Energy and Water in the Great Lakes

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1. Introduction

In 2005 thermoelectric power production accounted for withdrawals of 140 billion gallons per day (BGD) representing 41% of total freshwater withdrawals, making it the largest user of water in the U.S., slightly ahead of irrigated agriculture (USGS 2005). In contrast thermoelectric water consumption was estimated to be 3.7 BGD or about 3% of total U.S. consumption (NETL 2008). Thermoelectric water consumption was roughly equivalent to that of all other industrial demands and represents one of the fastest growing sectors since 1980. In fact thermoelectric consumption is projected to increase by 42 to 63% between 2005 and 2030 (NETL 2008). This projected range in growth is a function of many factors including the fuel mix of the future power plant fleet, applied cooling technology, assumed air quality standards, and potential new policies regulating large water intake structures.

The nexus between thermoelectric power production and water use is not uniform across the U.S., but rather differs according to regional physiography, demography, power plant fleet composition, and the transmission network. That is, in some regions water demand for thermoelectric production is relatively small while in other regions it represents the dominate use. The later is the case for the Great Lakes region, which has important implications for the water resources and aquatic ecology of the Great Lakes watershed. This is today, but what about the future? Projected demographic trends, shifting lifestyles, and economic growth coupled with the threat of global climate change and mounting pressure for greater U.S. energy security could have profound effects on the region's energy future. Planning for such an uncertain future is further complicated by the fact that energy and environmental planning and regulatory decision-making is largely bifurcated in the region, with environmental and water resource concerns generally taken into account after new energy facilities and technologies have been proposed, or practices are already in place.

Based on these confounding needs, the objective of this effort is to develop Great Lakes-specific methods and tools to integrate energy and water resource planning and thereby support the dual goals of smarter energy planning and development, and protection of Great Lakes water resources. Guiding policies for this planning are the Great Lakes and St. Lawrence River Basin Water Resources Compact and the Great Lakes Water Quality Agreement. The desired outcome of integrated energy-water-aquatic resource planning is a more sustainable regional energy mix for the Great Lakes basin ecosystem.

A key feature of the integrated planning is the Great Lakes Energy-Water (GLEW) Model. The purpose of the model is to provide energy and environmental regulators, energy utilities and independent power generators with a tool to analyze the demand of specific technologies on water use/consumption and the related impact for a range of Great Lakes aquatic habitats. The model informs tradeoffs in water withdrawal and consumption for baseline and potential future energy mix scenarios and contextualizes these demands relative to the competition by development outside the thermoelectric sector. The model also informs important elements of the energy-water-aquatic resource nexus and the ecological risks and benefits associated with various future energy scenarios in the region.

Due to the complex relationship between energy production and environmental/ecological impacts, special care was taken to establish project objectives that were reasonable, logical, and attainable within the confines of the grant period and funding. As such, the project has relied heavily on existing institutional knowledge and research in order to advance the understanding of aquatic resource/energy nexus issues in the region. Specifically, the modeling exercises have relied heavily on existing tools and data that are readily available in the open literature, adapting them to the specific needs of Great Lakes basin. Details on the model, parameterization, and data are given in the next section.

2. Methods

This analysis adapts the Energy, Water and Power Simulation (EPWSim) model developed by Sandia National Laboratory (Tidwell et al. 2009) to address issues specific to the Great Lakes region. This decision framework is formulated within a system dynamics architecture (e.g., Sterman 2000) and implemented within the commercial software package Studio Expert 2008, produced by Powersim, Inc. (www.powersim.com). The model is designed to operate on an annual time step over a 28 year planning horizon, 2007 to 2035. The spatial extent of the model is defined both by the Great Lakes watershed as well as the accompanying “energyshed” (the geographic area over which electric power used in the Great Lakes Watershed is produced) (Figure 1).

At its highest level, GLEW model is organized according to six interacting modules, demography, electric power production, thermoelectric water demand, non-thermoelectric water demand, water supply, and environmental health. The demographic module simulates changes in population and gross state product (GSP) that in turn drives the demand for water in the non-thermoelectric sector and influences aspects of electric power demand. Within the electric power production module the demand for power is simulated along with the accompanying construction of new power plants to meet the growing need. Also modeled are plant retirements and/or retrofits required due to plant age, new emissions control requirements and or plant intake structure restrictions. Based on the mix of power plants, cooling type and associated production, water withdrawal and consumption are calculated by the thermoelectric water demand module. The non-thermoelectric water demand module calculates both withdrawal and consumption by source (lake, other surface water, and groundwater) and by use sector (municipal, industrial, mining, livestock, and agriculture). These growing demands are then compared to various water supply metrics to identify regions in danger of water stress. Finally, all of these factors are combined to provide an estimate of watershed environmental quality.

The nexus between electric power generation and water use must be viewed through the lens of multiple reference systems (e.g., electric power management regions, watersheds, states, and counties). To facilitate cross reference system analysis, the model is seeded with data representing the highest level of detail that is publically available. These data include such factors as population at the county level, changes in per capita water use at the state level, and stream gauge data at the watershed level. From these disparate scales the data are translated to a compatible reference system for analysis and observation. Translation is accomplished according to a simple areal or population weighted aggregation scheme. Lookup tables of the weighting functions necessary to move from one reference system to another are used to streamline this process.

Below a brief description of each module is provided.

2.1 Demographic Module

Population and gross state product (GSP) are the primary factors influencing the demand for non-thermoelectric water within the model. Both are simulated on an annual basis, computed at the county level. The manner in which population and gross state product influence the demand for water is defined in the non-thermoelectric water demand module description below.

Population growth is assumed to follow an exponential trajectory according to the relation

$$\begin{aligned} P_c(t) &= P_c(t-1) + \Delta P_c(t) \\ \Delta P_c(t) &= P_c(t-1) * PGR_c * \Delta t \end{aligned} \qquad 1$$

where P [persons] is the population, ΔP [persons] is the change in population experienced in a year, PGR is the population growth rate [yr^{-1}], t is time, Δt is the time step (one year), and the subscript c designates the county level. The source of data for the model is the 2000 Census (U.S. Census Bureau 2004). Specifically, the measured population in 2000 is used as the model's initial condition, while *PGR*s are determined from the change in population over the period 1990-2000. The measured *PGR* values can be used or adjusted by the model user.

Gross state product is modeled in essentially the same fashion

$$\begin{aligned} GSP_s(t) &= GSP_s(t-1) + \Delta GSP_s(t) \\ \Delta GSP_s(t) &= GSP_s(t-1) * GSPGR_s * \Delta t \end{aligned} \qquad 2$$

where GSP [\$] is the gross state product, ΔGSP [\$] is the change in gross state product experienced in a year, $GSPGR$ is the gross state product growth rate [yr^{-1}] and the subscript s designates a state level. The source of data for the model is the Bureau of Economic Analysis (BEA 2007). As the name implies, gross state product calculations are implemented at the state level. In this way, *GSP* values for 2000 form the initial conditions for the model, while *GSPGR*s are determined from the change in gross state product over the period 1990-2000. *GSP* is then estimated at a county level by simply downscaling the state level value by the ratio of county population to state population. In a fashion similar to population, the *GSPGR* values based on historical trends can be used or adjusted by the model user.

2.2 Electric Power Module

Electricity generation is modeled at the power plant level for the 583 plants currently in operation in the Great Lakes watershed (Figure 1). Plants are distinguished by geographic location; fuel type; installed capacity; annual power output; build date; cooling type; boiler type; and, utility vs. non-utility designation as recorded in the eGRID database (eGRID 2010). This database reflects the 2007 fleet of power plants, which serves as the initial condition for the electric power module. It is assumed that the existing power plants maintain 2007 production levels throughout their operational life. While it is recognized that production levels will change over time simulation of this complex and uncertain process is beyond the scope of this model.

Future demand for electric power is simulated according to Electricity Market Module Regions (EMMR) (Figure 1) as reported in the 2005 Annual Energy Outlook (EIA 2010). A portion of five different EMMRs intersect the Great Lakes watershed, including East Central Area Reliability Coordination Agreement (ECAR), Mid-Atlantic Area Council (MAAC), Mid-America Interconnected Network (MAIN), Mid-Continent Area Power Pool (MAPP), and Northeast Power Coordinating Council/ New York (NPCC-NY). For purposes of this analysis all growth in demand within an EMMR is assumed to be satisfied with new production within that EMMR. The portion of new electric power production to be located within the Great Lakes watershed is based on the 2005 ratio of Great Lakes watershed production within a given EMMR to total production in that EMMR. These ratios can be adjusted if there is reason to believe they will change in the future.

New electricity demand is first satisfied with electric capacity currently under construction as reported by EMMR (EIA 2010). Power plant construction beyond that which is currently on the books is apportioned according to the desired fuel mix specified by the analyst. Fuel type options include coal-steam; natural gas (NG) steam; natural gas combined cycle (NGCC); NG combustion; oil steam; oil combined cycle; oil combustion; nuclear; biomass; geothermal; concentrating solar ; solar photovoltaic (PV); wind; and, hydropower. New power plants are ordered when electricity demand exceeds 50% of the capacity of a new power plant. Power plants are not added immediately but follow a permitting and construction schedule. Build time, nameplate capacity and capacity factors for future plant construction are based on average values calculated by fuel type and EMMR from the 2010 eGRID data (for plants in the Great Lakes watershed).

Siting of new power plants is accomplished in such a way as to maintain the 2005 ratio of local watershed electric production to Great Lakes watershed production. By local we mean the U.S. Geological Survey 8-digit Hydrologic Unit Code (HUC) watershed. The order of siting roughly follows the rank order of watersheds from highest to lowest power production ratio. This simple treatment assumes that future power plants will be sited so as to take advantage of existing fuels transportation and/or electricity transmission infrastructure.

The electric power production module also simulates the retirement and/or retrofitting of power plants. The need to retire or retrofit an existing plant is necessitated by aging of the plant, new policies regulating large water intake structures, or new policies requiring augmentation of emissions controls. In the case of aging, once a plant reaches the end of its life expectancy equal to the maximum age it is retired or retrofitted. This decision is based on the age of the plant and its capacity factor (the percent of time that the power plant operates in an average year). If the plant is old and lightly used, it is likely that it will be retired rather than going to the expense of updating the plant. The life expectancy is set based on the current maximum age of a plant of a given fuel type in the Great Lakes watershed, while the capacity factor threshold is based on input from knowledgeable stakeholders. If the plant is retired the process above is used to site a new power plant to replace the lost production. Otherwise the plant will return with the same fuel and cooling type but with production levels and water use characteristics updated to the current averages for the Great Lakes watershed.

Recently EPA has published new regulation for comment that if adopted will make it difficult for power plants to continue use of open-loop cooling systems (CWA S316). Open-loop cooling simply involves the diversion of water from a river or lake through the plant's steam condenser and then returns that water back to the water source, just at a slight elevated temperature. The model identifies those plants with open loop cooling and determines whether to retire or retrofit the plant. This decision is based on the age of the plant and its current capacity factor, similar to that described above.

Finally, potential polices aimed at reducing green house gas emissions could require retirement or retrofitting of select power plants. Identification of such plants is initiated by calculating the required CO_2 emissions to be sequestered in a given year. This calculation begins by determining the carbon cap for that year. Given the uncertainty as to these limits, the analyst has full control over the settings for the calculation. Specifically, the start and final target dates can be changed as well as the final and intermediate target levels. The required sequestration levels are then simply calculated as the difference between the current CO_2 emission level and the CO_2 cap. The default is set at levels consistent with that of the proposed Kerry-Lieberman bill.

Based on the required sequestration of carbon, the model then determines which of the existing coal fired power plants will be closed, retrofitted, or continue to operate while paying associated emissions penalties. The order in which power plants are retrofitted/retired is based on the cost to retrofit as published in a recent analysis by NETL (2010). In this study NETL identified the coal-fired power plant population which was viable for retrofitting. The viable population for the analysis was defined as those active plants with a combined unit generation capacity greater than 100 MW, an average heat-rate below 12,500 Btu/kWh, and a location within 25 miles of a potential carbon sequestration opportunity. The associated capital expense, operating expense, and parasitic load associated with retrofitted carbon capture technology were then calculated for each "viable" plant. These cost values were evaluated by scaling plant-specific parameters and algorithms derived based upon the Conesville Study (NETL 2007a). Plants falling outside this population are retired once their aggregate CO_2 production rate exceeds the carbon cap.

Both existing (retrofitted) and new coal-fired power plants are assessed a parasitic energy loss of 30% due to implementation of carbon capture and sequestration (CCS), while natural gas and oil-fired plants are assessed a loss of 15% (NETL 2008). New plant builds due to decommissioning and/or parasitic losses at existing plants are assumed to follow the same fuel/cooling mix as for the build out of the entire future plant fleet.

2.3 Thermoelectric Water Demand

The thermoelectric water demand module calculates water withdrawals and consumption for the existing and future power plant fleet. These water use values are calculated on a plant by plant basis, according to the type of plant, its projected cooling type and the production rate. For new power plants this calculation is accomplished by multiplying the production rate, p_i, by the associated water withdrawal factor, $wwf_{f,c,}$, or water consumption factor, $wcf_{f,c}$

$$\begin{aligned} ww_i &= p_i * wwf_{f,c} \\ wc_i &= p_i * wcf_{f,c} \end{aligned} \quad 3$$

where *ww* indicates water withdrawal, *wc* indicates water consumption and the subscript *i* designates the plant, *f* the fuel type and *c* the cooling type. The water withdrawal/consumption factors are based on the original work of the National Renewable Energy Laboratory. These factors along with a brief description of their origin are given in Appendix A. The cooling type associated with new plant construction is at the discretion of the analyst. Cooling options include open-loop cooling, closed-loop cooling tower, closed-loop cooling pond and dry cooling.

As existing plants utilized older, less efficient technologies, the water withdrawal/consumption factors don't provide a fully accurate picture of water use. In this case we utilized information provided directly by water managers in the Great Lakes watershed (limited number of plants), water use available through NETL's Coal Power Plant Database (NETL 2007b) and county level water use statistics gathered by the USGS (2005; 1995). Use of the different databases is necessitated because of data gaps in the reported data. Where state or NETL data are available, they were used as the basis for water withdrawal and consumption. Where lacking those plants were sorted according to county and a preliminary estimate of their withdrawal and consumption was made using equation 3. These values were then adjusted in a proportional manner so as to match the measured USGS data (2005 data for withdrawal and 1995 data for consumption).

For existing plants the source of water was determined from information provided by local water mangers, NETL's Coal Power Plant Database (NETL 2007b), or the USGS (2005). Sources include the Great Lakes, other surface water and groundwater. For new plants the source is determined from the current thermoelectric water source mix of the watershed the new plant is sited.

Water penalties are applied in cases involving application of carbon capture and sequestration. The applied water penalty on a plant level basis is assessed based on the type of power plant and its electric power generation. It is assumed that all cooling for CCS related equipment will be handled through a wet recirculating (closed-loop) system. Associated water withdrawal and consumption factors are listed in the tables in Appendix A.

2.4 Non-Thermoelectric Water Demand Module

The non-thermoelectric water demand module within the GLEW model projects the future demand for water according to five different use sectors: municipal (including domestic, public supply, and commercial), industrial, agriculture, mining and livestock. Water withdrawal and consumption are tracked separately as are the resulting return flows. Also modeled is the source of the withdrawal, whether that be surface water, groundwater, or a Great Lake.

Water use statistics published by the U.S. Geological Survey (USGS) serve as the primary data source for the analysis (USGS 2005, 2000, 1995, 1990, 1985). Every five years since 1950 the nation's water-use data have been compiled and published by the USGS. Collection of this data is a collaborative effort between the USGS, state and local water agencies, and utilities. However, the level of detail at which these data are reported varies from year to year. Data from the 1985, 1990, and 1995 campaigns provide the most comprehensive picture of water use in the U.S. and also are the last years that consumptive water use was compiled. The last published water census by the USGS is 2005 (no reported consumptive use). As such, our projections of future water withdrawals utilize data from 1985-2005 while consumptive use projections are limited to data from the 1985-1995 campaigns.

Municipal water withdrawal, Q_M, is modeled at the 8-digit watershed level according to the relation

$$\begin{aligned} Q_{M,c}(t) &= P_c(t) * PCU_c(t) \\ PCU_c(t) &= PCU_c(t_{2005}) + (\Delta PCU_s * t_e) \end{aligned} \tag{4}$$

where P [person] is the population, PCU [L^3/person*t] is the per capita water withdrawal, ΔPCU is the rate of change in per capita water withdrawal [L^3/Person*t^2], t is time, t_e is the elapsed time since 2005, and the subscripts c and s denote watershed and state levels of aggregation, respectively. In this way, municipal water withdrawal is a function of both changing population and per capita water withdrawal. Changes in population are calculated according to the county level population growth rates reported by the Census Bureau (2004), as described above, while ΔPCU is based on historical trends (see below). Recognizing that care must be exercised when extending historical trends into the future, limits are placed on the total allowable change. Specifically, ΔPCU is not allowed to increase or decrease by more than 20% over the duration of the simulation. This limit is set based on the assumption that changes beyond ±20% would likely require major structural changes to the system, for example the extent to which an individual home owner might implement conservation measures. Once this maximum change is achieved ΔPCU is held constant throughout the rest of the simulation. Per capita water withdrawal rates published for 2005, $PCU(t_{2005})$, serve as the initial condition for the model.

Rates of change in per capita water withdrawal, ΔPCU, were calculated by simple linear regression using data from the USGS. Recognizing that meaningful trends in *PCU* could not be extracted at the watershed level (data were erratic, displaying little correlation across the three data sets), ΔPCU values were calculated from data aggregated at the state level. Each regression was inspected according to “goodness of fit”. In cases where the regression did not accurately represent the perceived trends (i.e., $R^2<0.6$) data were fitted by hand.

Industrial water withdrawal is relatively insensitive to changes in local population; rather, economic conditions, as represented by gross state product, act as a better indicator. As such, industrial water withdrawal, Q_I, is modeled as

$$\begin{aligned} Q_{I,c}(t) &= GSP_c(t) * WUI_c(t) \\ WUI_c(t) &= WUI_c(t_{2005}) + (\Delta WUI_s * t_e) \end{aligned} \tag{5}$$

where *GSP* is gross state product [$], *WUI* is the water withdrawal intensity [L^3/$*t] and ΔWUI is the rate of change in *WUI* [L^3/$*$t^2$]. In this case, industrial water withdrawal is a function of both changing gross state product and water withdrawal intensity (the amount of water required to produce a dollar of gross state product). Modeling of gross state product is described above, while modeling of *WUI* and ΔWUI are handled in a completely analogous manner to that described for *PCU* and ΔPCU above.

Irrigated agriculture, Q_A, is a function of the area irrigated, climate conditions and conservation practices

$$\begin{aligned} Q_{A,c}(t) &= A_c(t) * IR_c(t) \\ A_c(t) &= A_c(t_{2005}) + (\Delta A_s * t_e) \\ IR_c(t) &= IR_c(t_{2005}) + (\Delta IR_s * t_e) \end{aligned} \quad 6$$

where A is the area irrigated [L^2], IR is the irrigation requirement [L^3/t], is ΔA the rate of change in the irrigated area [L^2/t] and ΔIR is the rate of change in the irrigation requirement [L^3/t^2] (irrigation requirement responds both to climate and conservation drivers). Over the last 35 years, water withdrawal in the agricultural sector has remained relatively constant largely due to limited increases in the area irrigated and offsetting improvements in irrigation efficiencies (USGS 2005). For this reason, irrigation water withdrawal is assumed to remain constant over the duration of the simulation. Nevertheless, the model is designed to easily permit future changes to irrigated agriculture.

Other water use sectors such as mining and livestock fail to show a strong trend with population, GSP, or any other simple metric. Thus, water withdrawal in the livestock sector, Q_L, is simply modeled by extending its historical water withdrawal trend into the future

$$Q_{L,c}(t) = Q_{L,c}(t_{2005}) + (\Delta Q_{L,s} * t_e) \quad 7$$

where ΔQ_L is the rate of change in water withdrawal by the livestock sector [L^3/t^2]. It is calculated and implemented in a fashion similar to ΔPCU and ΔWUI above. Likewise, future water withdrawal by the mining sector is modeled according to Equation 7, with an appropriate change in parameters.

Once water withdrawal is calculated the fraction consumed and discharged to the waste water treatment plant is determined. Consumptive use is calculated in an identical fashion to that in equations 4-7 above, again using the data available from the USGS. The only difference is that consumptive use trends were calculated from data limited to the USGS census in 1985, 1990 and 1995. Also, the 1995 data serve as point from which future consumptive use values are calculated. Waste water discharges are calculated as the difference between use and consumption.

As the demand for water in a particular sector changes over time, so too will the mix of withdrawals from groundwater, surface water and Great Lake sources. Historical trends relative to changes in groundwater abstraction are used to project future supply choices

$$GWf_{n,c}(t) = GWf_{n,c}(t_{2005}) + (\Delta GWf_{n,s} * t_e) \quad 8$$

where $GWF_{n,c}(t_{2005})$ is the fraction of supply taken from groundwater in 2005 [%], $\Delta GWf_{n,s}$ is rate of change in the fraction taken from groundwater [%/t] and the subscript n designates the water use sector. $\Delta GWf_{n,s}$ is calculated and applied similarly to that of ΔPCU and ΔWUI .

Likewise the percent water coming from a Great Lake is allowed to change, in this case according to a user defined rate of change (set by a slider bar). The resulting supply taken from surface water is simply determined as that not taken from groundwater or the Great Lakes.

2.5 Water Supply Module

Stream gauge statistics based on extended sampling periods provide one of the best measures of surface water availability. As these gauged flows are affected by activities upstream of the gauge, the measured statistics account for upstream reservoir operations, evaporative losses, groundwater-stream interaction, withdrawals, etc. In this way, the mean daily flow provides a good measure of the average surface water supply available at the gauge location, while the accompanying exceedance flows provide a measure of the variability in supply at that point. Likewise, the gauged average daily base flow index (that portion of the stream flow contributed by groundwater discharge) provides a good measure of the sustainable groundwater recharge available for use.

The basis of the water supply modeling is the USGS National Hydrographic Dataset (NHD). Specifically, the USGS has stream flow data from 23,000 gauges in which the available sampling record has been statistically analyzed to give the minimum and maximum daily flows, mean daily flow, key percentiles (1, 5, 10, 20, 25, 50, 75, 80, 90, 95, 99) of daily flow (exceedance values), and the base flow index (Stewart et al. 2006). For each watershed we have identified the NHD gauge with the longest record and which is the closest to the point of watershed discharge. Specifically, surface and groundwater availability has been compiled at the 8 -digit Hydrologic Unit Code [HUC] level (107 watersheds comprising the Great Lakes watershed [Croley 2002]). As activities upstream of the gauge will affect the measured flow, the NHD long term statistics are constantly adjusted in the model for changes in consumptive use upstream of the gauge. Specifically, changes in water consumption (post 2005) are sequentially aggregated across watersheds from headwater to the gauge. The aggregated consumption is then subtracted from the long term gauge statistics to yield an adjusted measure of water availability.

2.6. Environmental Quality Module

Decisions concerning future water use have implications for the environmental quality for the Great Lakes region. Two measures of environmental quality are calculated as a part of the GLEW model. The first addresses future water use decisions and their impact on basin water resources as measured through limits established by the Great Lakes and St. Lawrence River Basin Water Resources Compact (the Compact). Specifically, the model tracks new power plant construction (built after 2007) that will exceed either the Compact withdrawal or consumption threshold for permitting, registration and/or reporting (withdrawal and consumption thresholds are tracked individually). Compact thresholds are given below in Table 1.

Table 1: Great Lakes and St. Lawrence River Basin Compact Withdrawal and Consumption Thresholds for Permitting, Registration and/or Reporting

State	Withdrawal (MGD)	Consumption (MGD)
Illinois	any lake diversion	2
Indiana	2 from a lake or 1 from stream	none

New York	all diversions	2
Michigan	1	none
Minnesota	0.0027	2
Ohio	any lake diversion	2
Pennsylvania	0.1	5
Wisconsin	0.1	2
Compact	none	5

The second measure focuses on the potential for aquatic impacts. This measure is derived from original work of the Professor Mark Bain of Cornell University, a member of the GLEW Project Team (Bain 2011). Specifically, the low flow indicator is calculated as it is the most sensitive metric to water use decisions in the region. For this indicator stream flows for the month of August are used as this is when the lowest flows are realized and it is the month in which human use tends to be the highest. The low flow indicator, X (dimensionless) is calculated according to the following formulae:

X% = (mean basin August streamflow MGD) divided by
((mean basin August streamflow MGD)+(sum of all water uses in August MGD)) 9

Environmental quality thresholds associated with the low flow indicator are set as follows:
< 50% for environmental needs results in significant environmental losses
50-80% for environmental needs will likely maintain good environmental conditions
>80% for environmental needs is likely to result in excellent environmental conditions

Relative to the model August streamflows for each of the 8-digit watersheds were acquired from (Croley 2002), August water demands were not immediately available so they were estimated from available annual average water use data (e.g., USGS 2005). These annual water use measures were adjusted for peak summer water use. Annual average thermoelectric and industrial use were increased by 25% (EIA 2010) for the month of August reflecting warmer weather and thus higher electric power demands and higher cooling burden. Irrigation demands were increased by a factor of 3 as it is assumed that the majority of irrigation is limited to a 3 month window in the summer. Likewise municipal use is increased by 30% to reflect that most all outdoor irrigation (as reflected by the consumptive municipal use) will also be limited to this 3 month window.

2.7 GLEW Model Verification

Efforts have been made to evaluate results provided by the GLEW model. To the extent possible, the dynamics of key variables have been calibrated to match published projections. Specifically, gross state project (GSP) has been calibrated to follow the projected trends for U.S. Bureau of Economic Analysis's reference case (BEA 2007), while population growth at the county level aggregated to the national level is calibrated to the Census Bureau's reference projections (U.S. Census Bureau 2004). Electric power demands are taken directly from EIA (2010) projections by EMMR.

Efforts have also been made to verify the water use projections produced by the model through comparisons drawn with other water use studies published in the open literature. The availability of such studies is limited to the national scale. Comparisons are drawn with three different studies each exploring the sustainability of our nation's water supply (Guldin 1989, Brown 1999, Roy et al., 2005). Each study utilized the USGS water use database to establish initial water use figures. The Guldin and Brown studies then projected future use at the national level, while the Roy et al. study approached future water use projections from a more regionalized view. Results from the three studies are provided in Table 2. Model results are given in terms of total freshwater withdrawals. Most notable in this data is the relatively large spread in results. As such, this highlights the difficulty in exactly forecasting future water use. Nevertheless, the modeled results are seen to fall in between the various other projections, while skewed to the lower end of the range.

Table 2. Comparison of water use projections with those documented in other studies (BGD).

Year	Guldin, 1989	Brown, 1999	Roy et al., 2005	Model
2020	461	349	-	347
2025	-	-	451	361
2030	495	356	-	366

Finally, it should be noted that the purpose of this modeling is not to provide predictions of future water use and associated environmental quality. Rather, the purpose is to provide a comparison in relative terms between competing "energy futures". Results should be taken in terms of broad trends. Examples of how the results of the modeling should be interpreted include: which futures produce the greatest changes; what is the relative change between futures; how are changes distributed across the watershed and in time?

2.8 Interactive Interface

The decision support tool is designed to be accessible to the professional and lay public alike, requiring no specialized software (Excel is the only requirement). The model operates on a laptop computer and can be used to demonstrate key variables and processes associated with the electric power-water nexus. The model operates in real-time with a user-friendly interface that includes slider bars, buttons and switches for changing key input variables, and real-time output graphs, tables, and geospatial maps (displayed interactively through Google Earth™) showing results. These features allow a wide range of users to experiment with alternative electric power-water use strategies and learn from the results. Ultimately, the model can be distributed to users on CD or via the internet.

2.9 Database

Data supporting the GLEW model is organized and managed within an Excel Database that communicates directly with the model software. The database stores initial conditions as well as key parameters and rates of change needed by the model. The database is organized according to a number of worksheets each of which contain data supporting an individual module of the model. Specifically, there are worksheets that contain data concerning, population; gross state product; power plant locations; thermoelectric water use factors (by plant type); water use rates by sector and location; mean and exceedance gauge data by watershed; and, associated lookup tables for translation between different reference systems.

Beyond the baseline data used by the model, the database also includes various calculations needed to prepare these data for use in the model. Calls to the database from the model are fully automated within the simulation environment.

3. Results

Our analysis starts with a review of conditions as of 2007; that is, the water demand across different use sectors; current competition between thermoelectric power production and other water use sectors; and, the state of environmental quality across the Great Lakes watershed. Attention then turns to projecting future energy-water-aquatic resource futures. To help with this analysis, five alternative scenarios, as described in Section 3.2 below, are explored. In each case the consequences for water withdrawals and consumption are considered as well as how such change influences aquatic resources. It should be noted that the scenarios considered here are but a small subset of drivers, policies, and action metrics that could be investigated with the GLEW model.

3.1 Water and Electric Power in 2007

Figure 2 shows the distribution of water withdrawal and consumption in 2007 across the use sectors of municipal, industrial, thermoelectric, mining, livestock and irrigation for the Great Lakes watershed. In total, 34.2 BGD of freshwater are withdrawn from the basin. **Withdrawals for thermoelectric production requires 25.9 BGD or 76% of the regional withdrawals, representing by far the largest user of water in the basin**. Other sector withdrawals include municipal at 3.8 BGD (11%), industrial at 3.3 BGD (10%), irrigation at 0.4 BGD (1%), mining at 0.4 BGD (1%) and livestock at 0.2 BGD (1%).[1] These 2007 withdrawal estimates were calculated starting with the USGS 2005 values and then projecting growth in demand to 2007 according to the procedures outlined in Section 2.4. Thermoelectric water withdrawal was calculated as described in Section 2.3.

Unlike withdrawal, consumptive water use is not dominated by the thermoelectric sector. The industrial sector leads consumption at 1.6 BGD, or 53% of all consumption. Other freshwater consumptive uses include municipal at 0.6 BGD (21%), thermoelectric at 0.4 BGD (13%), irrigation at 0.29 BGD (10%), livestock at 0.05 BGD (2%), and mining at 0.03 BGD (1%). These consumptive use estimates were calculated starting with the USGS 1995 values and then projecting growth in demand to 2007 according to the procedures outlined in Section 2.4. Thermoelectric water consumption was calculated as described in Section 2.3.

There are three basic water sources in the basin, the Great Lakes, other surface water and groundwater. Relatively little saline water is used in the basin. The most heavily utilized source in the basin is the Great Lakes, in total 25.8 BGD of water are withdrawn from the Great Lakes (75%), 6.6 BGD from other surface water sources (19%), and 1.9 BGD from groundwater (6%). **Thermoelectric withdrawals account for 81% of all direct Great Lakes withdrawal**, while municipal accounts for 11%, 7% by industrial, and 1% by mining (Figure 3). Similarly, 62% of all consumed water in the basin is derived from the Great Lakes. Specifically, a total 1.9 BGD of

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[1] It should be noted that much of the withdrawn water is returned to the original water source (except in the case of groundwater withdrawal which are generally returned to a nearby surface water feature). The difference in volume is simply equal to consumption. The quality of the returned water is also often altered.

water are consumed from the Great Lakes, 0.7 BGD from other surface water sources, and 0.4 BGD from groundwater. Industrial consumption accounts for 56% of all consumption of lake water, while the municipal sector accounts for 26%, 17% by thermoelectric and 1% by mining (Figure 3). Figure 4 provides the withdrawal and consumption by water use sector from other surface water and groundwater sources (combined) in the Great Lakes watershed.

Of particular interest to this project is the electric power sector. To take a closer look at this sector, electric power capacity and its associated water withdrawal and consumption are disaggregated by power plant fuel type (Figure 5). A review of Figure 5 indicates that electric power capacity in the Great Lakes watershed is predominately generated by coal steam followed by natural gas (NG) steam, nuclear, hydroelectric and to a lesser extent natural gas combined cycle (NGCC), oil steam, wind, NG combustion, oil combustion, and biofuel. In 2007 the total electricity generation capacity for the region was 68,936 MW (583 plants). Of the total capacity 61,444 MW (336 plants) is associated with thermoelectric generation, while 2392 MW (163 plants) of this thermoelectric capacity is associated solely with a combustion cycle (i.e., no water use).

Associated water withdrawal and consumption (Figure 5) do not track exactly the electric power capacity due to differences in operations and water use coefficients (Appendix A) across the fuel types. Withdrawals are largely attributed to coal steam production and to a slightly lesser extent nuclear. In contrast the largest consumption is associated with nuclear followed by coal steam. This reversal between withdrawal and consumption is simply a function of the water use coefficients. Withdrawal levels are noted to be over 50 times greater than consumption. This reflects the fact that 59% of the thermoelectric generation capacity in the region (a total of 80 plants) utilizes open-loop cooling. Here we have neglected evaporative losses off reservoirs serving hydroelectric power plants. These losses are neglected as the reservoirs generally serve multiple purposes including irrigation/municipal/industrial water storage, flood control and recreation. Thus it is particularly difficult to appropriately distribute these losses to the multiple sectors (so we don’t associate the evaporative losses with any particular sector).

Figures 2-5, which are aggregated at the regional-level, tell only a part of the story. In particular, water withdrawal/consumption and electric generation capacity are not uniformly distributed across the watershed. Figure 6 presents water withdrawal and consumption by state and sector. Here we have excluded withdrawal and consumption taken directly from the lakes. In other words this is the water taken directly from the watersheds and groundwater aquifers in each of the states. Water withdrawal is dominated in each state by thermoelectric power generation. In all but Indiana, thermoelectric withdrawals are larger than all other sector withdrawals combined. Consumption gives a very different picture in which the industrial sector dominates, while thermoelectric, municipal and irrigation consumption are of similar magnitude but vary considerably by state. This is largely because most thermoelectric power plants in the Great Lakes basin use open-loop cooling systems that have high water withdrawal requirements but relatively low water consumption factors.

Electricity generation capacity also varies by state and sector (Figure 7). Generation capacity for coal, nuclear and natural gas is relatively evenly distributed by state while oil and hydroelectric capacity are largely limited to New York and Michigan. Here we show all capacity physically located with the Great Lakes watershed regardless of the type of plant (i.e., thermoelectric or not) or the source of cooling water. Also shown in Figure 7 is the physical location of all thermoelectric power plants that utilize a steam cycle (combustion plants excluded). The plants are further coded by fuel type.

Water demands and power production are further disaggregated to the 8-digit watershed level (Figures 8-9). The most striking feature of the water withdrawal/consumption maps is the significant variability among watersheds as well as the difference between use patterns for the thermoelectric and non-thermoelectric sectors (Figure 8). Thermoelectric withdrawals and consumption vary from watershed to watershed with many watersheds having no water use for thermoelectric power. In contrast, every watershed is characterized by at least some non-thermoelectric water use. It is also interesting to note that water withdrawals for thermoelectric dominate over non-thermoelectric, while the opposite is true of consumption. Again, this is likely because most thermo-electric power systems in the Great Lakes watershed use open loop cooling, so very little water is consumed by this sector (an estimated 1.5% of water withdrawn), while consumptive use is much greater for other water use sectors. Based on our calculated withdrawal and consumption values for 2007, the consumptive use factor for irrigation is 67%, 16% for the municipal sector, 47% for the industrial sector, 8.7 percent for mining and 25% for livestock. Maybe most important feature of Figure 8 is that thermoelectric withdrawal and consumption tend to occur in watersheds with large non-thermoelectric use.

Water demands for thermoelectric production have been further disaggregated by cooling water source (Figure 9). Water withdrawals (and associated consumption) directly from non-Great Lake water resources is shown. A total of 81 power plants or 26% of the Great Lakes watershed’s total electric generating capacity comes from thermo-electric power plants that withdraw water from groundwater or a Great Lakes tributary (as opposed to one of the Great Lakes). Looking at watershed and groundwater withdrawals and consumptive uses can help determine where those withdrawals/consumptive uses might have potential conflicts or measurable impacts on aquatic resources (e.g., by looking at the unique water supply and demand characteristics of that watershed). In terms of withdrawals 4.4 BGD of water are abstracted from surface water sources (other than the Great Lakes) and 0.75 BGD from groundwater. Consumptive use is similar with 0.082 BGD coming from surface water and 0.002 BGD from groundwater. Withdrawals from surface water are broadly distributed across the region while groundwater withdrawals are largely limited to central Michigan. It is also noted that areas of high water withdrawal largely correspond to areas of high consumption.

Of ultimate concern is the impact of water use choices on the environment and aquatic resources. To assist with this, the low flow indicator of environmental quality as established by the GLEW Environmental Team is calculated for current conditions and for each of the alternative energy futures or scenario analyses described in Section 3.2 below. Figure 10 shows the low flow indicator for conditions in 2007. Highest environmental quality values (shaded blue) are located in the Upper Peninsula and northern Michigan as well as far northeastern New York. These are largely areas removed from large human population centers. As of 2007, 62 watersheds are classified as in excellent condition, 21 in good condition, and 24 with vulnerable environmental conditions.

3.2. Scenario Analyses

According to the 2007 data presented above, thermoelectric power production plays a key role in water use in the Great Lakes region, while Figure 10 clearly indicates that several watersheds are environmentally vulnerable due to current water use. Even so, every indication suggests that the demand for water is going to increase. Based on projections from the U.S. Census Bureau (2004), population within the Great Lakes watershed is expected to grow from 22.6 M in 2007 to 29.9 M by 2035, a 32% increase. Over the same period of time electric power demand is projected to grow from 230 to 288 million mega Watt hours (MMWh) (EIA 2010), also a 25% increase.

We do not know exactly how the U.S. population will grow, how power and water use characteristics will change in time, or how the electric power plant fleet will evolve to meet the growing needs. Nor do we know what policies may be enacted that impact the energy and water sectors. For this reason we utilize a series of five possible future realities, termed scenarios, to explore the nexus between energy and water. These include:

1. ***Business as Usual Case (BAU).*** This scenario assumes population growth consistent with that estimated by the Census Bureau and growth in power demand that follows EIA projections (as noted directly above). Siting of new power plants is accomplished in such a way as to maintain the 2005 ratio of local watershed electric production (8-digit watershed) to Great Lakes watershed production. New power plant construction is assumed to adopt a similar fuel mix (Figure 5) and cooling mix (62% open-loop, 31% closed-loop cooling tower, and 7% closed-loop cooling pond) to that characterizing the fleet in 2007. Likewise, new plants will utilize the current mix of source water for thermoelectric production; specifically, 79% Great Lakes, 18% other surface water and 3% groundwater. Also assumed is that there will be no changes to current policies regulating power plant intake structures or green-house gas emissions.
2. ***No New Open Loop Cooling (NNOLC).*** This scenario adopts the same assumptions as the BAU scenario with two exceptions. First, no new power plant construction will utilize open loop cooling. Second, a worst-case assumption was used which depends less on lake water for new construction. Here, worst-case is from the perspective of the tributary surface waters. Specifically, the new source water mix is taken as 15% Great Lakes, 70% other surface water and 15% groundwater. This worst-case shift in source water looks at the possibility that the reduced volume of water required for cooling (shift from open-loop to closed-loop cooling) coupled with the relatively high cost of lake-front property might lead to a shift away from the Great Lakes as the water source. Another assumption, that siting factors other than lake-front property costs are dominant in determining future plant locations and resulting in no change to the current ratio of water sources (79% Great Lakes, 18% other surface water and 3% groundwater), is explored in Appendix B.
3. ***Open Loop Cooling Prohibited (OLCP).*** This scenario employs a new policy restricting use of open-loop cooling intake structures on both new and existing power plants. In this case no new power plants will utilize open loop cooling. Also, all existing power plants with open loop cooling will be retired or converted to a closed loop system (see the electric power module section for details). Any plant older than 35 years with a capacity factor of 20% or lower is assumed to be retired (thresholds based on the professional judgment of the GLEW project team). The policy will take effect in 2015 with a target

achievement date of 2030. All other assumptions are similar to that in the BAU case except that the water source mix for future power plant construction is distributed according to 15% Great Lakes, 70% other surface water and 15% groundwater (this same scenario but with the current mix of source water is shown in Appendix B). This scenario is designed to be an extreme case requiring all open loop plants to retrofit or retire with most of the resulting new development occurring away from the Great Lakes.

4. ***Renewable Portfolio Standard (RPS).*** This scenario adopts the same assumptions as that for the NNOLC case except for the assumed future fuel mix employed in new plant construction. The new mix favors renewables in efforts to achieve the production targets set in the RPS policies set by the Great Lakes states. The model as it is currently configured does not balance electricity production at the state level, hence specific state RPS targets cannot be managed by the model. Noting that most Great Lakes states have aggressive RPS targets we consider a case that favors high renewable expansion while utilizing a fuel mix with accompanying low water demand. Specifically, new plant construction is assumed to be limited to 50% wind, 25% biofuel and 25% NGCC.
5. ***Carbon Capture and Sequestration (CCS).*** This scenario adopts a policy capping green-house gas emission. Here we assume green-house gas levels must be reduced to 20% of the levels in 2007. The policy will take effect in 2015 with a target achievement date of 2030. Selection of plants for retirement is based on the work of NETL (2007a, b) as described in Section 2.2. New plant construction is assumed to follow the mix in the RPS scenario and new cooling type mix and source water will follow that in the NNOLC case.

We now project into the future to the year 2035. As future demands are unknowable the analysis utilizes five alternative energy futures or scenarios (as described above). Each scenario aims to quantify tradeoffs in terms of water withdrawal, water consumption, and environmental vulnerability to low flows (an indicator of impact on aquatic resources) relative to the five scenarios. Also of interest is understanding the extent to which new thermoelectric power production will compete with growing demands in other water use sectors. Other analyses will help identify how each scenario is likely to risk compliance with or trigger a regional review under the Great Lakes and St. Lawrence River Basin Water Resources Compact.

Power Production: For all five scenarios, future demand for electric power is driven by the reference projections of EIA (2010). Nevertheless, the scenarios largely result in different requirements for construction of new electric power generation capacity (Figure 11). The BAU and NNOLC scenarios result in similar growth in capacity; specifically, the region’s capacity grows to 77,704MW, which represents a 13% increase. There is no difference in capacity as the two cases only differ in the applied cooling system. The OLCP scenario results in the lowest 2035 generation capacity. The projected capacity of 74,828 MW (8.5% increase) is lower than the BAU case because many poorly utilized plants have been retired and replaced with plants with a higher capacity factor. The RPS scenario results in a sizeable increase over the BAU scenario. This capacity of 87,347 MW (27%) reflects the relatively low capacity factors associated with NGCC, wind and biofuel generation relative to the BAU mix which is heavy in coal and nuclear generation. Additional capacity is required to operate carbon capture and sequestration equipment resulting in a projected capacity of 98,134 MW (42% increase) for the CCS scenario.

Regional Withdrawal and Consumption: Variation in thermoelectric power production and mix of power plant fuel type across the five scenarios result in differences in thermoelectric water demand. Figure 12 gives the projected water withdrawal and change in withdrawal between 2007 and 2035. Withdrawal across the five scenarios is further compared against thermoelectric withdrawals in 2007 and projected withdrawals in 2035 by the municipal and industrial sectors. There is a large disparity in withdrawal across the five scenarios. **Highest growth in withdrawal is associated with the BAU case, 2695 MGD or a 10% increase.** It is also noted that most of this water will come from the Great Lakes (80%). The NNOLC case results in the second largest rise in withdrawal at 37 MGD. Due to retirement of plants on the basis of age and the assumption that only 15% of future withdrawals will be from the Great Lakes (in all cases except BAU it is assumed that the reduced volume for water required closed-loop cooling coupled with the relatively high cost of lake-front property will encourage higher utilization of non-Great Lakes water), total withdrawals from the Great Lakes decrease by72 MGD while stream and groundwater withdrawals increase to 109 MGD. The RPS case follows a very similar trend but with an overall decrease in withdrawals of 36 MGD. This is a function of the very low water use by NGCC and biofuels and no water use by wind combined with the retirement of a few plants on the basis of age. Larger reductions are realized by the CCS case as even more plants are retired, this time due to requirements to retrofit on the basis of green-house gas emissions. This results in a decrease of 2859 MGD coming both from plants sourcing the Great Lakes and basin streams. As expected **the largest reductions in total water withdrawals are associated with the OLCP case, falling by 22,671 MGD or an 87% reduction.** 82% of this reduction is from Great Lakes withdrawals. Growth in the municipal and industrial sectors is calculated at 803 and 1008 MGD, respectively. This growth is relatively small in comparison to the potential range of change in the thermoelectric sector. Although not reflected here, industrial sector withdrawals will likewise be impacted by EPA's proposed 316b regulation.

In contrast, consumptive water use increases for all five scenarios. Figure 13 provides projected consumption and change in consumption between 2007 and 2035. **The scenario with the least growth in consumption is the RPS with an increase of 31 MGD (7.6% increase).** This reflects the very low water use associated with NGCC and wind generation. The next highest growth comes with the BAU case, 42 MGD or a 10% increase. The NNOLC case results in an increase of 88 MGD (22% increase). This 46 MGD increase over the BAU case simply reflects the higher consumptive use associated with closed-loop systems. The OLCP scenario results in the interesting case of increasing consumption of 65 MGD (16%), midway between the BAU and NNOLC cases. The reason that the OLCP doesn't result in a higher consumption than the NNOLC is because of the retirement of older plants with less efficient cooling equipment (e.g., higher consumptive use coefficients) and subsequent replacement with newer plants with lower consumptive use factors (Appendix A). The highest growth is associated with the CCS case, 97 MGD (24%). This case does not benefit from retirement of the same set of plants as the OLCP case and additional water is consumed in the carbon capture and sequestration process.

Growth in consumptive use by the municipal sector is of similar magnitude to thermoelectric, 105 MGD (16.6%). Industrial growth is roughly double that of thermoelectric and municipal at 230 MGD (14.5%). Note that growth in consumptive use is more focused on stream and groundwater sources for the thermoelectric cases (except the BAU). This is because of our assumption of source distribution (15% Great Lakes, 70% streams, 15% groundwater). Municipal and industrial are still assumed to heavily rely on the Lakes.

Local Withdrawal and Consumption: We now turn our attention to how new water demands for thermoelectric production are distributed locally, that is by 8-digit watershed. Recall that the model assumes that new power plants are sited so as to maintain the 2005 ratio of local watershed electric production to Great Lakes watershed production. Here we **limit our analysis to changes in tributary (non Great Lake) surface and groundwater withdrawals**. The picture for consumptive use will follow closely that for withdrawal and thus would be redundant. Great Lakes withdrawal and consumption are distributed across the entire body of water and thus would not benefit from a localized analysis.

Figure 14 shows new stream withdrawals (not water from the Great Lakes) for the period 2007 to 2035. Shown are new thermoelectric withdrawals for each of the 5 scenarios plus a separate graph showing new non-thermoelectric withdrawals. Ultimately, these graphs show the change in demand for water (withdrawals) under each thermo-electric power generation scenario for each watershed between 2007 and 2035. Figure 14a, which depicts non-thermoelectric growth in water demand, shows a clustering of higher growth near high-population areas. However, this association is limited by the fact the many municipal areas rely heavily on Great Lakes water which is not reflected in this map. The highest projected growth in water demand from thermo-electric power generation by an individual watershed is 55 MGD which occurs under the BAU scenario, while numerous watersheds have negligible projected growth.

The greatest watershed-level increase in withdrawal is realized with the BAU scenario (Figure 14). Most high growth watersheds are located near the Great Lakes reflecting our assumption to site new plants where the current highest density of power production occurs. Individual watershed demands range from 120 MGD to most seeing negligible new thermoelectric withdrawal. The NNOLC scenario shows very minimal growth in thermoelectric withdrawal. In fact only a handful of watersheds indicate any growth in water demand, with the largest new water demands being less than 20 MGD. The OLCP scenario results in many watersheds realizing a net reduction in thermoelectric water withdrawal. In fact, roughly 20 watersheds show a net reduction while only 4 show an increase. New water withdrawals by individual watersheds range from -700 to 20 MGD. The RPS scenario map looks almost identical to that of the NNOLC case due to the fact that both assume no new open loop cooling and neither is subject significant retirement or retrofitting of existing plants. The CCS scenario shows a mix of watersheds experiencing net growth and net reduction in withdrawal. The several watersheds showing growth reflect the expanded need for electric power generation due to CCS. The fact that fewer watersheds result in net reductions relative to OLCP scenario reflects the retirement of fewer plants with open loop cooling that depend on surface water sources.

Figure 15 shows changes in groundwater withdrawal for Great Lakes 8-digit watersheds under each of the scenarios. Comparison of new non-thermoelectric groundwater withdrawal (Figure 15a) to new non-thermoelectric surface water withdrawal (Figure 14a) reveals a very similar pattern. That is, both appear to reflect areas of high human activity and thus the demand for greater water supplies from the Great Lakes, surface water and groundwater resources. Growth in groundwater demand ranges from negligible in many watersheds to 30 MGD at a maximum.

The five maps corresponding to the different scenarios show relatively similar results. This is largely due to the fact of the relatively small number of thermo-electric power plants relying on groundwater in the region. One watershed experiences a significant decline in water withdrawal while another realizes a relatively large increase (70 MGD). The decline is associated with a plant retirement while the one large plant is an artifact of the plant placement algorithm. That is a large new plant happened to be sited in a watershed dependent on groundwater (the siting order was disrupted in the OLCP case). Otherwise the BAU case shows a few additional watersheds with growth in groundwater withdrawal while the OLCP scenario resulted in a few additional watersheds with net reductions in withdrawal.

Environmental Analysis: A key interest to this analysis is the potential impact of thermoelectric power expansion on environmental quality of the Great Lakes watershed. To explore this issue the low flow indicator (Equation 9) is utilized. This indicator is a ratio of streamflow to water withdrawal during the driest time of year, which is also the time of year of highest human demand. Thus, increasing withdrawals for thermoelectric production will reduce this ratio. When this ratio dips below 0.5 there is the potential for environmental degradation.

Figure 16 compares the number of watersheds in the Great Lakes basin that are classified as excellent, good, or vulnerable relative to environmental quality. Using 2007 data for the BAU case against which we can compare the five scenarios, 78% of the HUC-8 watersheds are classified as good or excellent, while 22% (24 watersheds) were classified as vulnerable. According to the five future energy scenarios, the number of new vulnerable watersheds could either increase or decrease by 2035. Under the BAU scenario 6 new basins change to vulnerable status, the scenario subject to the greatest new withdrawals. The NNOLC and RPS scenarios result in three watersheds shifting to vulnerable, while the CCS results in no new vulnerable watersheds. In contrast, the OLCP scenario reduces the number of vulnerable watersheds from 24 to 18 (an improvement of 6 watersheds). The retirement and/or retrofitting of older plants with open-loop cooling are no doubt the cause of this improvement.

Of interest is the contribution of thermoelectric withdrawals to watersheds classified as vulnerable. Ignoring thermoelectric withdrawals (i.e., looking only at withdrawals by other water use sectors) only 14 watersheds (13%) would be classified as vulnerable (Figure 16). This is in contrast to the 24 watersheds classified as vulnerable when all withdrawals are considered. If thermoelectric withdrawals are ignored in 2035, 15 watersheds would be classified as vulnerable, this is in contrast to between 18 and 30 as projected under the 5 future scenarios (Figure 16).

Vulnerable watersheds can also be viewed at the 8-digit watershed level. Figure 17 shows the low flow indicator for all five scenarios. Also shown is the low flow indicator in 2035 if no thermoelectric withdrawals were to occur. Sensitive watersheds are largely located along the western side of Lake Michigan, western Michigan, southwestern Lake Erie, and south of Lake Ontario. These sensitive areas tend to match areas of high human activity and high thermoelectric power production. Differences across the 5 scenarios can be detected with careful inspection.

Differences among the scenarios are more evident in Figure 18 where increases in water withdrawal are shown for those basins which have been identified as hydrologically vulnerable or sensitive (e.g., where the low flow indicator is 0.5 or less using Equation 9). To make these new withdrawals more evident, watersheds with a net reduction in withdrawal are not shown in these figures (see Figure 14 for basins with reduced withdrawals). From these figures it is evident that only the BAU scenario results in any significant increase in withdrawal from sensitive watersheds (only case that assumes any new open loop cooling). In this case a couple of watersheds experience growth of 100 MGD and a few others grow by about 20 MGD. Maximum growth in any single sensitive watershed for the other 4 cases is less than 20 MGD. What is interesting is that over these four cases (NNOLC, OLCP, RPS, and CCS) the number of vulnerable watersheds range from 18 to 27, yet the maximum new withdrawal is less than 20 MGD. This suggests that a number of these watersheds are right on the edge between good and vulnerable conditions.

From Figure 18 the number of sensitive watersheds where thermoelectric withdrawals occur can be determined. In 2007 nineteen of the 24 sensitive watersheds had thermoelectric withdrawals (Figure 10). New construction in the BAU, NNOLC, and OLCP scenarios occurred in 9, 7, and 5 sensitive watersheds, respectively. In the case of the RPS and CCS, all sensitive watersheds had some new thermoelectric activity (27 and 24, respectively); however, levels of new withdrawal were very small. This jump in the number of basins reflects the relatively large number of small NGCC and biofuels plants constructed under these scenarios.

It should be recalled that this analysis has assumed a business as usual case in terms of siting new power plants. That is, new plants are assumed to be built in those watersheds with the highest density of existing power plants (i.e., siting of new power plants maintain the 2005 ratio of local watershed electric production to Great Lakes watershed production). This assumption is not unreasonable given the desire to maximize utilization of existing transmission capacity and utilization available plant facilities/land (i.e., adding new unit at an existing facility). However, careful siting might also attempt to locate plants away from environmentally sensitive areas.

Compact Analysis: Also of interest to this analysis is the potential impact on thermoelectric power expansion from water use regulation pursuant to the Great Lakes and St. Lawrence River Basin Water Resources Compact. To explore this issue, the number of times the compact withdrawal and consumption thresholds (state thresholds as given in Table 1) are triggered by a new power plant is calculated. Figure 19 compares the total withdrawal and consumption subject to regulation and permitting for the five future energy scenarios (total regulation and permitting over the entire Great Lakes Watershed). There is a large spread in the number of plants that may require regulation and permitting, ranging from 22 for the NNOLC scenario to 113 for the CCS scenario. The lowest number of potentially regulated new withdrawals is associated with the NNOLC and OLCP scenarios which tend to have the lowest overall withdrawals. The BAU scenario has the next largest number of potentially regulated new withdrawals (34) as associated withdrawals are increased over the NNOLC and OLCP cases. The RPS and CCS have a significantly larger number of potentially regulated new withdrawals, 84 and 113 respectively. This big jump in number is due to the much larger number of plants constructed (NGCC and biofuels are small and have lower capacity factors relative to coal and nuclear which dominate the new construction for other scenarios).

To accomplish this analysis new plants are assumed to be sized to the average of current plants in the basin and operate according to the average capacity factors (size and capacity averages by fuel type). All plants will not be built to these averages and hence the chances of triggering a permitting threshold will be different than presented here. However, what this analysis displays is that it is likely that many of the new plants will need to obtain water withdrawal permits.

The number of plants exceeding the compact consumption threshold are less than that for withdrawal (Figure 19), ranging from 1 to 12. This is largely due to the fact that the consumption thresholds are generally larger for each state than the corresponding withdrawal threshold. The highest number of exceeding plants is associated with the NNOLC and OLCP scenarios, 12 and 12 respectively. This trend is counter to the withdrawal case because the NNOLC and OLCP cases have higher consumption and lower withdrawals due to the shift from open-loop to closed-loop cooling. The BAU has no new plants exceeding the consumption threshold, largely due to the heavy use of open-loop cooling. The RPS and CCS scenarios have few plants that exceed the consumption threshold, 2 each. This is because relatively small and low water use plants are being constructed.

Figures 20 and 21 map the plants that would be subject to permitting and regulation by 8-digit watershed, respectively. This reflects the location where the greatest density of plant construction is occurring which is consistent across all cases (as we have assumed new construction will mimic the historic density of power production in the Great Lakes Watershed). Plants exceeding both the withdrawal and consumption compact thresholds also tend to be clustered in New York and Wisconsin where thresholds tend to be lower than other states. Facilities subject to permitting are also relatively common in Michigan, largely due to the high density of plant construction in select watersheds.

Again, it should be recognized that these results are highly dependent on assumptions concerning where future power plants are sited. Here we have assumed future siting fill follow very similar trends to that of the past.

4. Key Findings

According to the detailed analysis above, several key findings are summarized below:

1. Water withdrawal and consumption metrics for thermoelectric power generation are significant in the Great Lakes Watershed. The thermoelectric sector accounts for 76% of the basin’s withdrawals and 13% of the consumption. Most of this water use comes directly from the Great Lakes, accounting for 81% of all withdrawals from the Great Lakes.
2. Thermoelectric water use characteristics could radically change over the next 25 years due to increasing demands, and potential policies aimed at encouraging green energy development, reducing green-house gas emissions, and regulating large water intake structures. To explore the impacts associated with these possible changes, five alternative future energy scenarios were investigated, a Business as Usual (BAU); No New Open

Loop Cooling (NNOLC); Open-Loop Cooling Prohibited (OLCP); Renewable Portfolio Standard (RPS); and Carbon Capture and Sequestration (CCS).

3. According to these five scenarios, water withdrawals for thermoelectric power production in 2035 could grow by 2695 MGD (10%) for the BAU scenario or decrease by 22,671 MGD (87%) for the OLCP scenario. Alternatively, all cases result in growth in consumptive use ranging from 31 MGD (7.6%) for RPS to 97 MGD (24%) for the CCS scenario. Less dependence on direct lake diversions is expected if restrictions on open-loop cooling are enacted (cost of lake-front property would encourage siting of new facilities away from the lake).
4. In comparison non-thermoelectric withdrawals are projected to increase by 1811 MGD while consumption will grow by 335 MGD. Fortunately, some of the new growth in the thermoelectric sector is projected to occur in watersheds experiencing negligible non-thermoelectric growth.
5. Any increase in water use has the potential to impact environmental quality of the Great Lakes Watershed. To explore this energy-water-environment nexus a low flow indicator is calculated. It is the ratio of streamflow to total withdrawals in the driest and highest human water use month of the year (August). Watersheds with a ratio less than 0.5 are classified as having vulnerable environmental quality. In 2007, twenty-four watersheds or 22% were classified as vulnerable, 19 of which had some thermoelectric withdrawal. Projected growth in the thermoelectric sector is expected to increase the number of watersheds classified as hydrologically vulnerable by 3, 3, and 6 for the NNOLC, RPS and BAU cases respectively. The CCS and OLCP do not increase or reduce the number.
6. Also explored was the potential for new power plants to obtain water withdrawal permits pursuant to state programs required by the Great Lakes and St. Lawrence River Basin Water Resources Compact (state mandated thresholds were used). Permitted facilities would range from 22 (NOLC) to 113 (CCS) and tend to be clustered in New York, Wisconsin, and Michigan. Fewer facilities subject to permitting due to consumptive water use are projected ranging from 1 (BAU) to 12 (316b), which largely match the locations for withdrawal violations.

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Appendix A: Water Withdrawal and Consumption Factors

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December 1, 2010

Overview:

This document contains initial water withdrawal/consumption factors and parasitic energy use factors**.** Table 1 contains initial water consumption factors for renewable electricity technologies. Table 2 contains initial water consumption factors for non-renewable electricity technologies. Table 3 contains initial water withdrawal factors for non-renewable electricity technologies. Renewable water withdrawal factors are assumed to equal water consumption factors.

Methods:

We consider water withdrawals and consumption for the operational phase only. Operational water use in this study includes cleaning, cooling, and other process-related needs that occur during electricity generation, such as flue gas desulfurization (FGD) in coal facilities. The energy technologies addressed here consist of configurations of coal, natural gas, nuclear, geothermal, biopower, wind, solar photovoltaic (PV), and concentrating solar power (CSP) technologies. Cooling system technologies considered include wet recirculating technologies (cooling towers), once-through cooling system (open loop cooling), air-cooled condensing (dry cooling), hybrid wet and dry cooling systems (hybrid cooling), and pond cooling systems.

Estimates of water consumption and withdrawal have been calculated irrespective of geographic location. Withdrawal and consumption factors are often reported in terms of water intensity that are annual averages; water intensity of facilities may change from diurnal and seasonal variations in temperatures and humidity levels, but these inter-annual variations are not examined. This review did not alter (except for unit conversion) or audit for accuracy the estimates of water use published in studies. Also, because estimates are used as published, considerable methodological inconsistency is inherent which limits comparability. Additionally, no distinction is made between water types, which may include freshwater, saline water, or municipal waste water. Data sources include published academic literature, state and Federal government agency reports, non-governmental organizations' (NGO) reports, and industry submissions to government agencies for permitting procedures.

Certain sources report ranges of water consumption and withdrawal factors in place of specific values. If traceable individual case studies form the basis for the range given, the individual values are included as independent estimates within the set of estimates that are statistically analyzed. If a range is given and the underlying data points are not given, then the midpoint of that range is used for calculating an average value, and the high and low extremes are used for determining extreme ranges. This method of addressing ranges may lead to a slight bias toward data sources reporting explicit cases, and may also underestimate actual water use at facilities, as the midpoint of the range extremes are in general less than values reported from individual facilities.

Table 1. Water consumption factors for renewable technologies[2] (Gal/MWh)

Plant Type	Cooling	Technology	Primary factor	Low	High	Min	Max	n	Sources
PV	N/A	Utility Scale PV	16	0	32	0	33	3	11,18,20
Wind	N/A	Wind Turbine	0	0	1	0	1	2	1,12
CSP	Tower	Trough	896	796	995	725	1109	17	5,11,14,16,18,27,28,30-35
		Power Tower	793	738	847	751	912	4	18,27,28,31
	Dry	Trough	73	61	84	43	79	10	14,32-34
		Power Tower	26	26	26	26	26	1	3
	Hybrid	Trough	263	126	399	117	397	3	6,32
		Power Tower	170	57	283	102	302	2	6
	N/A	Stirling	5	4	5	4	6	2	4,18
		Fresnel	1000	1000	1000	1000	1000	1	6
Biopower	Tower	Steam	638	412	863	480	965	4	4,8,9
		Biogas	235	235	235	235	235	1	19
	Once-through	Steam	300	300	300	300	300	1	8
	Pond	Steam	390	390	390	390	390	1	8
	Dry	Biogas	35	35	35	35	35	1	9
Geothermal	Tower	Dry Steam-(freshwater)	0	0	0	0	0	1	11
		Dry Steam-(geothermal fluid)	1796	1796	1796	1796	1796	1	11
		Flash-(freshwater)	12	2	22	5	19	2	4,17
		Flash-(geothermal fluid)	2583	1853	3314	2067	3100	2	17
		Binary	3088	1872	4303	1700	3963	3	11,15
		EGS	4272	3057	5488	2885	5147	4	9,11,15
	Dry	Flash	0	0	0	0	0	1	9
		Binary	0	0	0	0	0	1	9
		EGS	1185	1185	1185	1185	1185	1	9
	Hybrid	Binary	221	221	221	221	221	1	15
		EGS	1406	1406	1406	1406	1406	2	9,15

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[2] Primary factors represent simple averages, whereas low and high values represent averages minus and plus one standard deviation, respectively.

Table 2. Water consumption factors for conventional technologies[3] (Gal/MWh)

Plant Type	Cooling	Technology	Primary Factor	Low	High	Min	Max	n	Sources
Nuclear	Tower	Generic	684	542	825	581	845	5	8,11,26,29
	Once-through	Generic	212	49	376	100	400	3	8,21,26
	Pond	Generic	560	560	560	560	560	1	8
Natural Gas	Tower	Combined Cycle	227	159	296	130	300	5	8,18,24-26
		Steam	853	639	1068	662	1170	4	4,11,22,29
		Combined Cycle with CCS	487	487	487	487	487	1	23
	Once-through	Combined Cycle	73	27	120	20	100	3	8,22,26
		Steam	240	169	311	95	291	2	4,11
	Pond	Combined Cycle	240	240	240	240	240	1	26
	Dry	Combined Cycle	2	0	5	0	4	2	8,26
	Inlet	Steam	340	340	340	340	340	1	4
Coal	Tower	Generic	702	423	981	480	1100	5	7,8,20,21,36
		Subcritical	519	398	640	394	678	6	23,24,26
		Supercritical	525	468	582	458	594	6	23,24,26
		IGCC	383	356	411	358	439	7	23,24
		Subcritical with CCS	1329	1329	1329	1329	1329	1	23
		Supercritical with CCS	1148	1148	1148	1148	1148	1	23
		IGCC with CCS	501	475	527	479	530	3	23
	Once-through	Generic	239	118	360	100	317	3	8,11,21
		Subcritical	107	73	141	71	138	3	26
		Supercritical	97	67	127	64	124	3	26
	Pond	Generic	390	390	390	390	390	1	8
		Subcritical	773	739	807	737	804	3	26
		Supercritical	37	6	67	4	64	3	26

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[3] Primary factors represent simple averages, whereas low and high values represent averages minus and plus one standard deviation, respectively.

Table 3. Water withdrawal factors for conventional technologies[4] (Gal/MWh)

Plant Type	Cooling	Technology	Primary Factor	Low	High	Min	Max	n	Sources
Nuclear	Tower	Generic	1026	919	1132	800	1101	2	8,26
	Once-through	Generic	40066	32418	47713	25000	60000	3	8,21,26
	Pond	Generic	800	800	800	500	1100	1	8
Natural Gas	Tower	Combined Cycle	210	157	263	150	250	3	8,26
		Steam	1203	1199	1206	950	1460	2	4,22
		Combined Cycle with CCS	N/A	N/A	N/A	N/A	N/A		
	Once-through	Combined Cycle	11380	8028	14732	7500	20000	2	8,26
		Steam	35000	35000	35000	10000	60000	1	4
	Pond	Combined Cycle	5950	5950	5950	5950	5950	1	26
	Dry	Combined Cycle	2	0	5	0	4	2	8,26
	Inlet	Steam	425	425	425	100	750	1	4
Coal	Tower	Generic	920	586	1254	500	1200	3	8,20,21
		Subcritical	500	472	528	463	531	4	26
		Supercritical	642	617	667	609	669	4	26
		IGCC	605	605	605	605	605	1	20
		Subcritical with CCS	N/A[5]	N/A	N/A	N/A	N/A		
		Supercritical with CCS	N/A	N/A	N/A	N/A	N/A		
		IGCC with CCS	1009	1009	1009	1009	1009	1	20
	Once-through	Generic	31102	21912	40292	20000	50000	3	8,12,21
		Subcritical	27082	27048	27116	27046	27113	3	26
		Supercritical	22584	22554	22614	22551	22611	3	26
	Pond	Generic	450	450	450	300	600	1	8
		Subcritical	17896	17862	17930	17859	17927	3	26
		Supercritical	15029	14998	15060	14996	15057	3	26

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[4] Primary factors represent simple averages, whereas low and high values represent averages minus and plus one standard deviation, respectively.

[5] N/A: Data not available

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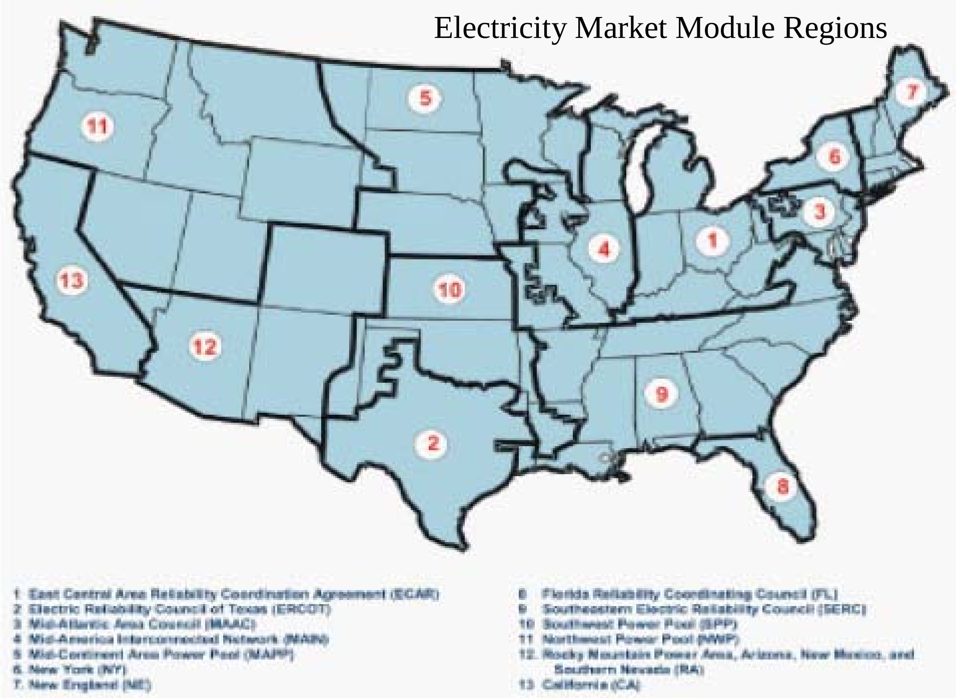

Electricity Market Module Regions

Figure 1: *Great Lakes watershed (top) and associated "energyshed" (Electricity Market Module Regions) that define the spatial dimensions of the modeling domain for the GLEW model.*

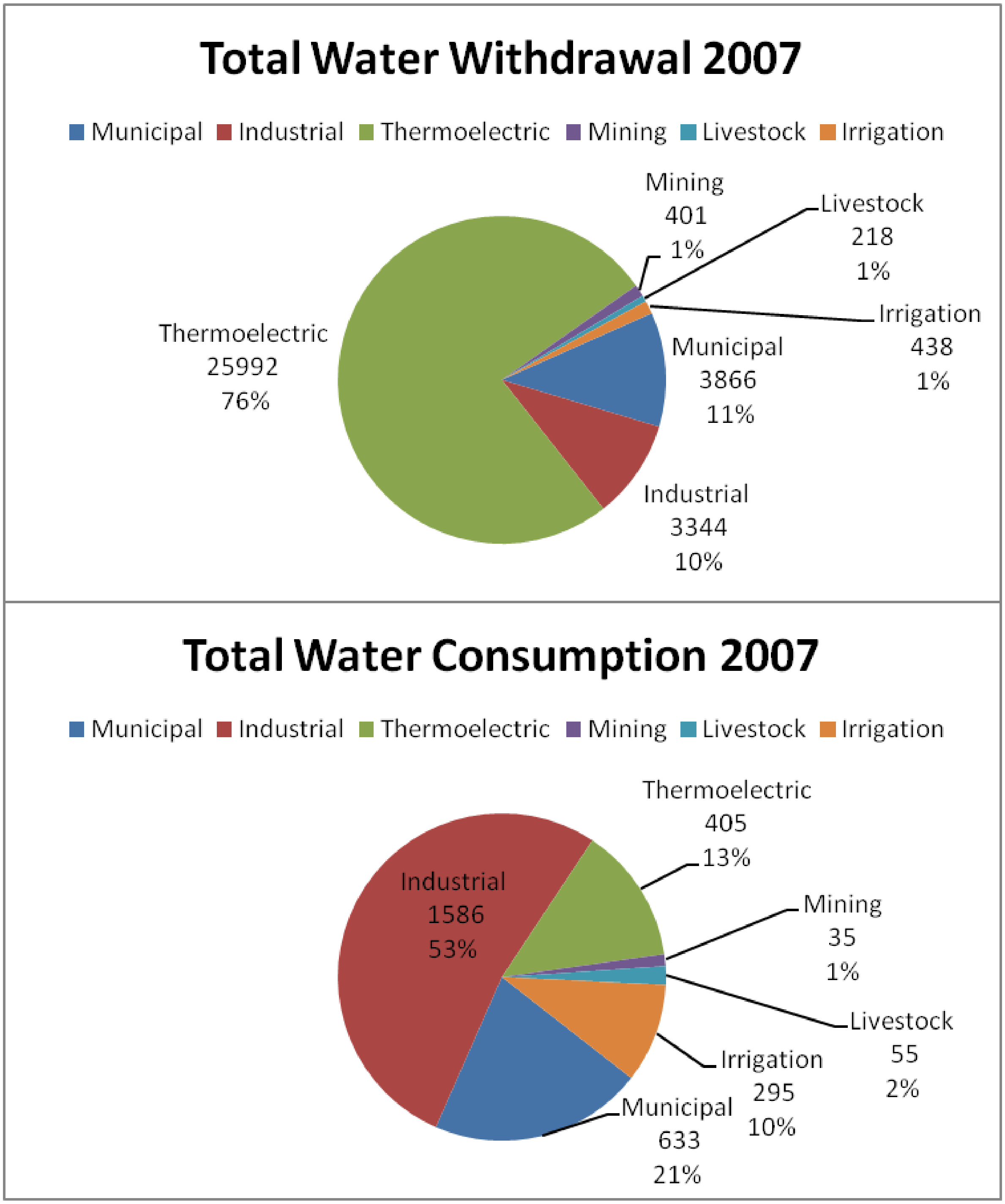


Figure 2: *Pie charts displaying total water withdrawal (top) and water consumption (bottom) for the Great Lakes watershed in 2007 by use sector.* Water values are in units of million gallons per day (MGD)

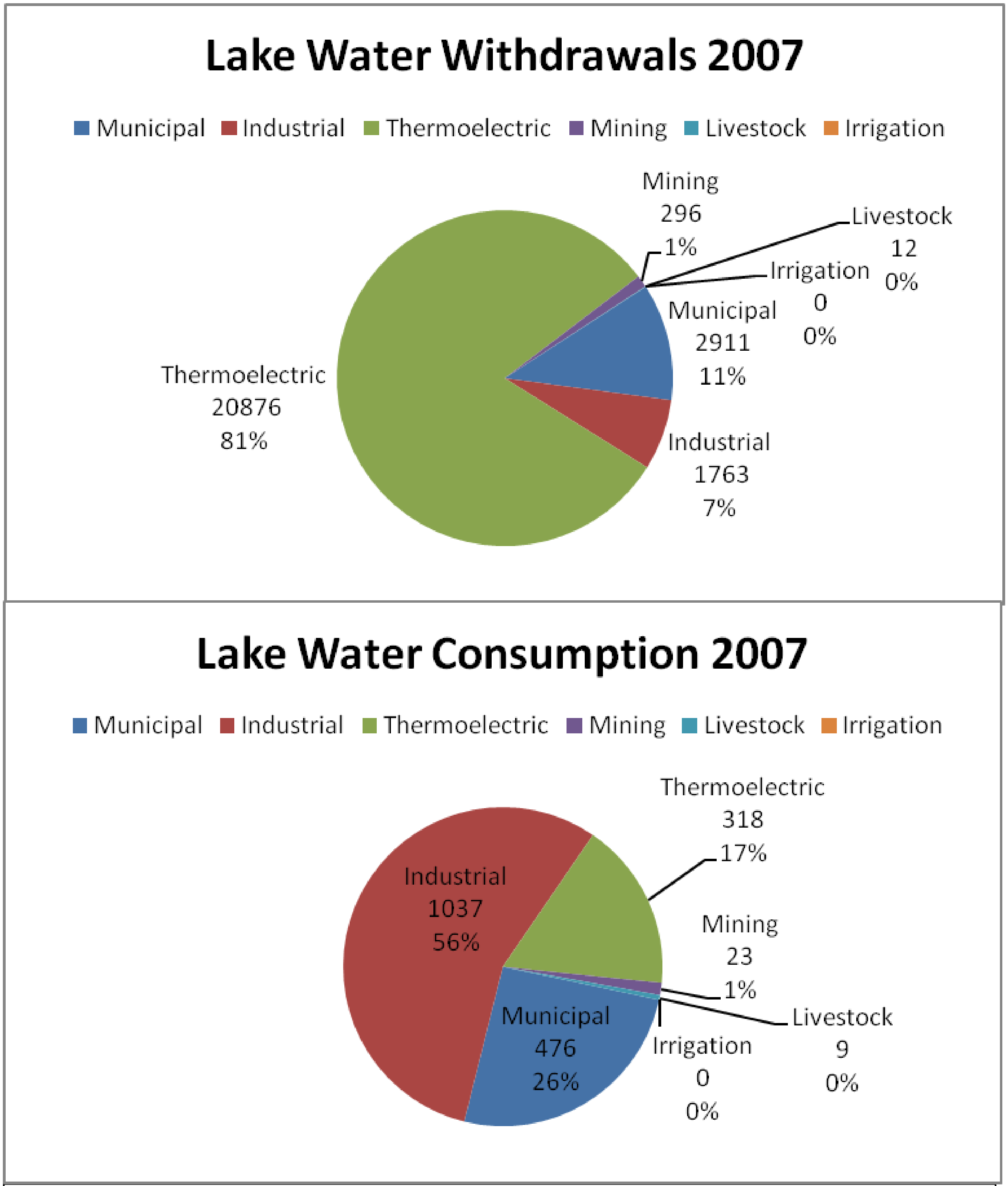
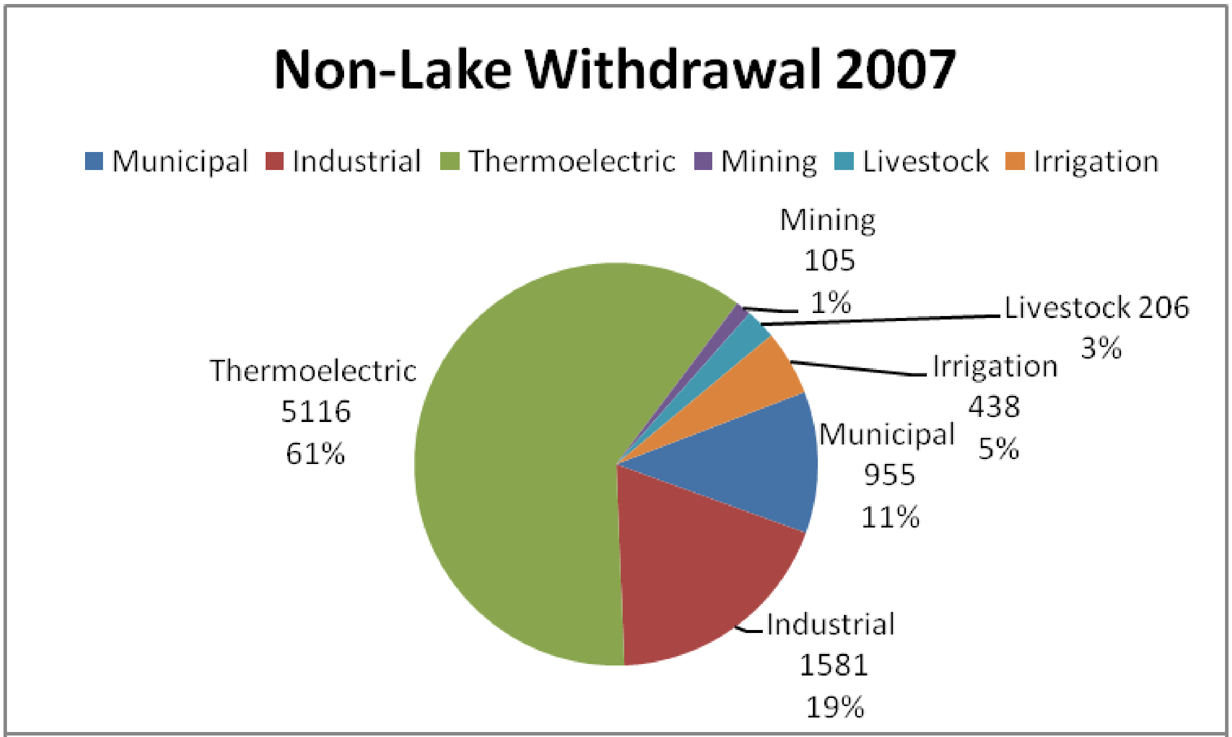


Figure 3: *Pie charts displaying water withdrawal (top) and water consumption (bottom) taken directly from the Great Lakes in 2007. Withdrawal and consumption values are in million gallons per day (MGD).*



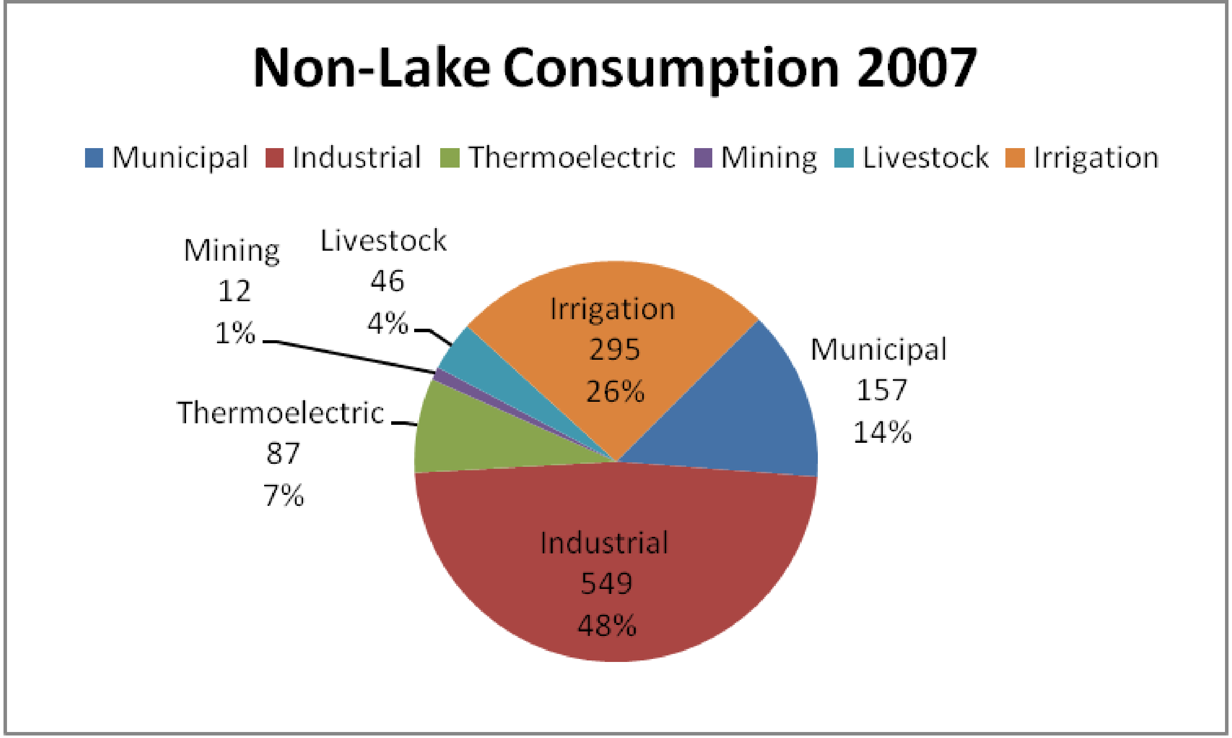


Figure 4: *Pie charts displaying water withdrawal (top) and water consumption (bottom) that is not taken directly from the Great Lakes in 2007. Withdrawal and consumption values are in million gallons per day (MGD).*

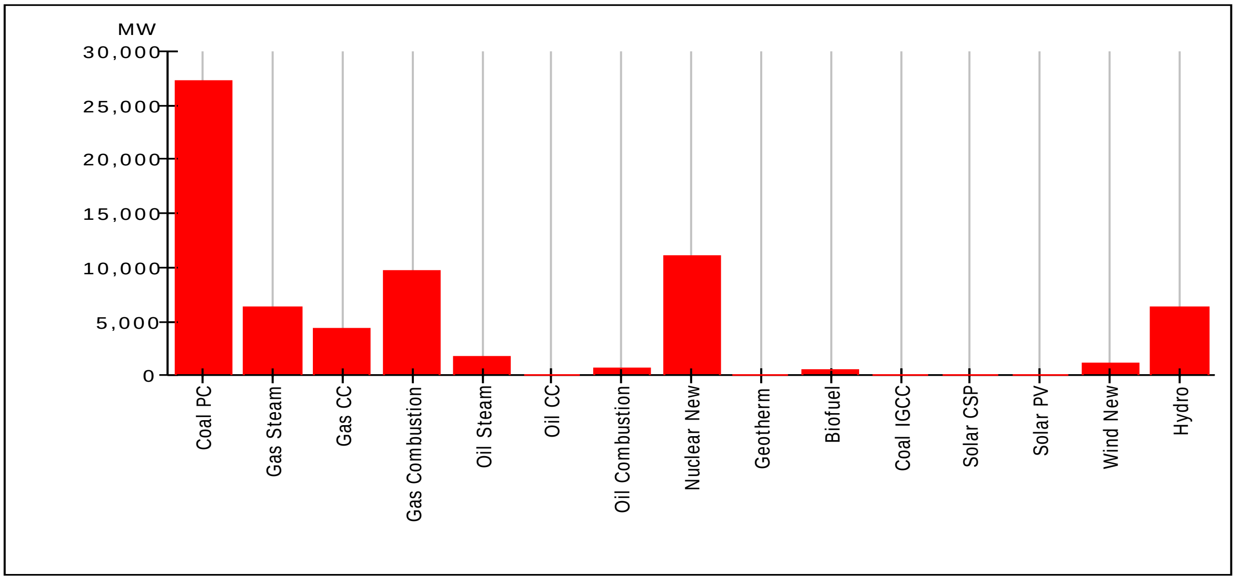


Figure 5: *Electric power capacity (top) and associated water withdrawal (middle) and consumption (bottom) for the Great Lakes watershed in 2007 by use sector.*

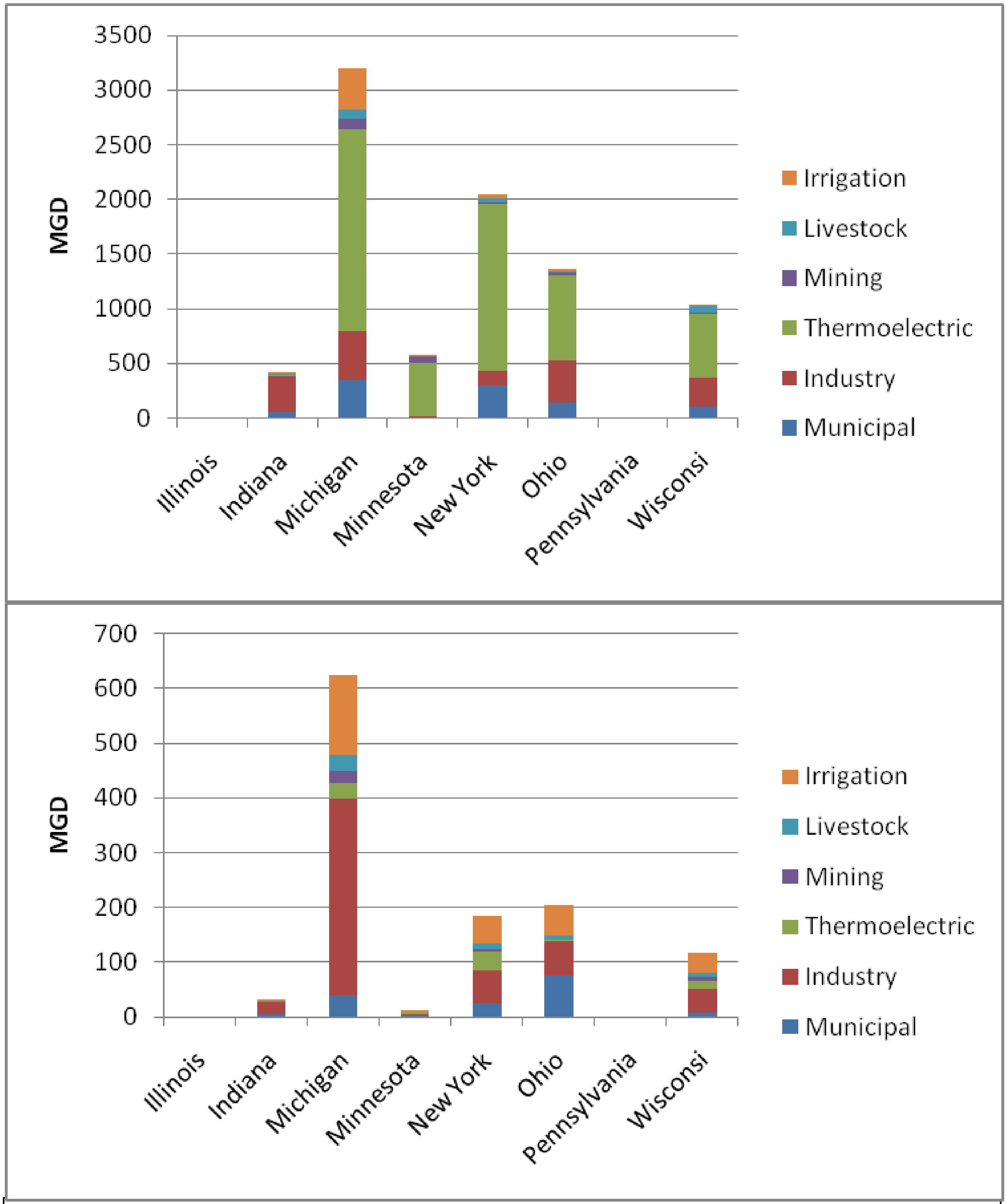


Figure 6: *Water withdrawal (top) and consumption (bottom) by state and water use sector in 2007. Data shown here do not include withdrawal and consumption taken directly from the Great Lakes.*

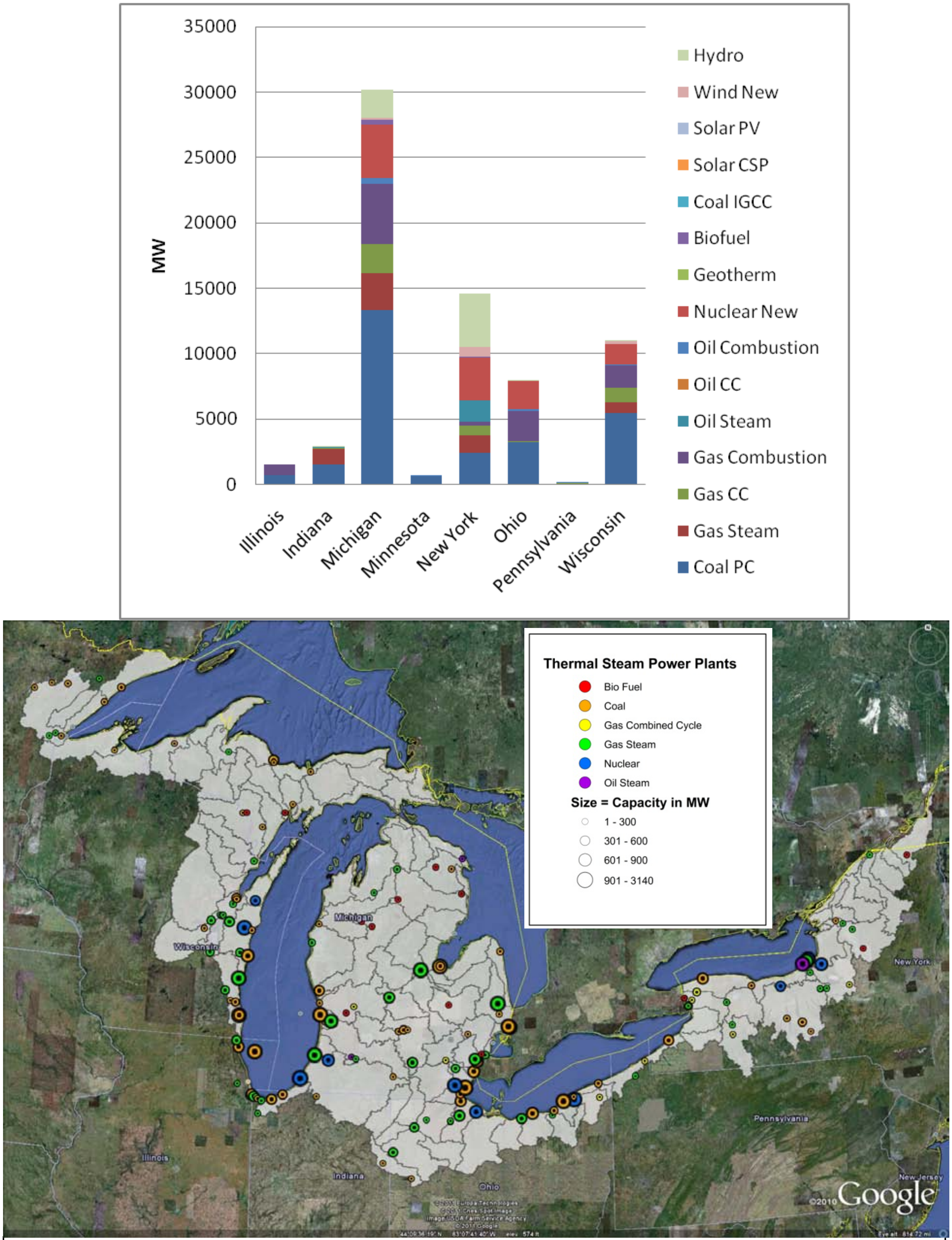
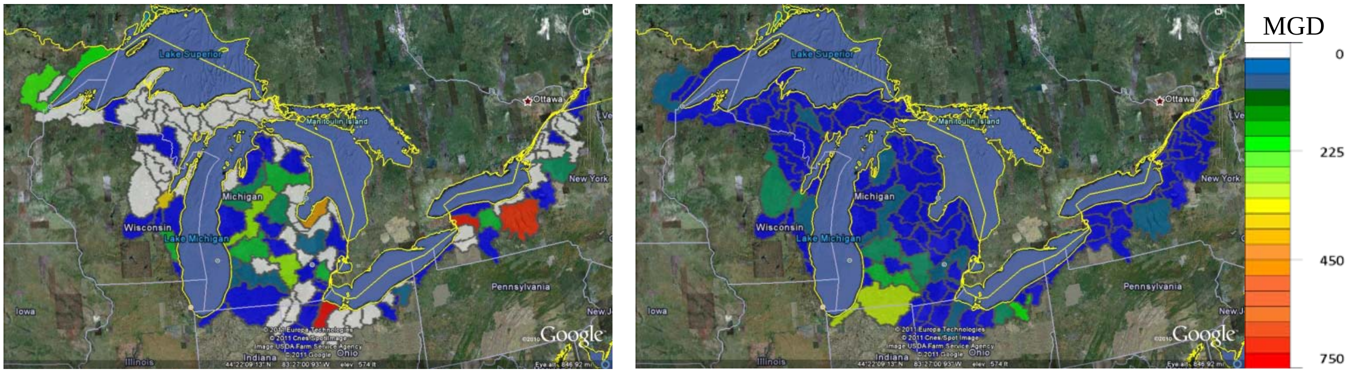
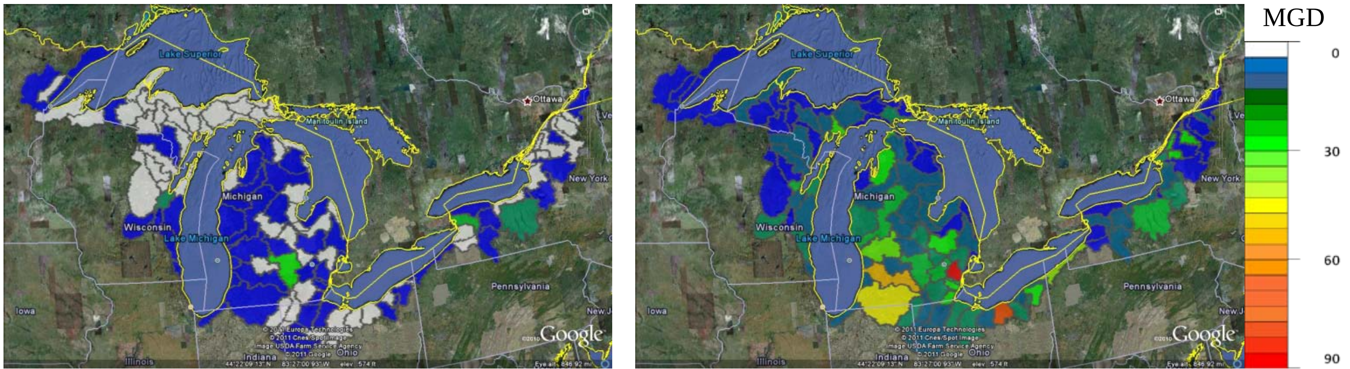


Figure 7: *Electric power generation capacity by state and water use sector in 2007 (top) and location of the thermoelectric power plants in the basin (below). Only those plants physically located within the Great Lakes watershed are included.*



a) Thermoelectric Withdrawals

b) Non-Thermoelectric Withdrawal

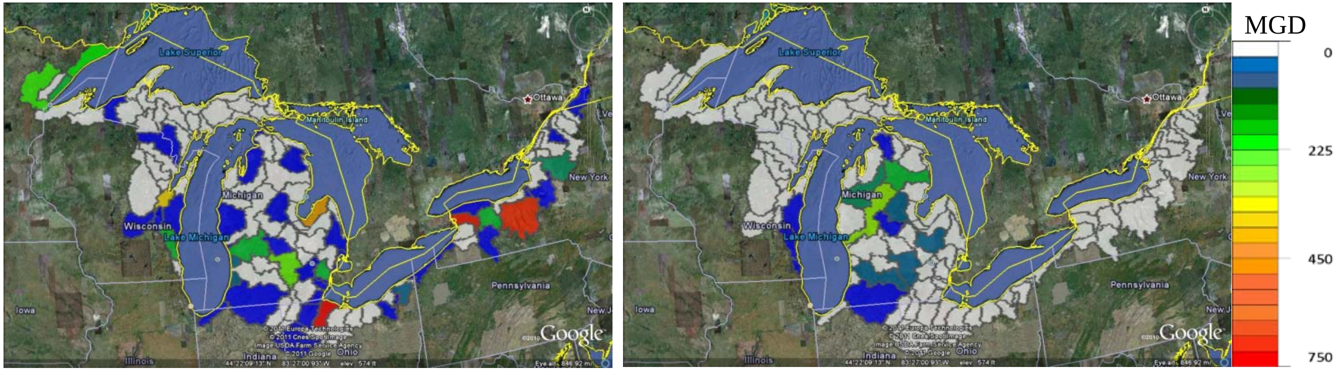


c) Thermoelectric Consumption

d) Non-thermoelectric Consumption

Figure 8: Thermoelectric (left) and non-thermoelectric (right) water withdrawal (top) and consumption (bottom) in the Great Lakes watershed in 2007. Data are displayed at the 8-digit watershed level in units of million gallons per day (MGD).

a) Surface Water Withdrawals b) Groundwater Withdrawals



c) Surface Water Consumption d) Groundwater Consumption

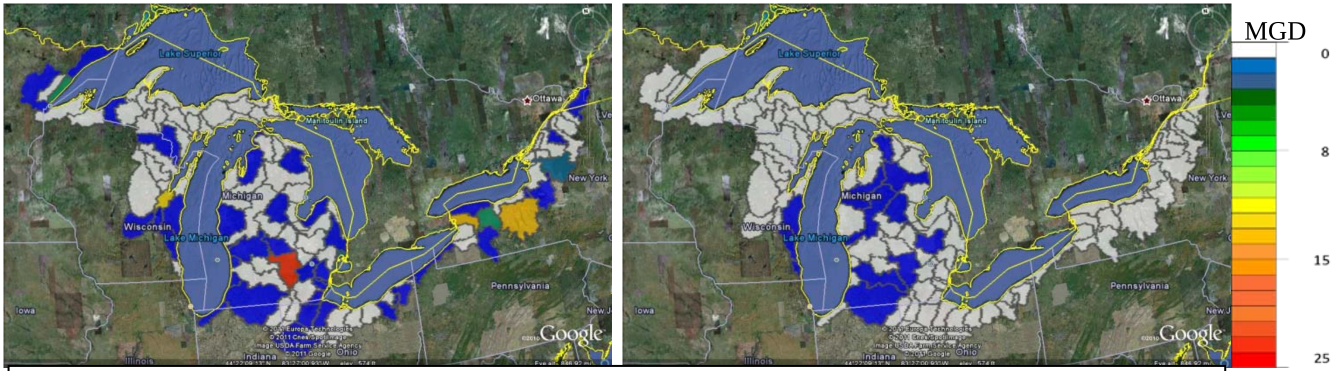


Figure 9: Thermoelectric water withdrawal (top) and consumption (bottom) from **surface water** (left) and **groundwater** (right) sources in the Great Lakes watershed in 2007. Data are displayed at the 8-digit watershed level in units of million gallons per day (MGD). Only withdrawals directly from basin watersheds or aquifers are shown; water withdrawn directly from the Great Lakes is not included.

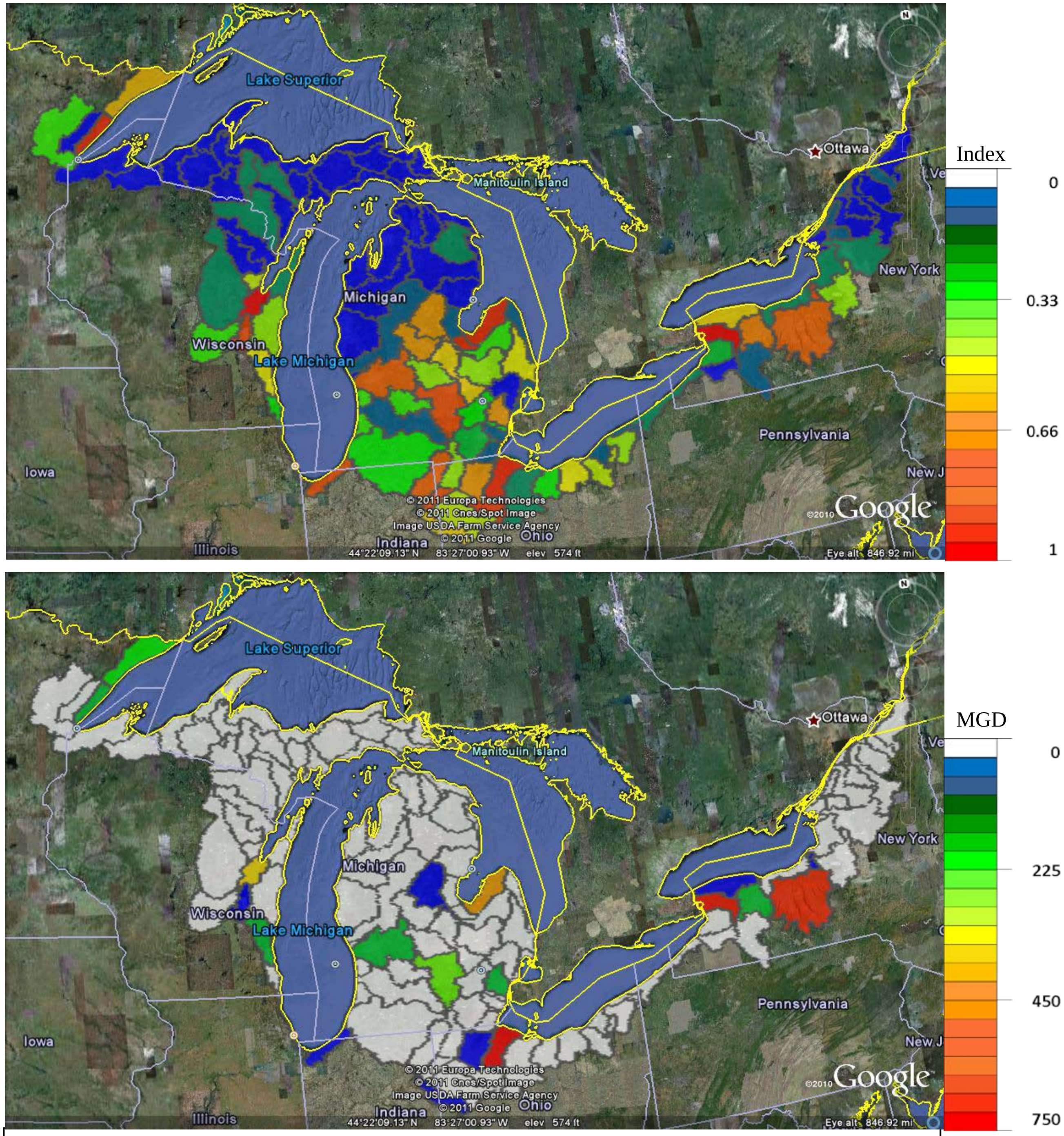


Figure 10: Low flow environmental quality indicator for 2007 (top) and the total thermoelectric water withdrawal from basins where environmental quality is classified as vulnerable (bottom) (Equation 9). Vulnerable or sensitive watersheds are shown by warmer colors (i.e., the closer to red, the more vulnerable the watershed).

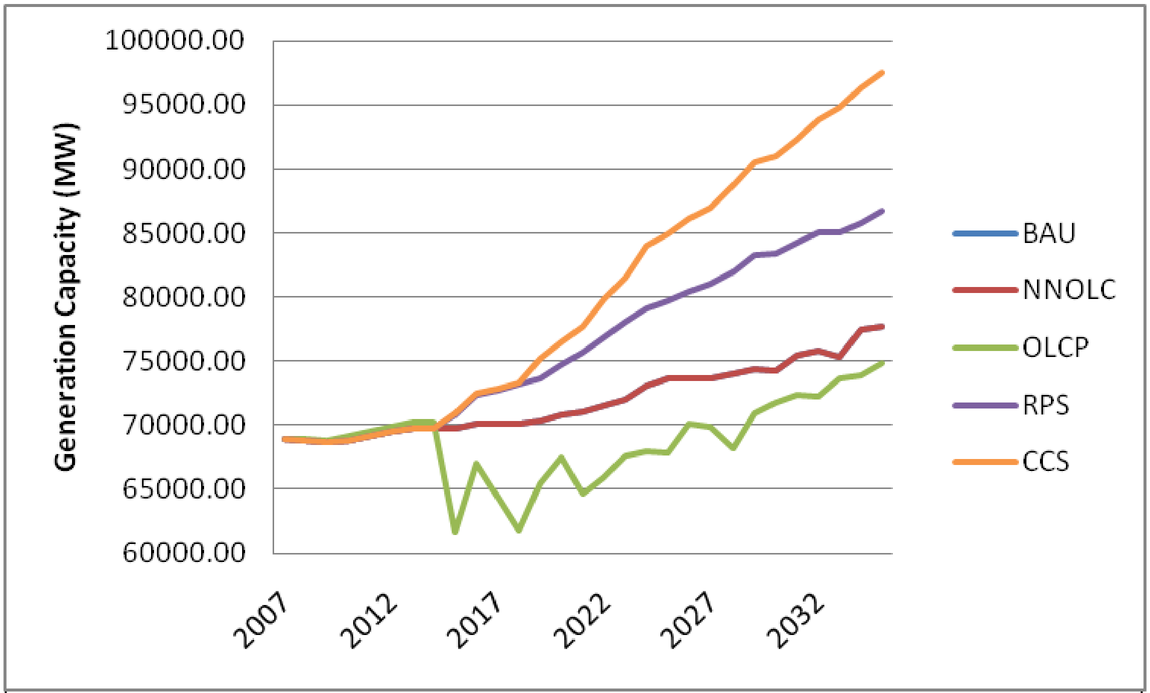
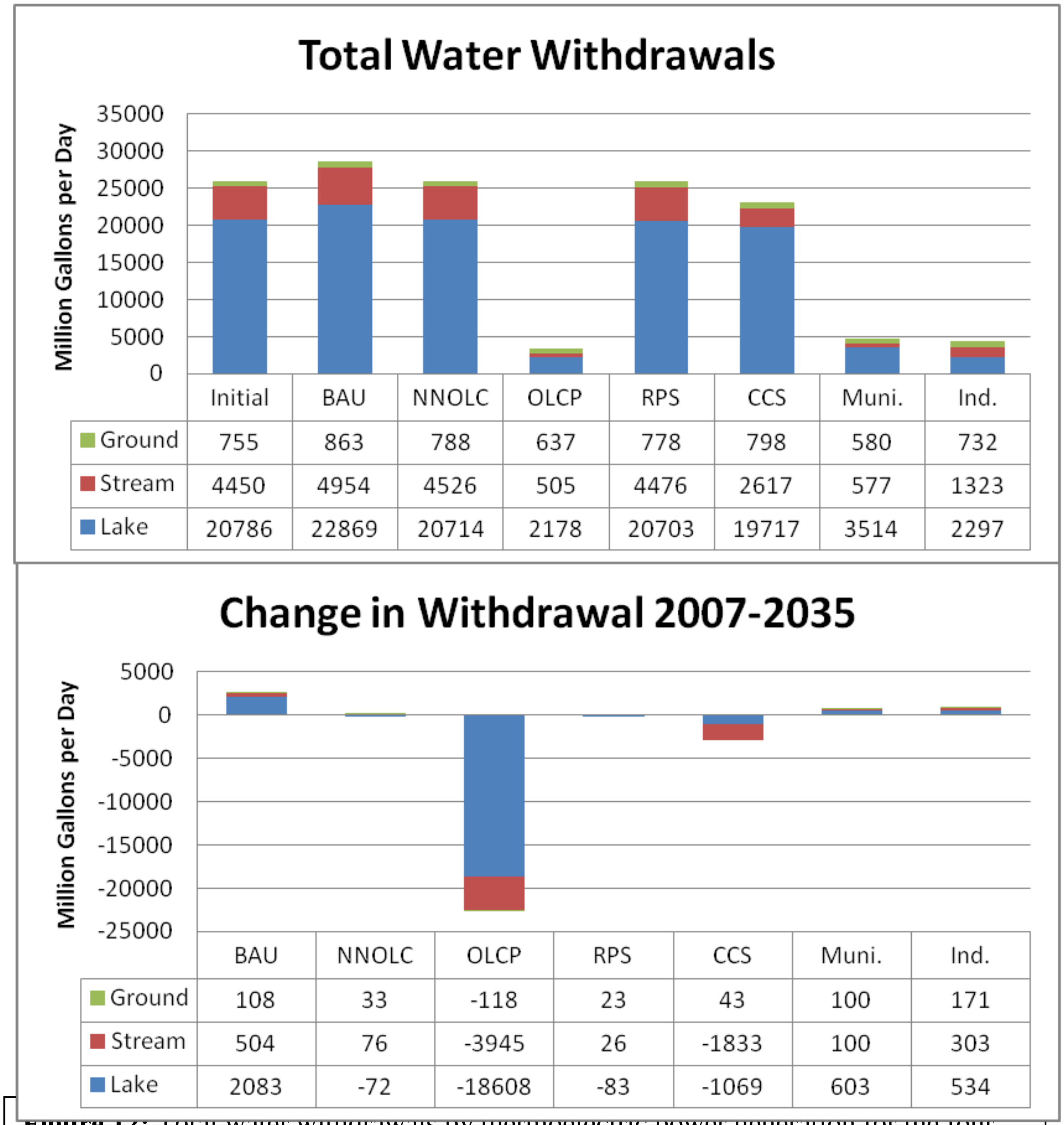


Figure 11: Projected change in electric power generation capacity in the Great Lakes Watershed for the 5 alternative future scenarios.

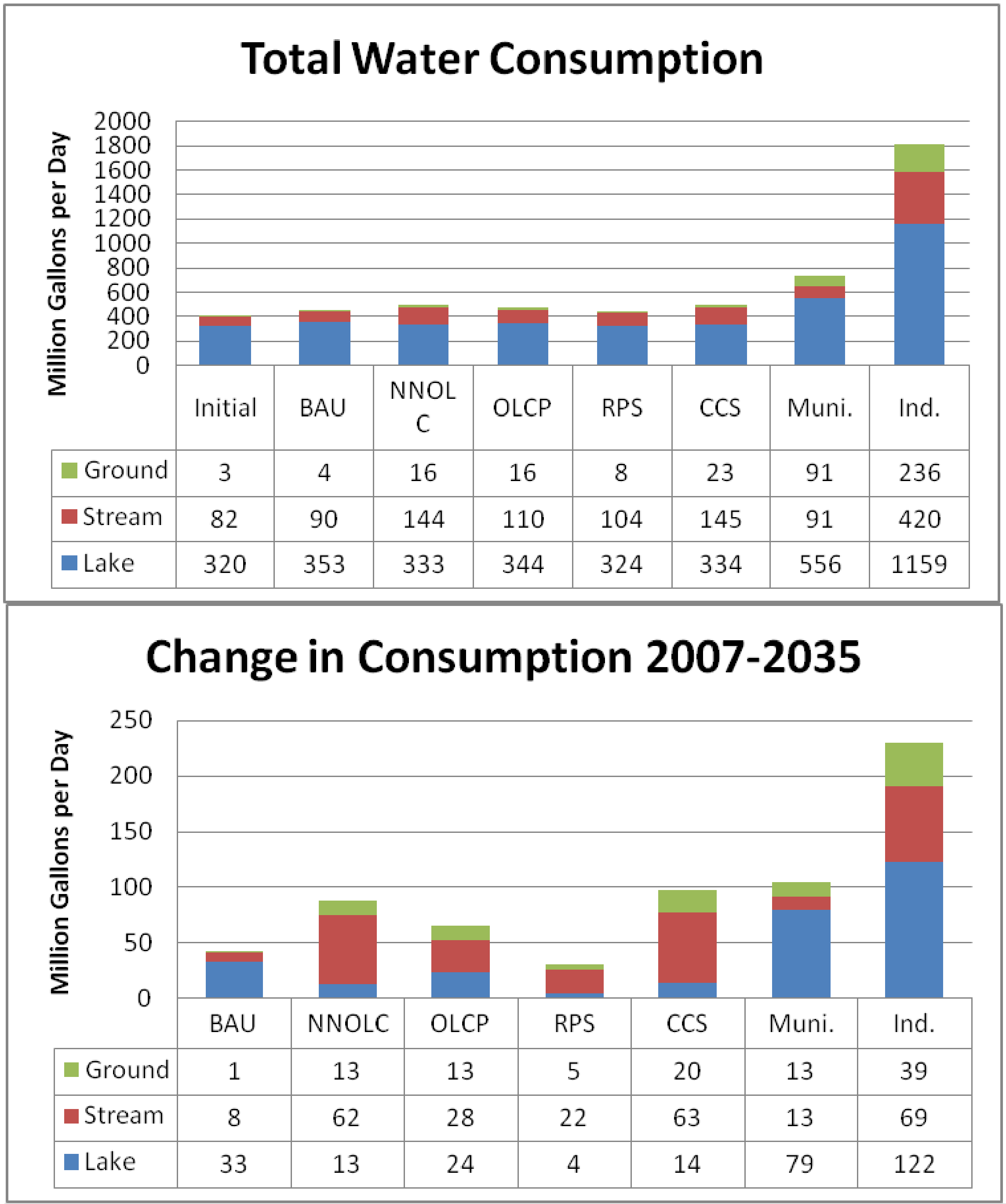

Total Water Withdrawals

	Initial	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
🟩 Ground	755	863	788	637	778	798	580	732
🟥 Stream	4450	4954	4526	505	4476	2617	577	1323
🟦 Lake	20786	22869	20714	2178	20703	19717	3514	2297

Change in Withdrawal 2007-2035

	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
🟩 Ground	108	33	-118	23	43	100	171
🟥 Stream	504	76	-3945	26	-1833	100	303
🟦 Lake	2083	-72	-18608	-83	-1069	603	534

Figure 12: Total water withdrawals by thermoelectric power generation for the four alternative scenarios (top) and the change in water withdrawal between 2007 and 235 (bottom). Also included are withdrawals by the municipal and industrial sectors. Withdrawals are disaggregated by source (Great Lakes, stream, or groundwater).



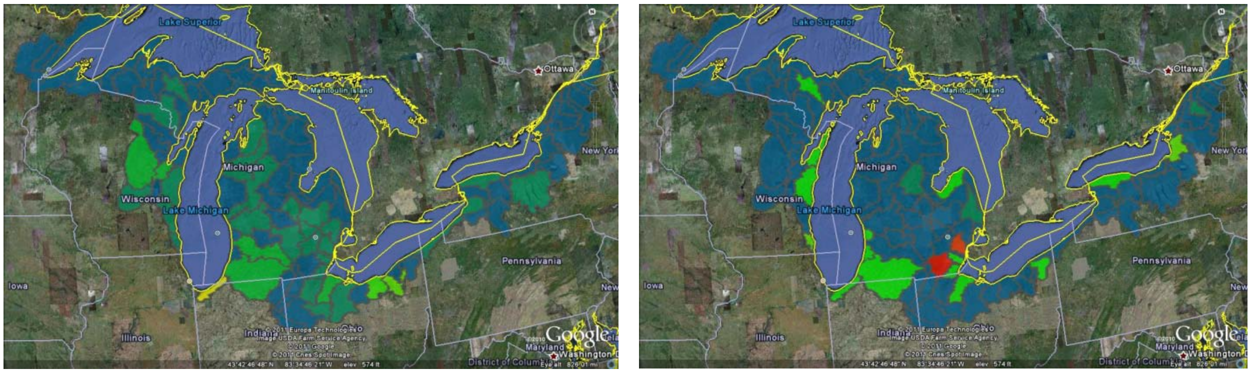
	Initial	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
🟩 Ground	3	4	16	16	8	23	91	236
🟥 Stream	82	90	144	110	104	145	91	420
🟦 Lake	320	353	333	344	324	334	556	1159

	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
🟩 Ground	1	13	13	5	20	13	39
🟥 Stream	8	62	28	22	63	13	69
🟦 Lake	33	13	24	4	14	79	122

Figure 13: Total water consumption by thermoelectric power generation for the four alternative scenarios (top) and the change in water withdrawal between 2007 and 235 (bottom). Also included is consumption by the municipal and industrial sectors. Consumption is disaggregated by source (Great Lakes, stream, or groundwater).

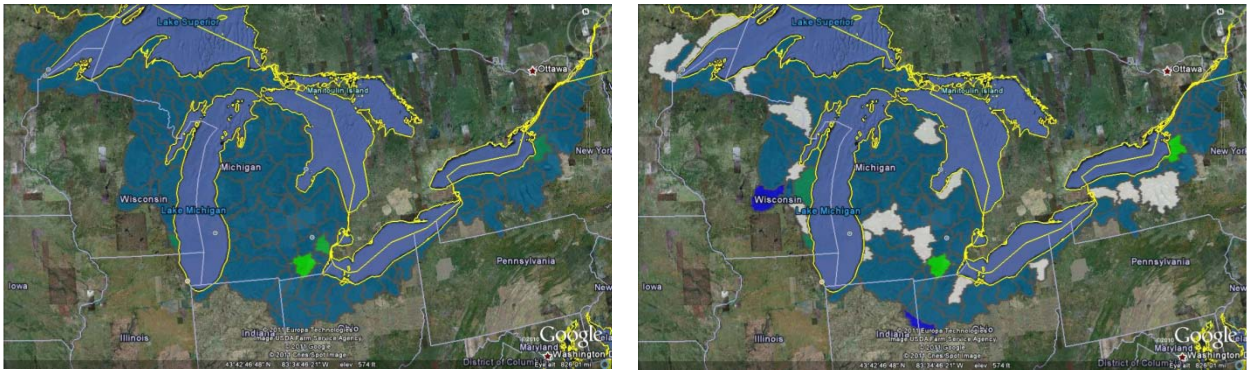
a) New Non-Thermoelectric Withdrawals

b) New Thermoelectric Withdrawals: BAU



c) New Thermoelectric Withdrawals: NNOLC

d) New Thermoelectric Withdrawals: OLCP



e) New Thermoelectric Withdrawals: RPS

f) New Thermoelectric Withdrawals: CCS

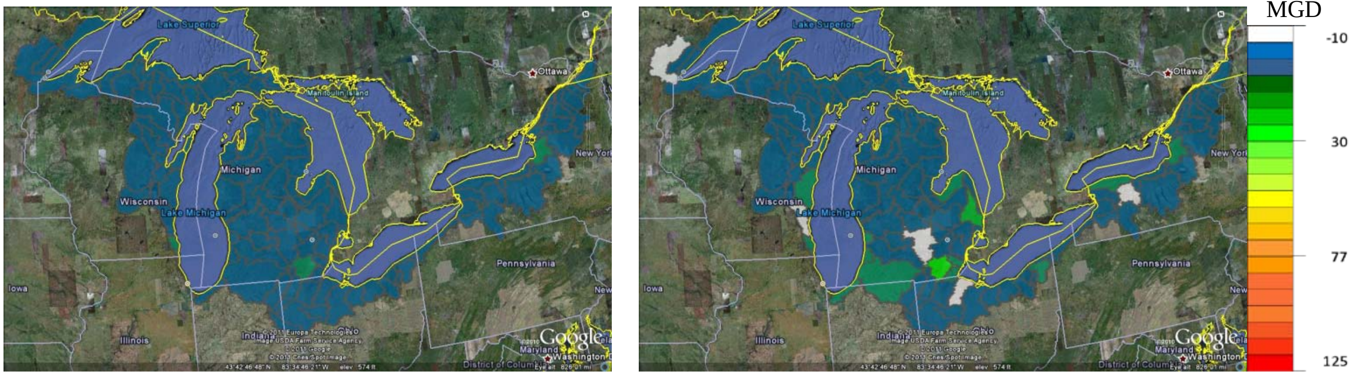
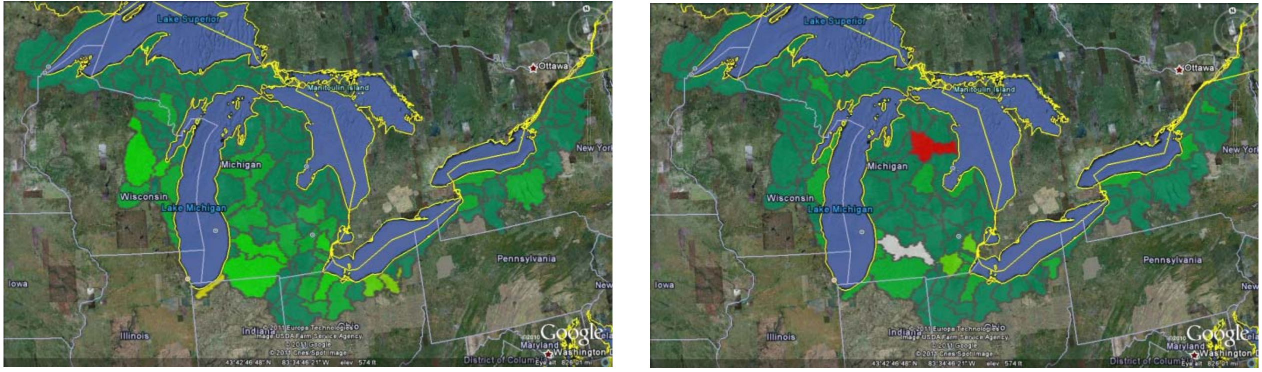
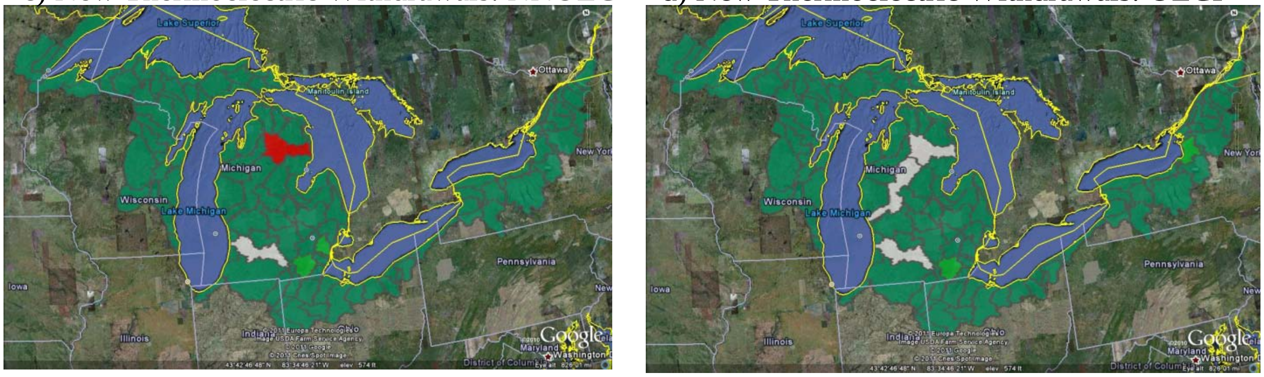


Figure 14: Change in surface water withdrawals between 2007 and 2035. Shown are new withdrawals by non-thermoelectric demands (a) and thermoelectric power generation for the five future scenarios (b-f). Note that watersheds colored white or light blue are where there has been a net reduction in withdrawals. Blue-green designates area of little to no change.

a) New Non-Thermoelectric Withdrawals b) New Thermoelectric Withdrawals: BAU



c) New Thermoelectric Withdrawals: NNOLC d) New Thermoelectric Withdrawals: OLCP



e) New Thermoelectric Withdrawals: RPS f) New Thermoelectric Withdrawals: CCS

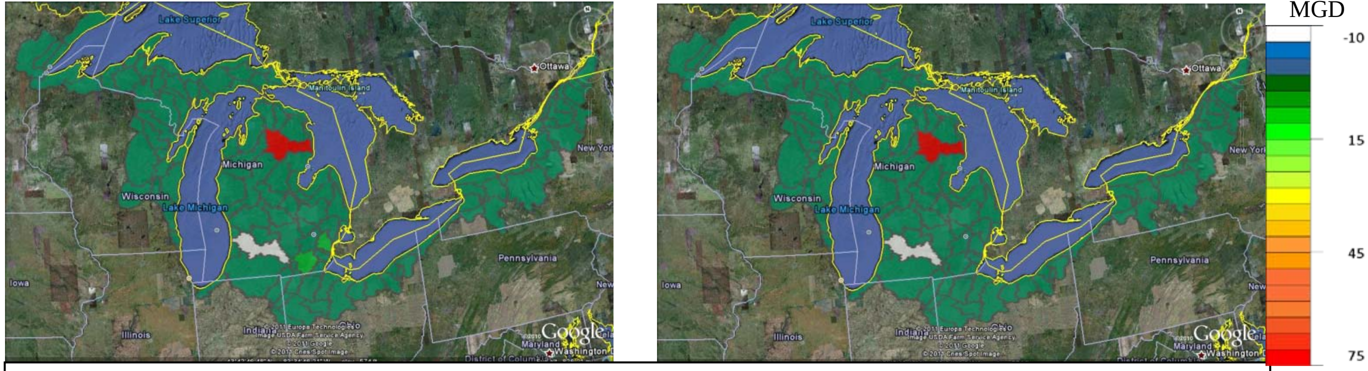


Figure 15: Change in groundwater withdrawals between 2007 and 2035. Shown are new withdrawals by non-thermoelectric demands (a) and thermoelectric power generation for the five future scenarios (b-f). Note that watersheds colored white are where there has been a net reduction in withdrawals. Dark-green designates area of little to no change.

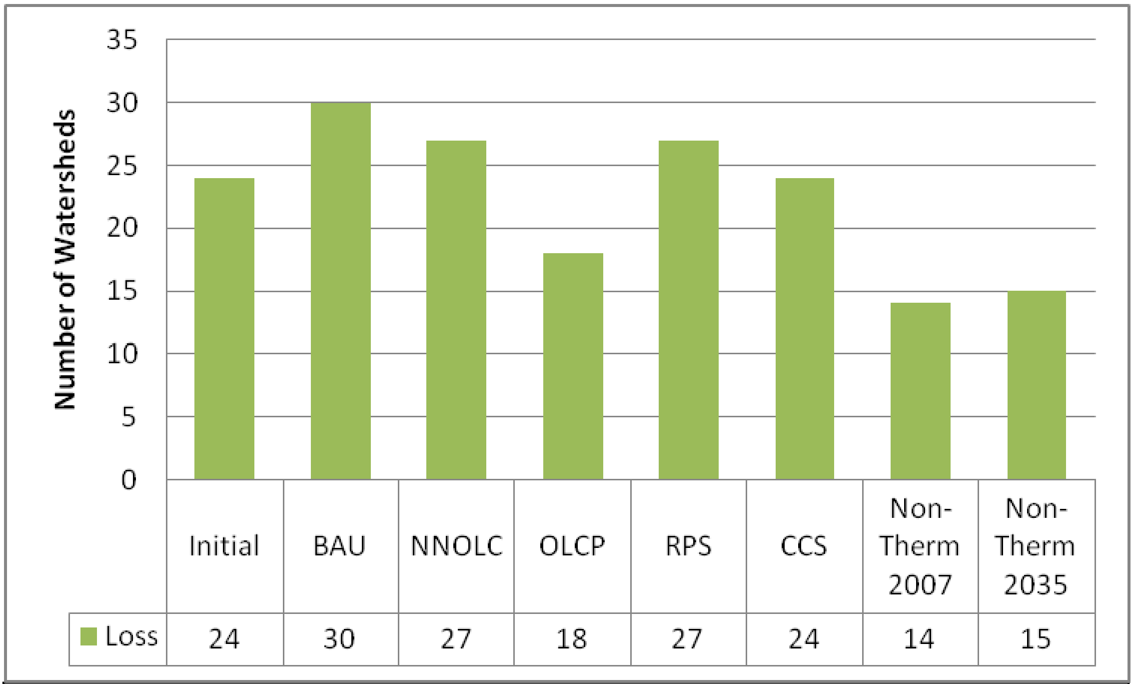
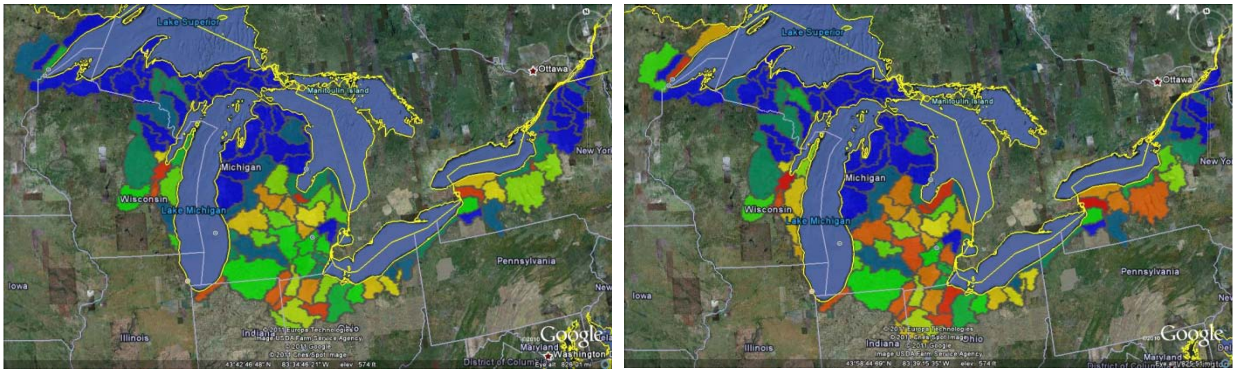
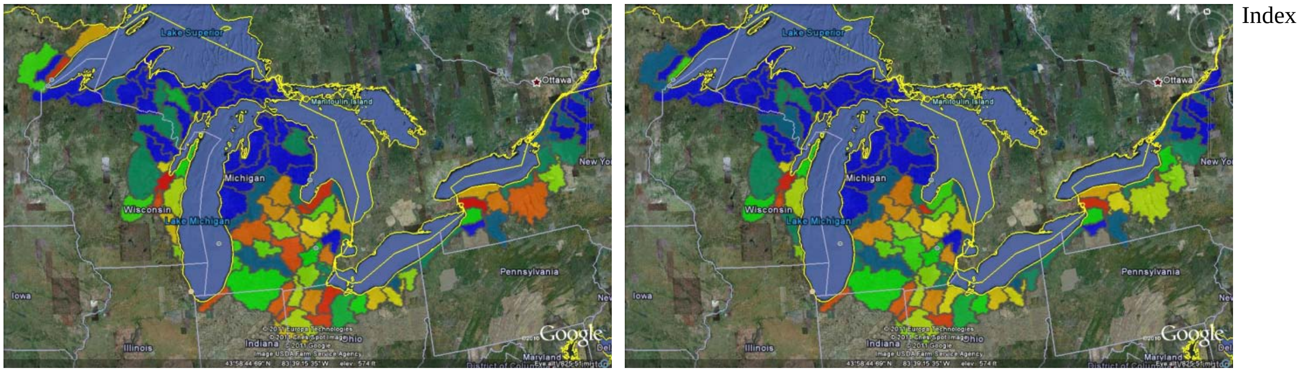


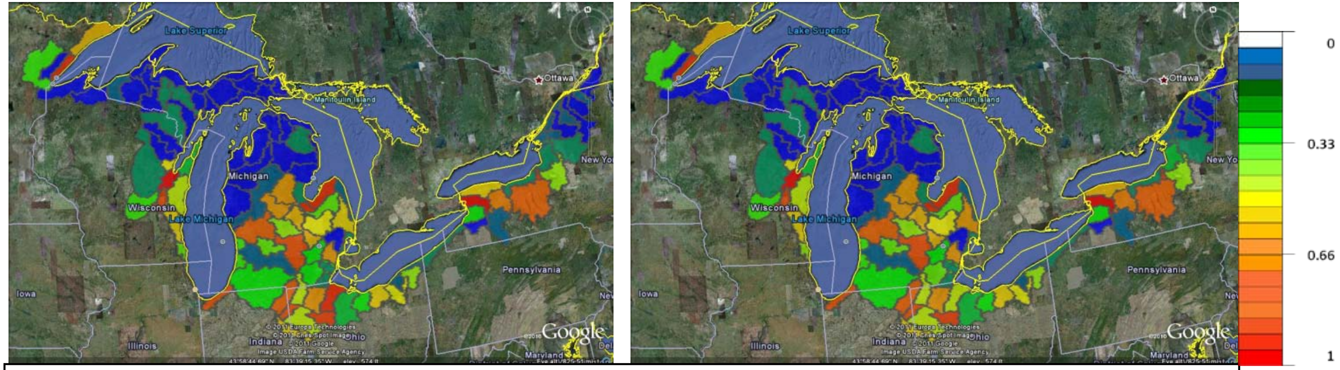
Figure 16: Number of watershed classified as having vulnerable environmental quality. This classification is based on the low flow indicator given by Equation 9. Also given are calculated values where thermoelectric withdrawals were neglected (i.e., identify which watersheds would improve if thermoelectric withdrawals were discontinued).


a) Low Flow Index: Non-Thermo Only

b) Low Flow Index: BAU


c) Low Flow Index: NNOLC

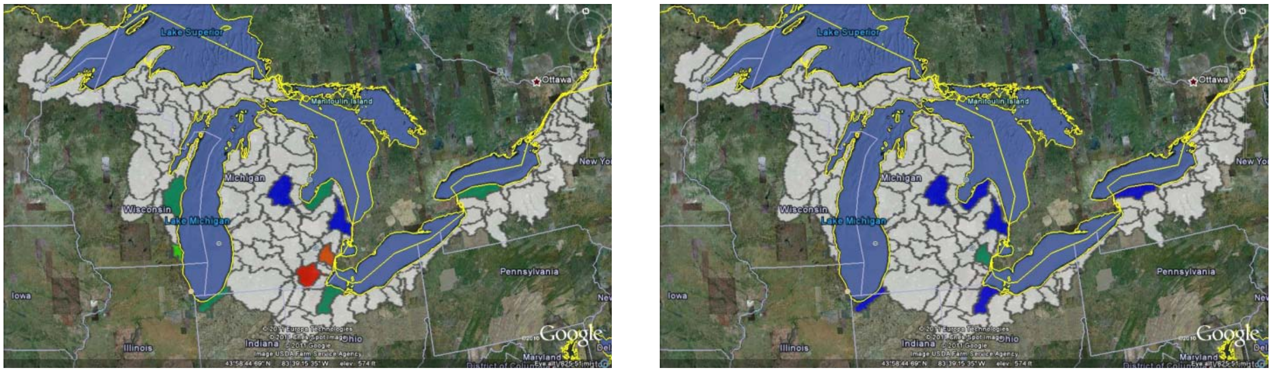
d) Low Flow Index: OLCP


e) Low Flow Index: RPS

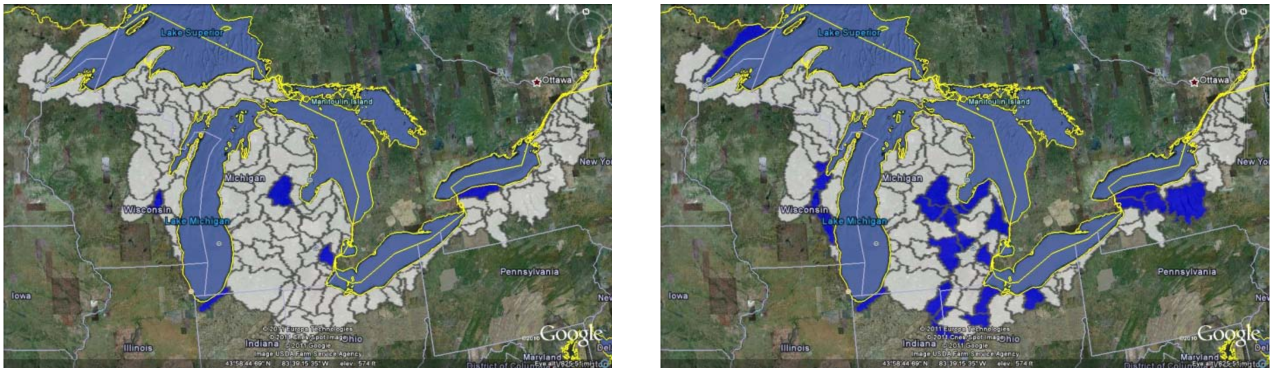
f) Low Flow Index: CCS

Figure 17: Low flow index for the year 2035. Maps for the case where the index is calculated with thermoelectric withdrawals ignored (a) and all withdrawals for the 5 future energy scenarios (b-f). Values above 0.5 (warm colors) indicate vulnerable or sensitive watersheds.

a) Withdrawal from Sensitive Basins: BAU b) Withdrawal from Sensitive Basins: NNOLC



c) Withdrawal from Sensitive Basins: d) Withdrawal from Sensitive Basins: RPS



e) Withdrawal from Sensitive Basins: CCS

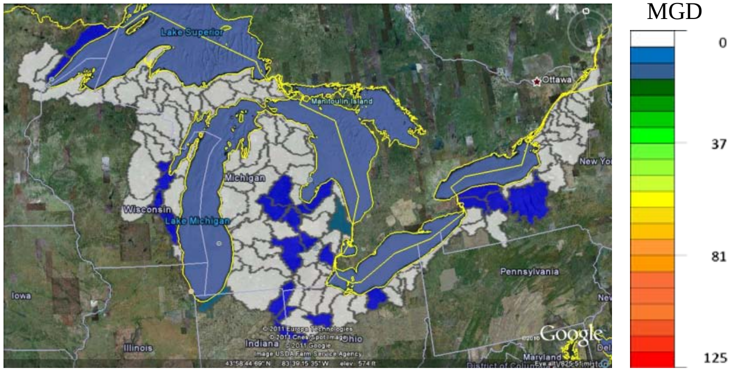


Figure 18: New water withdrawals by thermoelectric power generators in vulnerable or sensitive watersheds (Equation 9). Maps developed by overlaying new thermoelectric withdrawals (Figure 14) with basin classified with vulnerable environmental quality (Figure 17). These maps show the nexus between thermoelectric development under the 5 different future scenarios and watersheds with environmental sensitivity. To make differences apparent basins with reduced water withdrawal are not shown.

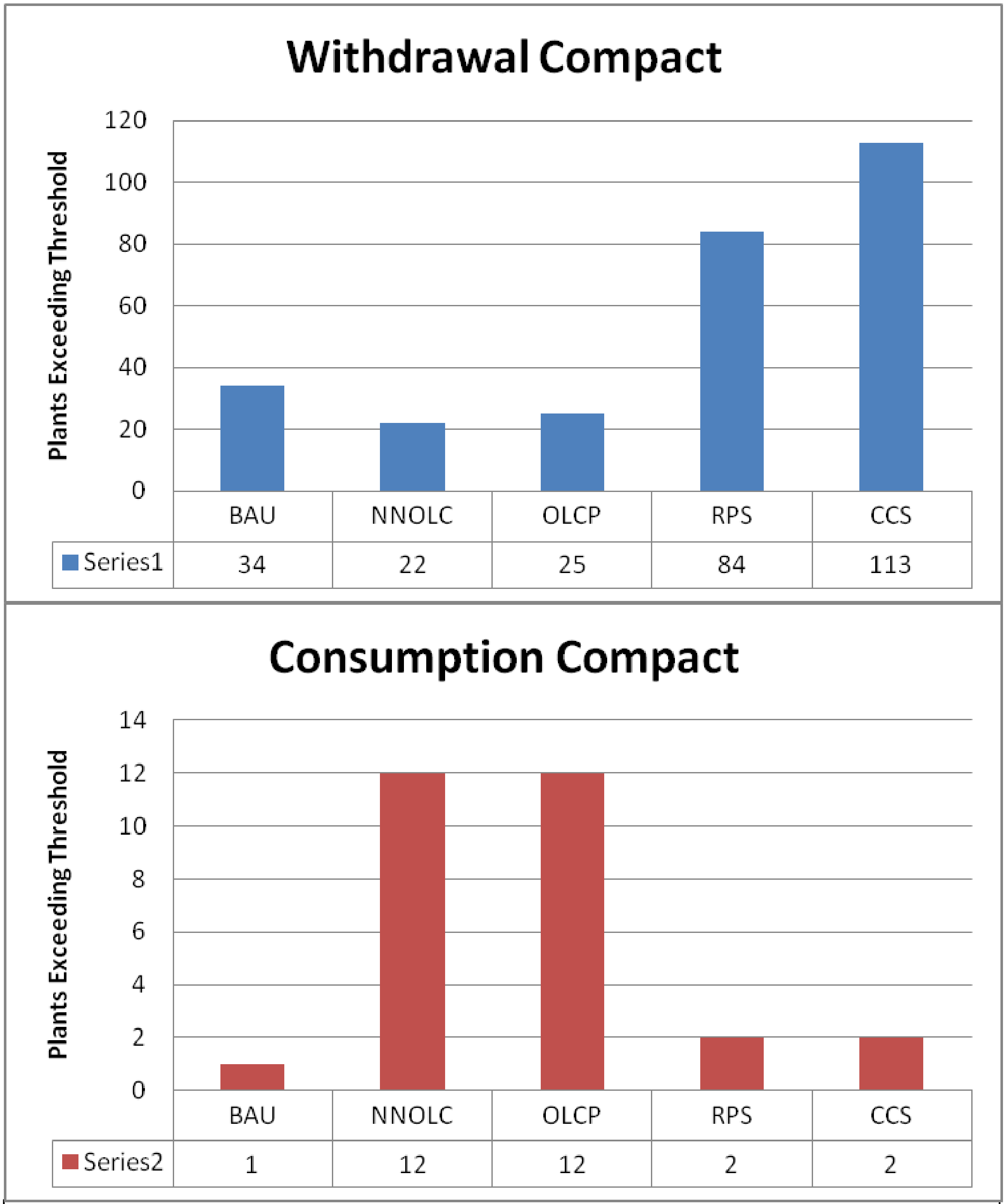
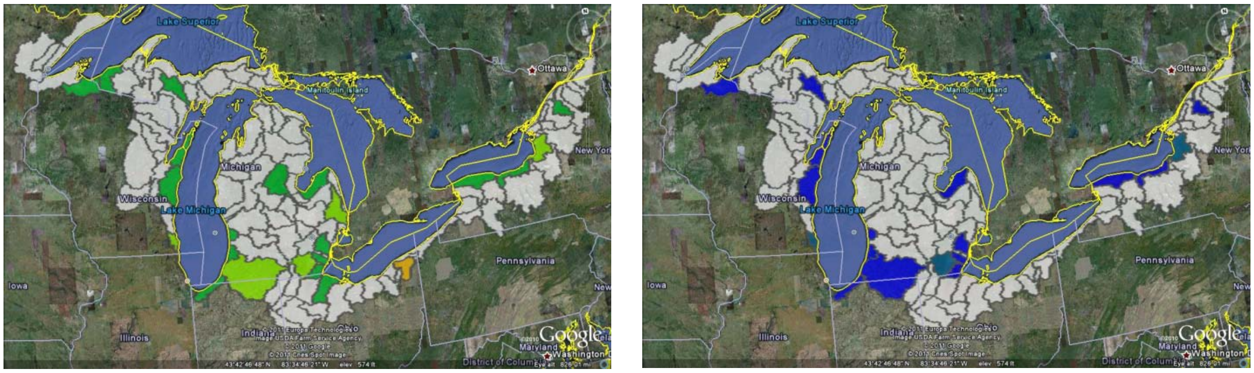
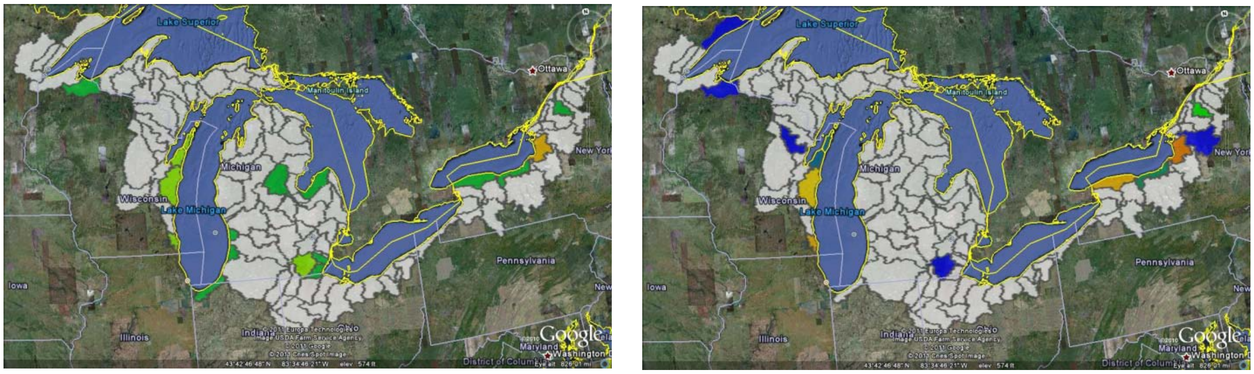


Figure 19: Number of new power plants whose water withdrawal (top) or consumption (bottom) exceeds the respective threshold for the Great Lakes and St. Lawrence River Basin Water Resources Compact.



a) Plants Exceeding Threshold: BAU

b) Plants Exceeding Threshold: NNOLC



c) Plants Exceeding Threshold: OLCP

d) Plants Exceeding Threshold: RPS

e) Plants Exceeding Threshold: CCS

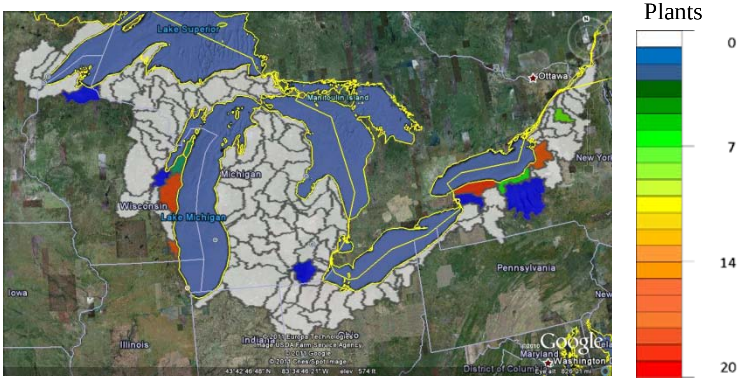
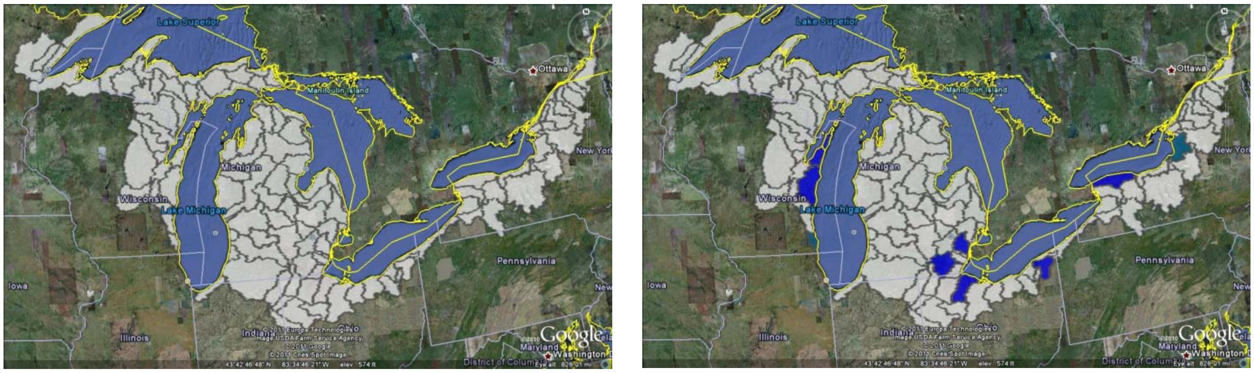
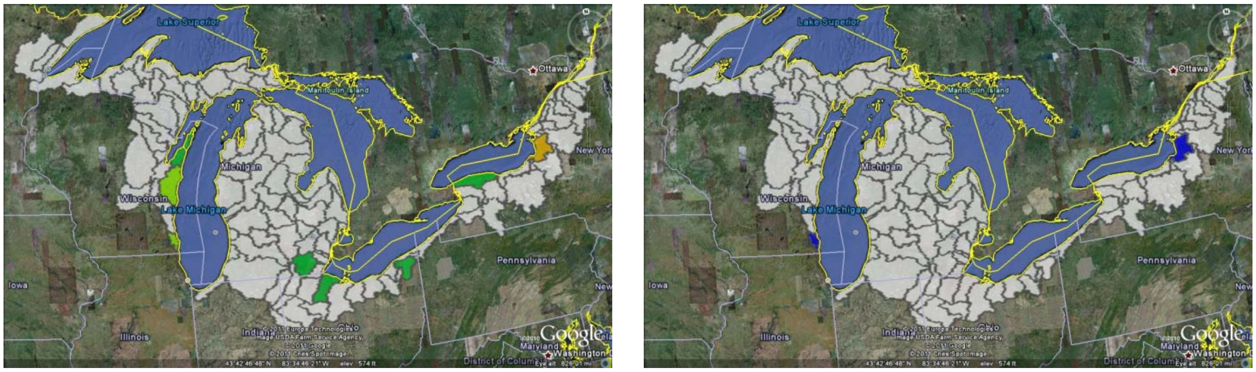


Figure 20: Number of new power plants whose water withdrawal exceeds the threshold for the Great Lakes and St. Lawrence River Basin Water Resources Compact. Results are presented by 8-digit watershed.

a) Plants Exceeding Threshold: BAU b) Plants Exceeding Threshold: NNOLC



c) Plants Exceeding Threshold: OLCP d) Plants Exceeding Threshold: RPS



e) Plants Exceeding Threshold: CCS

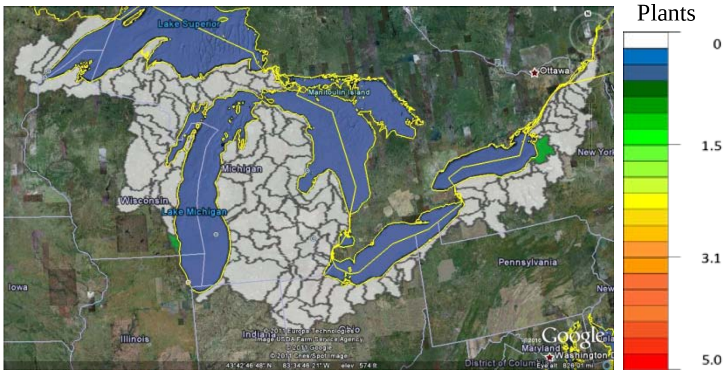


Figure 21: Number of new power plants whose water consumption exceeds the threshold for the Great Lakes and St. Lawrence River Basin Water Resources Compact. Results are presented by 8-digit watershed.

Appendix B: Data for additional scenarios

In this appendix data is presented for two additional scenarios. The scenarios presented here follow closely that in the body of the report with the exception of mix of source water assumed for use by newly constructed power plants. Specifically, the scenarios are:

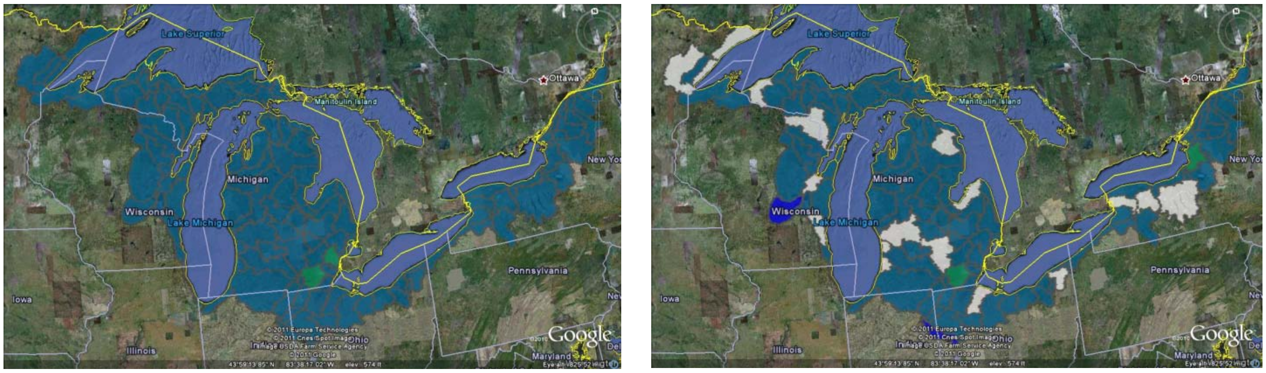
- NNOLC scenario as above with the exception that new plants will utilize the current mix of source water for thermoelectric production; specifically, 79% Great Lakes, 18% other surface water and 3% groundwater.
- OLCP scenario as above with the exception that new plants will utilize the current mix of source water for thermoelectric production; specifically, 79% Great Lakes, 18% other surface water and 3% groundwater.

The table below provides raw data calculated in year 2035 as presented for the other scenarios in Figures 12, 13, 16 and 19.

	No New Open Loop Cooling			**Open Loop Cooling Prohibited**		
	Great Lake	**Other Surface Water**	**Groundwater**	**Great Lake**	**Other Surface Water**	**Groundwater**
Withdrawal (MGD)	20784	4468	775	1794	448	625
Change in Withdrawal (MGD)	-2	18	20	-18992	-4002	-130
Consumption (MGD)	388	98	6	414	66	7
Change in Consumption (MGD)	68	16	3	94	-16	4
Vulnerable Plants	27			18		
Plants Requiring Withdrawal Permit	22			25		
Plants Requiring Consumption Permit	12			12		

Figure B1 shows the change in surface water withdrawal and groundwater withdrawal for the two scenarios in a fashion similar to Figures 14 and 15.

a) New Surface Water Withdrawals: NNOLC b) New Surface Water Withdrawals: OLCP



c) New Groundwater Withdrawals: NNOLC d) New Groundwater Withdrawals: OLCP

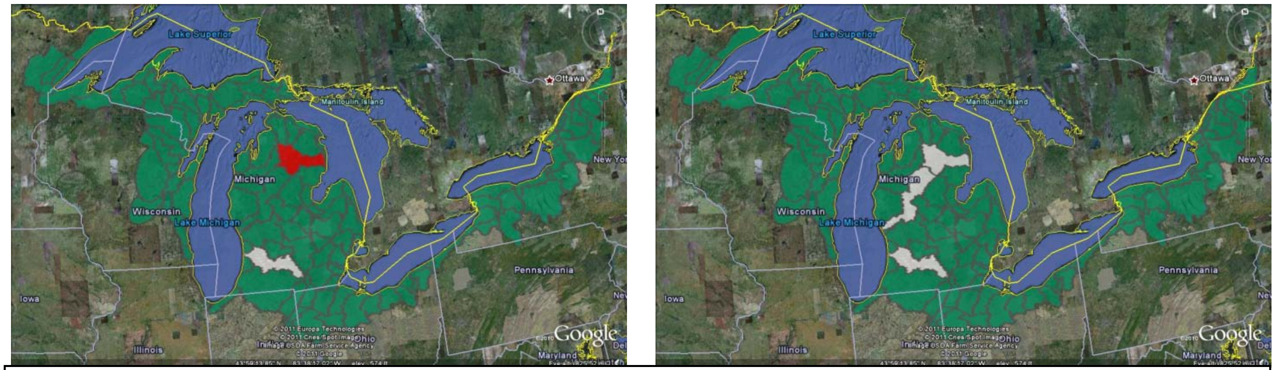


Figure B1: Change in surface water (top) and groundwater (bottom) withdrawals between 2007 and 2035. Shown are new withdrawals by thermoelectric power generation for the NNOLC and OLCP scenarios with a source water mix that favors the Great Lakes (different from the body of the report). Data are reported in million gallons per day are plotted at the same scales as used in figures 14 and 15, respectively.

These results show very similar total withdrawal and consumption for thermoelectric power production to the corresponding scenarios in the body of the report; however, the majority of the new withdrawals/consumption is now from the Great Lakes. The interesting result is that there is no change in the number of plants sited in vulnerable watersheds or the number of plants requiring compact permitting. The reason for this lack of change in the OLCP scenario is that these metrics are largely influenced by the retirement/retrofitting of existing power plants. The changes made to this scenario, utilizing the current source water mix, will not affect which plants are retired/retrofitted; thus, reductions in withdrawal/consumption due to retirement/retrofitting are the same regardless of our assumptions of source water for future construction. In the case of NNOLC the changes in overall withdrawal are very small compared to the current withdrawal and thus this relatively small shift of source water from the watershed to Great Lakes has little to no affect. In terms of compact permitting due to consumption (consumption does increase), the compact does not depend on the source of the water so again there is no change.

Appendix C: Tables with raw new power plant production data by watershed and fuel type.

Business as Usual (BAU) Scenario: all data in MWh

Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030101	Manitowoc-Sheboygan	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030102	Door-Kewaunee	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030106	Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030110	Escanaba	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040001	Little Calumet-Galien	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040002	Pike-Root	3350700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050002	Black-Macatawa	1675350	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080103	Pigeon-Wiscoggin	1675350	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080201	Tittabawassee	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090001	St. Clair	0	1747620	0	0	0	0	0	0	0	153300	0	0	0	105120	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130001	Oak Orchard-Twelvemile	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140101	Irondequoit-Ninemile	0	0	0	0	1300860	0	0	0	0	0	0	0	0	0	0
4140102	Salmon-Sandy	3350700	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	131400
4140201	Seneca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050001	St. Joseph	1675350	873810	0	420480	0	0	0	0	0	153300	0	0	0	0	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Business as Usual (BAU) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100001	Ottawa-Stony	1675350	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4100002	Raisin	1675350	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100010	Cedar-Portage	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110004	Grand	1675350	873810	0	0	0	0	0	0	0	153300	0	0	0	105120	131400
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150304	Grass	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0

					No New Open Loop Cooling (NNOLC) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030101	Manitowoc-Sheboygan	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030102	Door-Kewaunee	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030106	Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030110	Escanaba	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040001	Little Calumet-Galien	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040002	Pike-Root	3350700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050002	Black-Macatawa	1675350	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080103	Pigeon-Wiscoggin	1675350	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080201	Tittabawassee	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090001	St. Clair	0	1747620	0	0	0	0	0	0	0	153300	0	0	0	105120	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130001	Oak Orchard-Twelvemile	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140101	Irondequoit-Ninemile	0	0	0	0	1300860	0	0	0	0	0	0	0	0	0	0
4140102	Salmon-Sandy	3350700	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	131400
4140201	Seneca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050001	St. Joseph	1675350	873810	0	420480	0	0	0	0	0	153300	0	0	0	0	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					No New Open Loop Cooling (NNOLC) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100001	Ottawa-Stony	1675350	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4100002	Raisin	1675350	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100010	Cedar-Portage	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110004	Grand	1675350	873810	0	0	0	0	0	0	0	153300	0	0	0	105120	131400
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150304	Grass	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0

Open Loop Cooling Prohibited (OLCP) Scenario: all data in MWh

Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030101	Manitowoc-Sheboygan	3350700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030102	Door-Kewaunee	1675350	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030106	Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030110	Escanaba	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040001	Little Calumet-Galien	1675350	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4040002	Pike-Root	3350700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050002	Black-Macatawa	1675350	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080103	Pigeon-Wiscoggin	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080201	Tittabawassee	1675350	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090001	St. Clair	0	1747620	0	0	0	0	0	0	0	0	0	0	0	210240	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130001	Oak Orchard-Twelvemile	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140101	Irondequoit-Ninemile	0	873810	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4140102	Salmon-Sandy	3350700	0	0	0	0	0	0	7708800	0	0	0	0	0	0	131400
4140201	Seneca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050001	St. Joseph	0	1747620	0	420480	0	0	0	0	0	0	0	0	0	0	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Open Loop Cooling Prohibited (OLCP) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100001	Ottawa-Stony	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100002	Raisin	1675350	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100010	Cedar-Portage	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110004	Grand	1675350	0	0	0	0	0	0	0	0	306600	0	0	0	0	0
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150304	Grass	0	0	0	0	1300860	0	0	0	0	0	0	0	0	0	0
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0

					Renewable Portfolio (RPS) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Stean	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030101	Manitowoc-Sheboygan	0	0	2146200	0	0	0	0	0	0	153300	0	0	0	840960	0
4030102	Door-Kewaunee	0	0	306600	0	0	0	0	0	0	153300	0	0	0	735840	0
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4030106	Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4030110	Escanaba	0	0	306600	0	0	0	0	0	0	0	0	0	0	630720	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	630720	0
4040001	Little Calumet-Galien	0	873810	919800	0	0	0	0	0	0	306600	0	0	0	420480	0
4040002	Pike-Root	1675350	873810	2759400	0	0	0	0	0	0	153300	0	0	0	210240	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	525600	0
4050002	Black-Macatawa	0	0	1533000	0	0	0	0	0	0	613200	0	0	0	525600	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	0	0	0	0	525600	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080103	Pigeon-Wiscoggin	0	0	613200	0	0	0	0	0	0	613200	0	0	0	525600	0
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080201	Tittabawassee	0	0	306600	0	0	0	0	0	0	153300	0	0	0	1051200	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4090001	St. Clair	0	873810	1533000	0	0	0	0	0	0	306600	0	0	0	735840	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4130001	Oak Orchard-Twelvemile	0	0	2146200	0	0	0	0	0	0	613200	0	0	0	315360	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4140101	Irondequoit-Ninemile	0	0	306600	0	0	0	0	0	0	0	0	0	0	1156320	0
4140102	Salmon-Sandy	1675350	1747620	1839600	0	0	0	0	0	0	153300	0	0	0	210240	0
4140201	Seneca	0	0	0	0	0	0	0	0	0	0	0	0	0	735840	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4050001	St. Joseph	0	0	3372600	0	0	0	0	0	0	153300	0	0	0	210240	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	735840	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0

					Renewable Portfolio (RPS) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	0	0	459900	0	0	0	525600	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	131400
4100001	Ottawa-Stony	0	0	1226400	0	0	0	0	0	0	919800	0	0	0	420480	0
4100002	Raisin	1675350	873810	1226400	0	0	0	0	0	0	306600	0	0	0	105120	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100010	Cedar-Portage	0	873810	1533000	0	0	0	0	0	0	153300	0	0	0	210240	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	153300	0	0	0	315360	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4110004	Grand	0	0	2146200	0	0	0	0	0	0	459900	0	0	0	420480	0
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	153300	0	0	0	735840	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150304	Grass	0	0	306600	0	0	0	0	0	0	613200	0	0	0	840960	0
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	210240	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0

					Carbon Capture and Sequestration (CCS) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	131400
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030101	Manitowoc-Sheboygan	0	0	2146200	0	0	0	0	0	0	1379700	0	0	0	315360	0
4030102	Door-Kewaunee	0	0	0	0	0	0	0	0	0	306600	0	0	0	946080	131400
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4030106	Brule	0	0	0	0	0	0	0	0	0	153300	0	0	0	105120	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030110	Escanaba	0	0	0	0	0	0	0	0	0	0	0	0	0	1156320	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	153300	0	0	0	630720	0
4040001	Little Calumet-Galien	0	0	613200	0	0	0	0	0	0	1839600	0	0	0	630720	0
4040002	Pike-Root	1675350	0	4292400	0	0	0	0	0	0	153300	0	0	0	0	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	630720	0
4050002	Black-Macatawa	0	0	1226400	0	0	0	0	0	0	1379700	0	0	0	630720	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	525600	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	153300	0	0	0	525600	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080103	Pigeon-Wiscoggin	0	0	0	0	0	0	0	0	0	766500	0	0	0	1471680	0
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080201	Tittabawassee	0	0	306600	0	0	0	0	0	0	306600	0	0	0	1051200	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4090001	St. Clair	0	0	2759400	0	0	0	0	0	0	919800	0	0	0	420480	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	153300	0	0	0	420480	0
4130001	Oak Orchard-Twelvemile	0	0	2452800	0	0	0	0	0	0	1073100	0	0	0	315360	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4140101	Irondequoit-Ninemile	0	0	0	0	0	0	0	0	0	459900	0	0	0	1261440	0
4140102	Salmon-Sandy	1675350	0	4599000	0	0	0	0	0	0	0	0	0	0	0	0
4140201	Seneca	0	0	306600	0	0	0	0	0	0	0	0	0	0	630720	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050001	St. Joseph	0	0	2759400	0	0	0	0	0	0	1379700	0	0	0	105120	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	153300	0	0	0	630720	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0

					Carbon Capture and Sequestration (CCS) Scenario: all data in MWh											
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	0	0	0	0	0	0	1156320	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100001	Ottawa-Stony	0	0	1226400	0	0	0	0	0	0	1226400	0	0	0	525600	0
4100002	Raisin	1675350	0	2452800	0	0	0	0	0	0	919800	0	0	0	0	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100010	Cedar-Portage	0	0	1226400	0	0	0	0	0	0	1533000	0	0	0	525600	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	153300	0	0	0	420480	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4110004	Grand	0	0	1226400	0	0	0	0	0	0	1992900	0	0	0	210240	0
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	0	0	0	0	1051200	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150304	Grass	0	0	306600	0	0	0	0	0	0	459900	0	0	0	1261440	131400
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	315360	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	420480	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	105120	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	210240	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0

	No New Open Loop Cooling (NNOLC) using historic ratio of lake to watershed water use: all data in MWh															
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030101	Manitowoc-Sheboygan	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030102	Door-Kewaunee	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030106	Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030110	Escanaba	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040001	Little Calumet-Galien	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040002	Pike-Root	3350700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050002	Black-Macatawa	1675350	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080103	Pigeon-Wiscoggin	1675350	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080201	Tittabawassee	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090001	St. Clair	0	1747620	0	0	0	0	0	0	0	153300	0	0	0	105120	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130001	Oak Orchard-Twelvemile	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140101	Irondequoit-Ninemile	0	0	0	0	1300860	0	0	0	0	0	0	0	0	0	0
4140102	Salmon-Sandy	3350700	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	131400
4140201	Seneca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050001	St. Joseph	1675350	873810	0	420480	0	0	0	0	0	153300	0	0	0	0	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	No New Open Loop Cooling (NNOLC) using historic ratio of lake to watershed water use: all data in MWh															
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100001	Ottawa-Stony	1675350	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4100002	Raisin	1675350	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100010	Cedar-Portage	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110004	Grand	1675350	873810	0	0	0	0	0	0	0	153300	0	0	0	105120	131400
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150304	Grass	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0

	Open Loop Cooling Prohibited (OLCP) using historic ratio of lake to watershed water use: all data in MWh															
Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4020102	Ontonagan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020103	Keweenaw Peninsula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020104	Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020105	Dead-Kelsey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020201	Betsy-Chocolay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020202	Tahquamenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4020203	Waiska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030101	Manitowoc-Sheboygan	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030102	Door-Kewaunee	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030103	Duck-Pensaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030104	Oconto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030105	Peshtigo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030106	Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030107	Michigamme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030108	Menominee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030109	Cedar-Ford	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030110	Escanaba	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030111	Tacoosh-Whitefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030112	Fishdam-Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030201	Upper Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030202	Wolf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030203	Lake Winnebago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4030204	Lower Fox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040001	Little Calumet-Galien	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040002	Pike-Root	3350700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4040003	Milwaukee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050002	Black-Macatawa	1675350	0	0	0	0	0	0	0	0	0	0	0	0	210240	0
4050005	Maple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050006	Lower Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050007	Thornapple	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060101	Pere Marquette-White	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060102	Muskegon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060103	Manistee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060104	Betsie-Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060105	Boardman-Charlevoix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060106	Manistique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4060107	Brevoort-Millecoquins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070001	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070002	Carp-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070003	Lone Lake-Ocqueoc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070004	Cheboygan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070005	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070006	Thunder Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4070007	Au Sable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080101	Au Gres-Rifle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080102	Kawkawlin-Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080103	Pigeon-Wiscoggin	1675350	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4080104	Birch-Willow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080201	Tittabawassee	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4080202	Pine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080203	Shiawassee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080204	Flint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080205	Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4080206	Saginaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090001	St. Clair	0	1747620	0	0	0	0	0	0	0	153300	0	0	0	105120	0
4090003	Clinton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120102	Cattaraugus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120103	Buffalo-Eighteenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4120104	Niagara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130001	Oak Orchard-Twelvemile	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130002	Upper Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4130003	Lower Genesee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140101	Irondequoit-Ninemile	0	0	0	0	1300860	0	0	0	0	0	0	0	0	0	0
4140102	Salmon-Sandy	3350700	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	131400
4140201	Seneca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140202	Oneida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4140203	Oswego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150102	Chaumont-Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150303	Indian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050001	St. Joseph	1675350	873810	0	420480	0	0	0	0	0	153300	0	0	0	0	0
4050003	Kalamazoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4050004	Upper Grand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4090002	Lake St. Clair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Open Loop Cooling Prohibited (OLCP) using historic ratio of lake to watershed water use: all data in MWh

Accounting Unit Number	ACC Name	Coal PC	Gas Steam	Gas CC	Gas Comb	Oil Steam	Oil CC	Oil Combu	Nuclear N	Geotherm	Biofuel	Coal IGCC	Solar CSP	Solar PV	Wind New	Hydr
4090004	Detroit	0	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4090005	Huron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100001	Ottawa-Stony	1675350	0	0	0	0	0	0	0	0	153300	0	0	0	0	0
4100002	Raisin	1675350	0	0	0	0	0	0	7708800	0	0	0	0	0	0	0
4100003	St. Joseph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100004	St. Marys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100005	Upper Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100006	Tiffin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100007	Auglaize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100008	Blanchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100009	Lower Maumee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100010	Cedar-Portage	1675350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100011	Sandusky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4100012	Huron-Vermilion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110001	Black-Rocky	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110002	Cuyahoga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110003	Ashtabula-Chagrin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4110004	Grand	1675350	873810	0	0	0	0	0	0	0	153300	0	0	0	105120	131400
4120101	Chautauqua-Conneaut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150101	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150301	Upper St. Lawrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150302	Oswegatchie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150304	Grass	0	873810	0	0	0	0	0	0	0	0	0	0	0	105120	0
4150305	Raquette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150306	St. Regis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150307	Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4150308	Chateaugay-English	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010101	Baptism-Brule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010102	Beaver-Lester	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010201	St. Louis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4010202	Cloquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131400
4010301	Beartrap-Nemadji	0	0	0	0	0	0	11212.8	0	0	0	0	0	0	0	0
4010302	Bad-Montreal	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0
4020101	Black-Presque Isle	0	0	306600	0	0	0	0	0	0	0	0	0	0	0	0