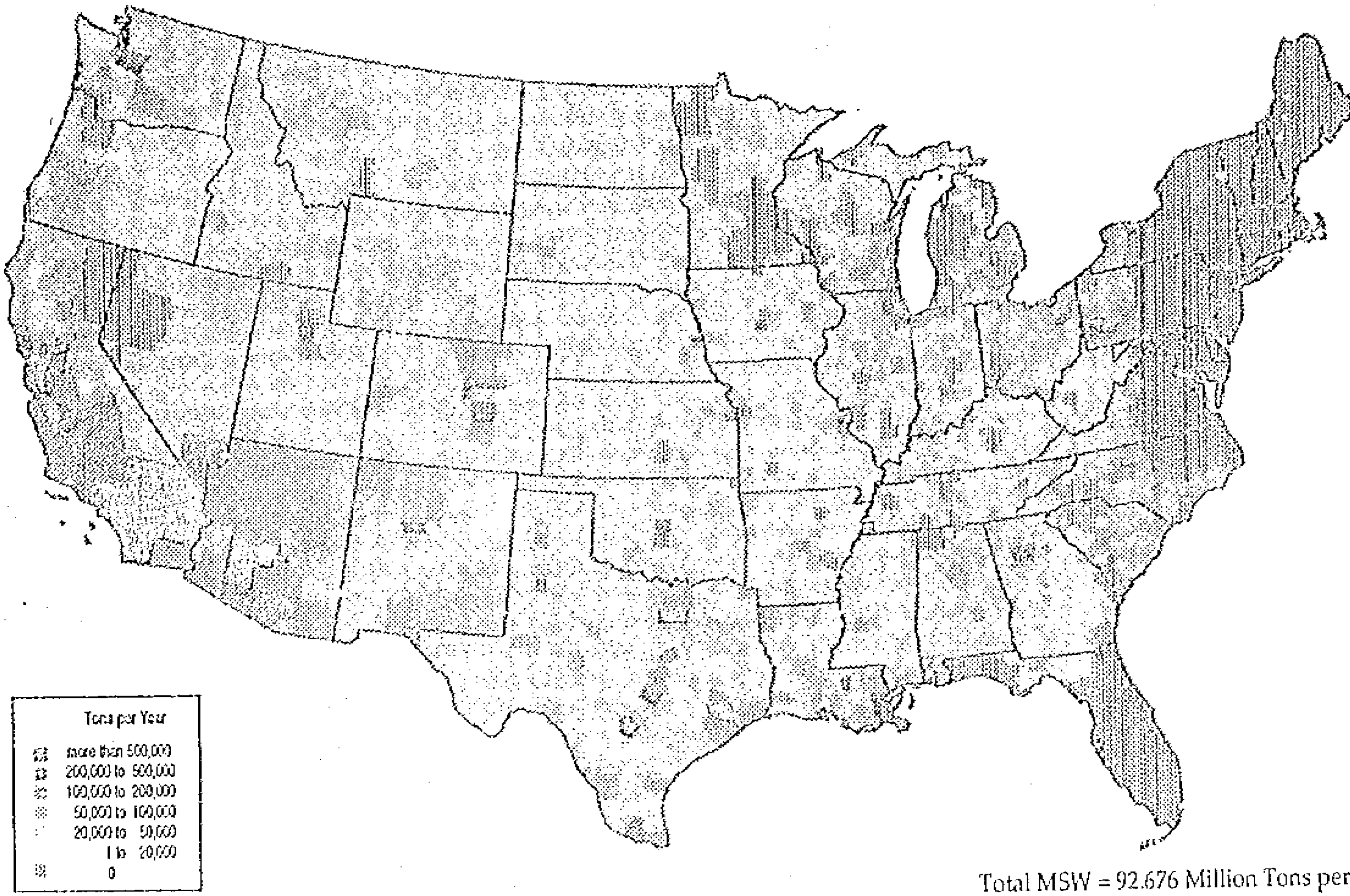
Map 4
MSW net of Composting and 25% Recycling, 2000



Total MSW = 162.752 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

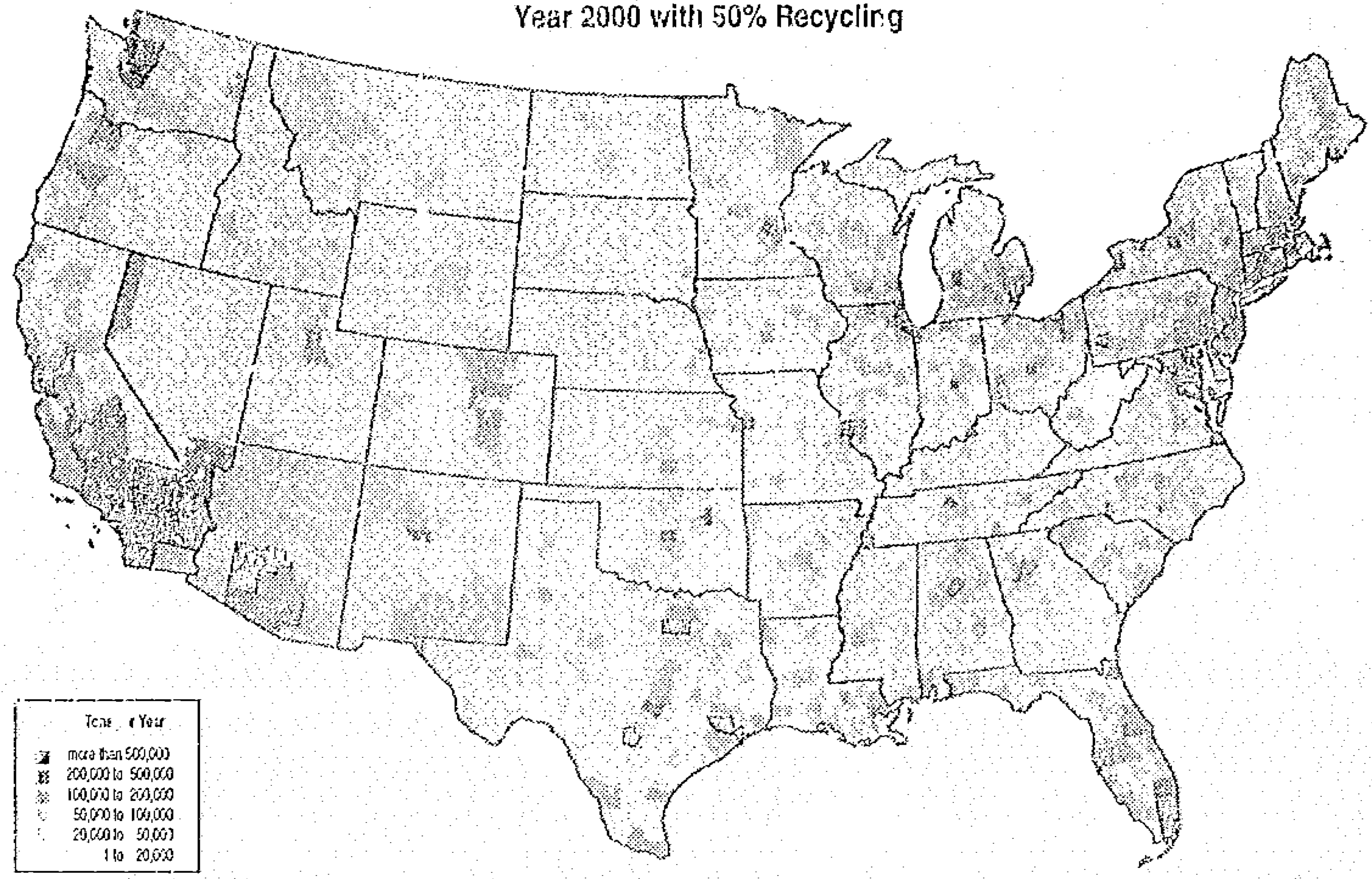
Map 5
MSW net of Composting, 25% Recycling, and Combustion Demand, 2000



Total MSW = 92.676 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

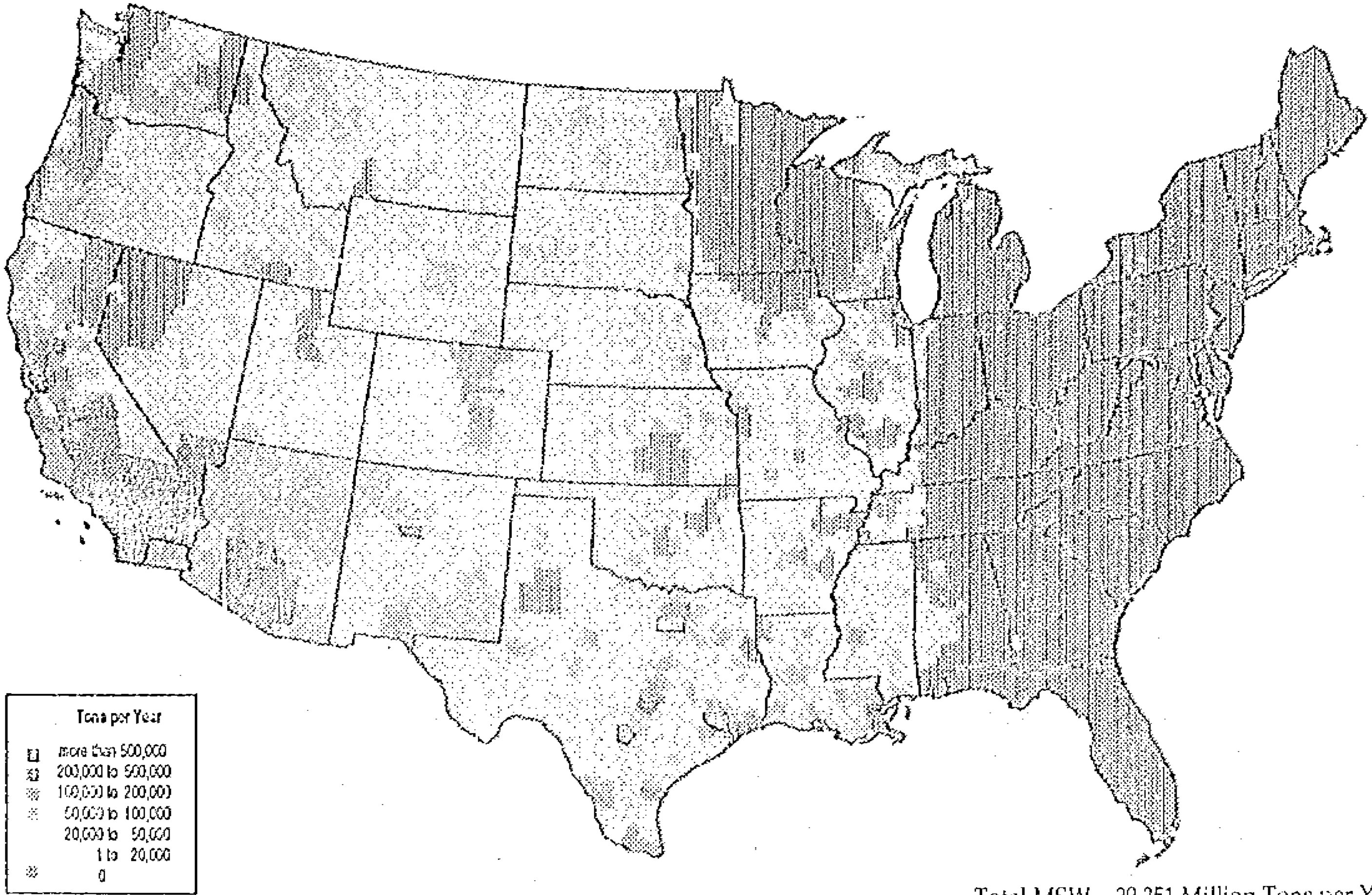
Map 6
MSW Production per County
After Composting and Recycling
Year 2000 with 50% Recycling



Total MSW = 109.426 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

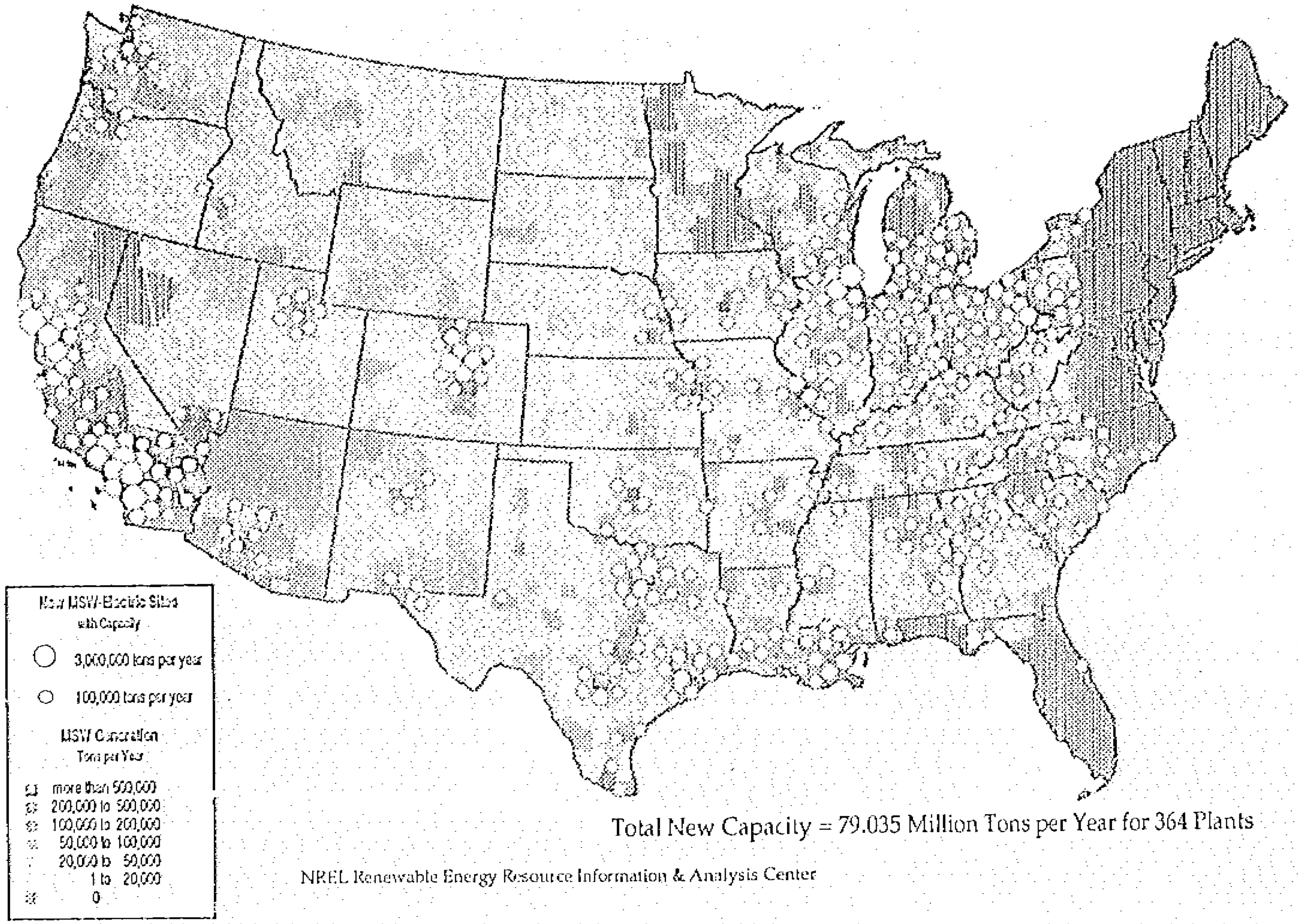
Map 7
MSW net of Composting, 50% Recycling, and Combustion Demand, 2000



Total MSW = 39.351 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

Map 8
Potential MSW-Power Sites with MSW net of Composting, 25% Recycling, and Existing Combustion, 2000



Total New Capacity = 79.035 Million Tons per Year for 364 Plants

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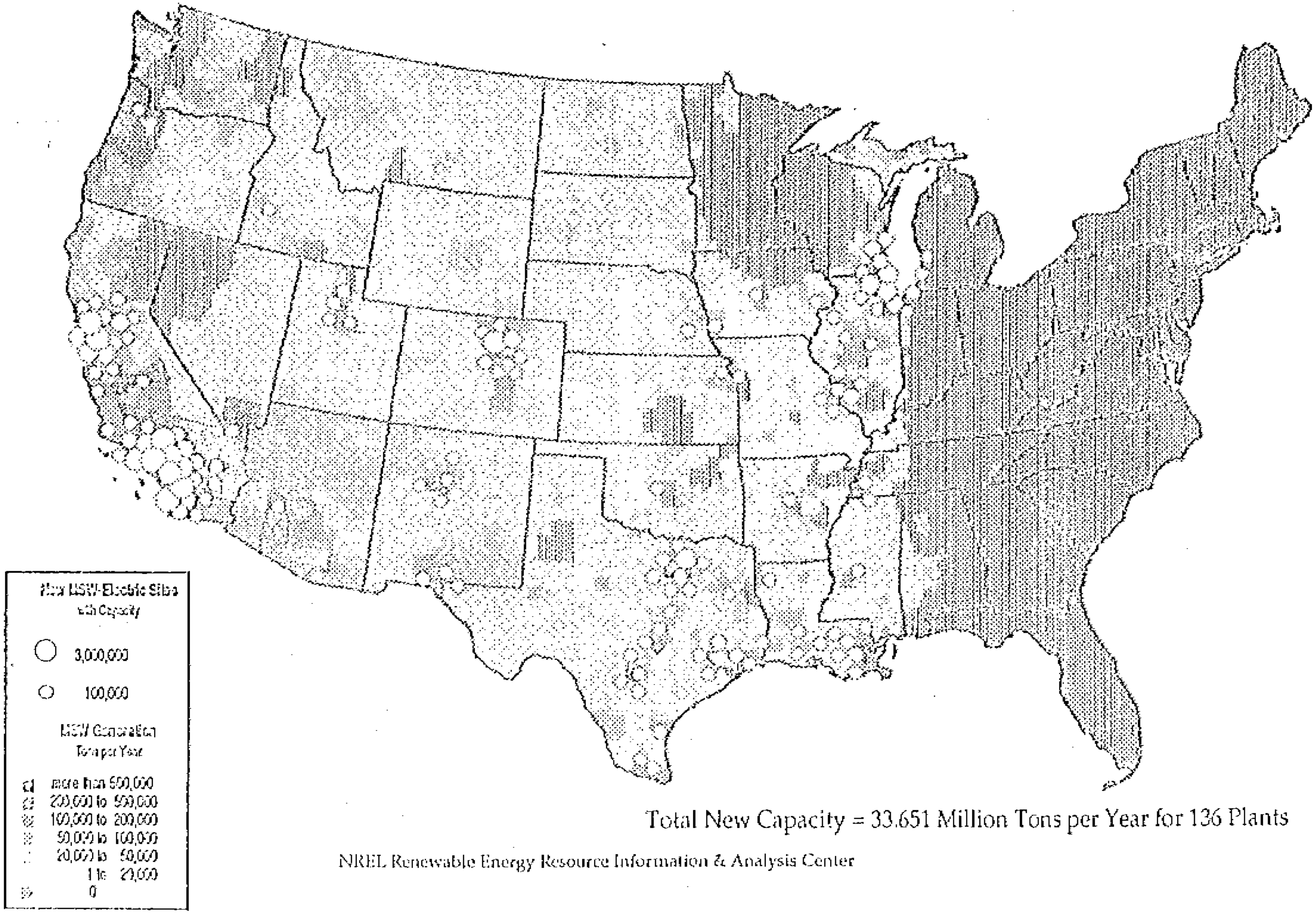
Map 9
Potential MSW-Power Sites with MSW net of Composting, 50% Recycling, and Existing Combustion, 2000



Total New Capacity = 33.651 Million Tons per Year for 136 Plants

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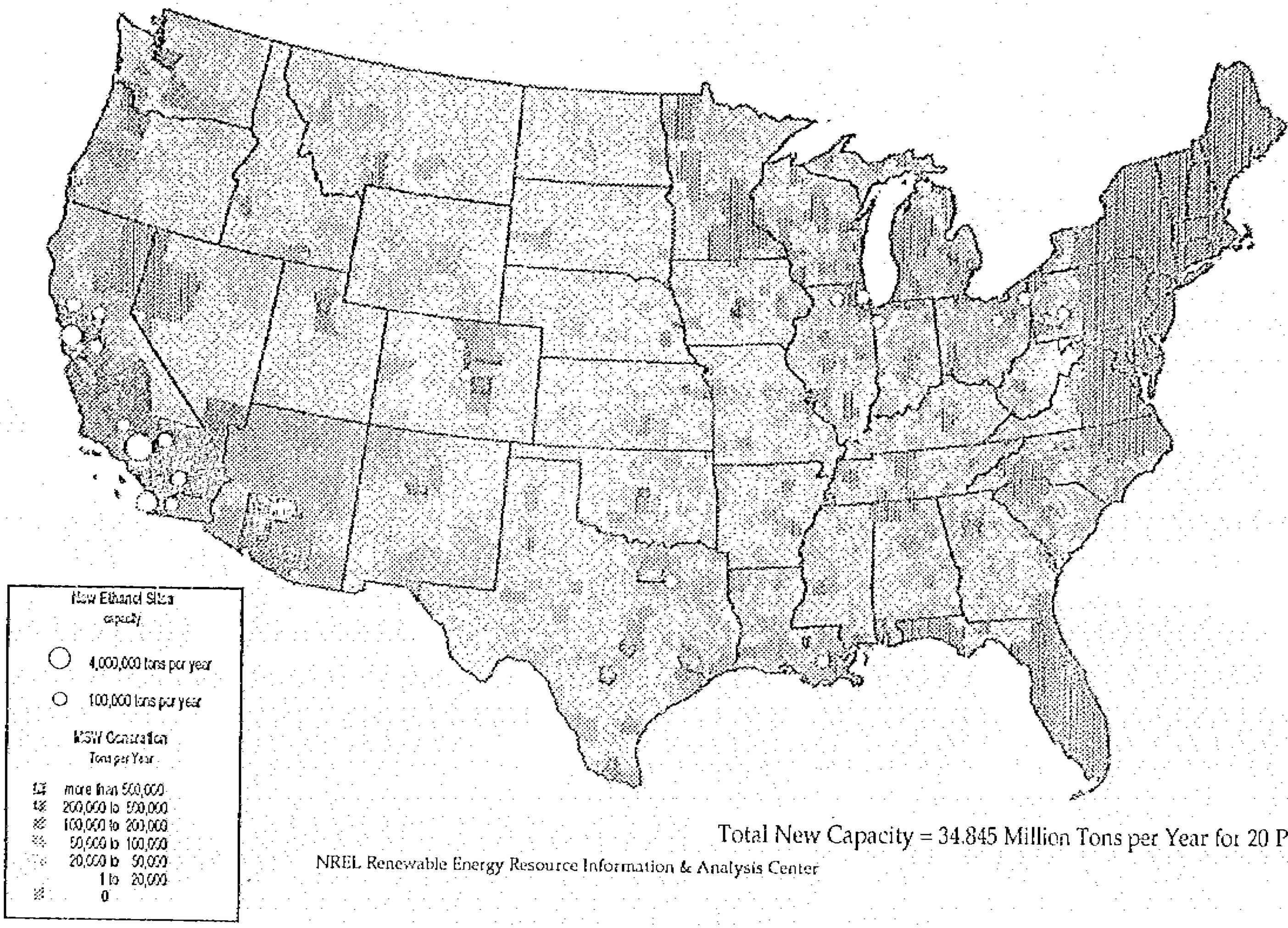
Map 10
Potential MSW-Ethanol Sites with MSW net of Composting, 25% Recycling, and Existing Combustion, 2000



Total New Capacity = 34.845 Million Tons per Year for 20 Plants

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