Integrating Energy and Water Resources Decision Making in the Great Lakes Basin

An Examination of Future Power Generation Scenarios and Water Resource Impacts

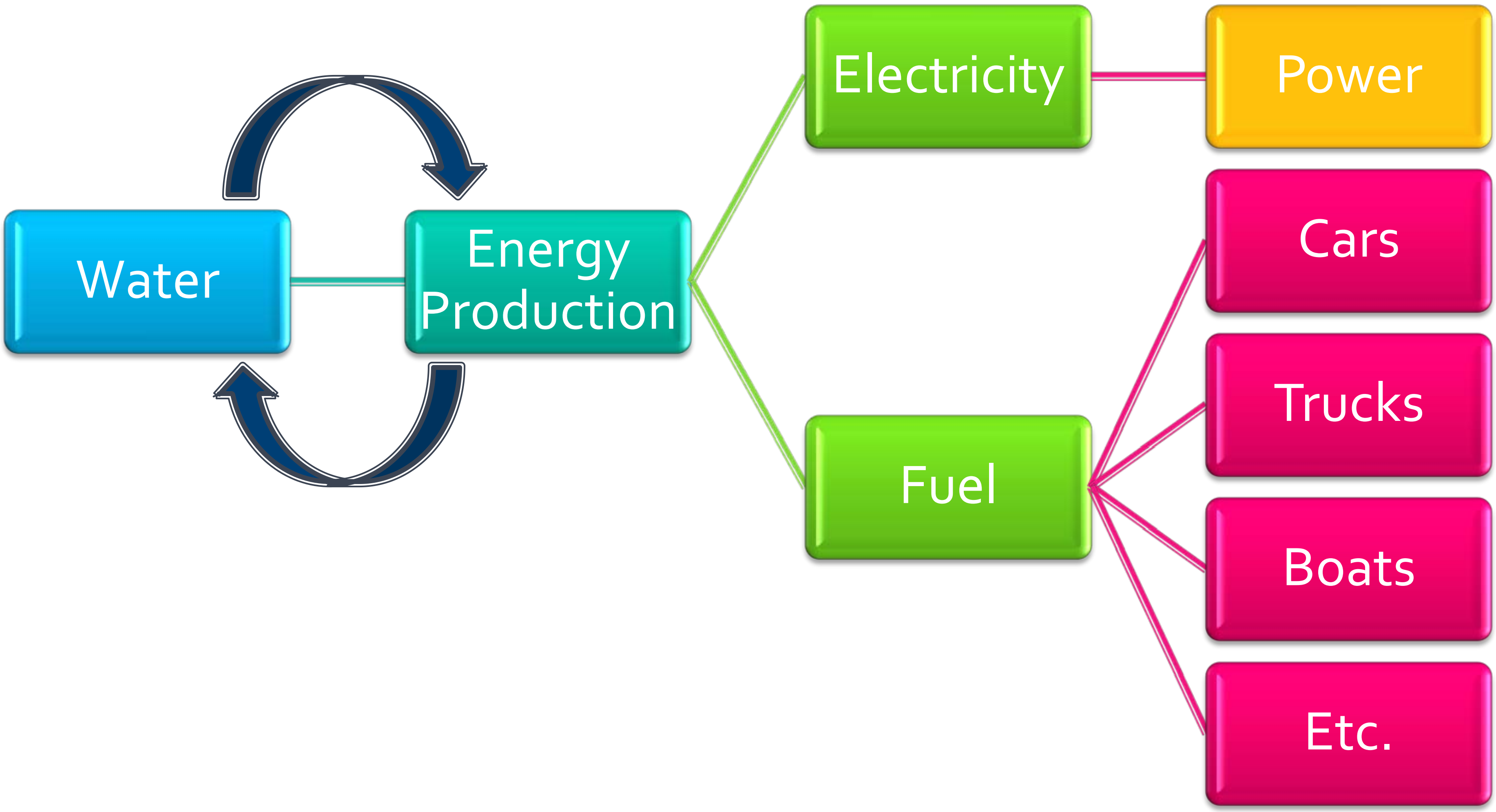
Great Lakes Energy-Water Nexus Initiative

Great Lakes Commission des Grands Lacs

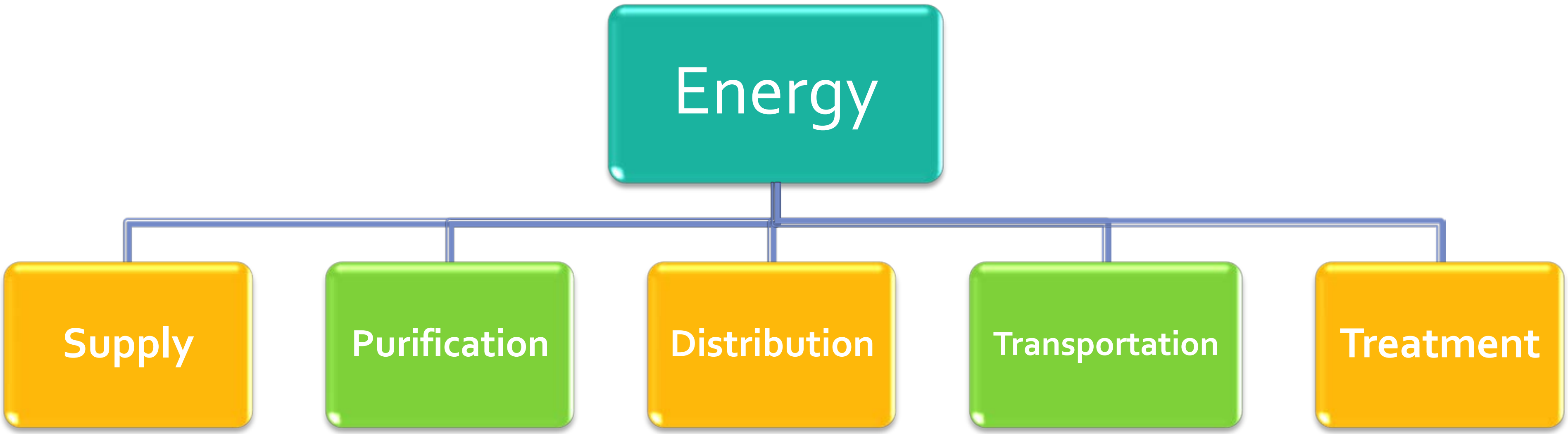
Panel & Presentation Overview

Great Lakes Commission	• **Victoria Pebbles, Program Director:** Energy-water linkages in the Great Lakes basin; project overview • **Cassie Bradley, Sea Grant Fellow:** Assessing watershed vulnerabilities using aquatic resource metrics • **Vitaly Peker, GIS Project Specialist:** Introduction to the new GLEW interactive mapping tool
Sandia National Laboratories	• **Vince Tidwell, Technical Staff:** Development and results of GLEW modeling efforts
Great Lakes Environmental Law Center	• **Nick Schroeck, Executive Director:** Water use policies & regulations
Natural Resources Defense Council	• **John Moore, Attorney:** Electric power markets and environmental considerations

Energy Requires Water



Water Requires Energy



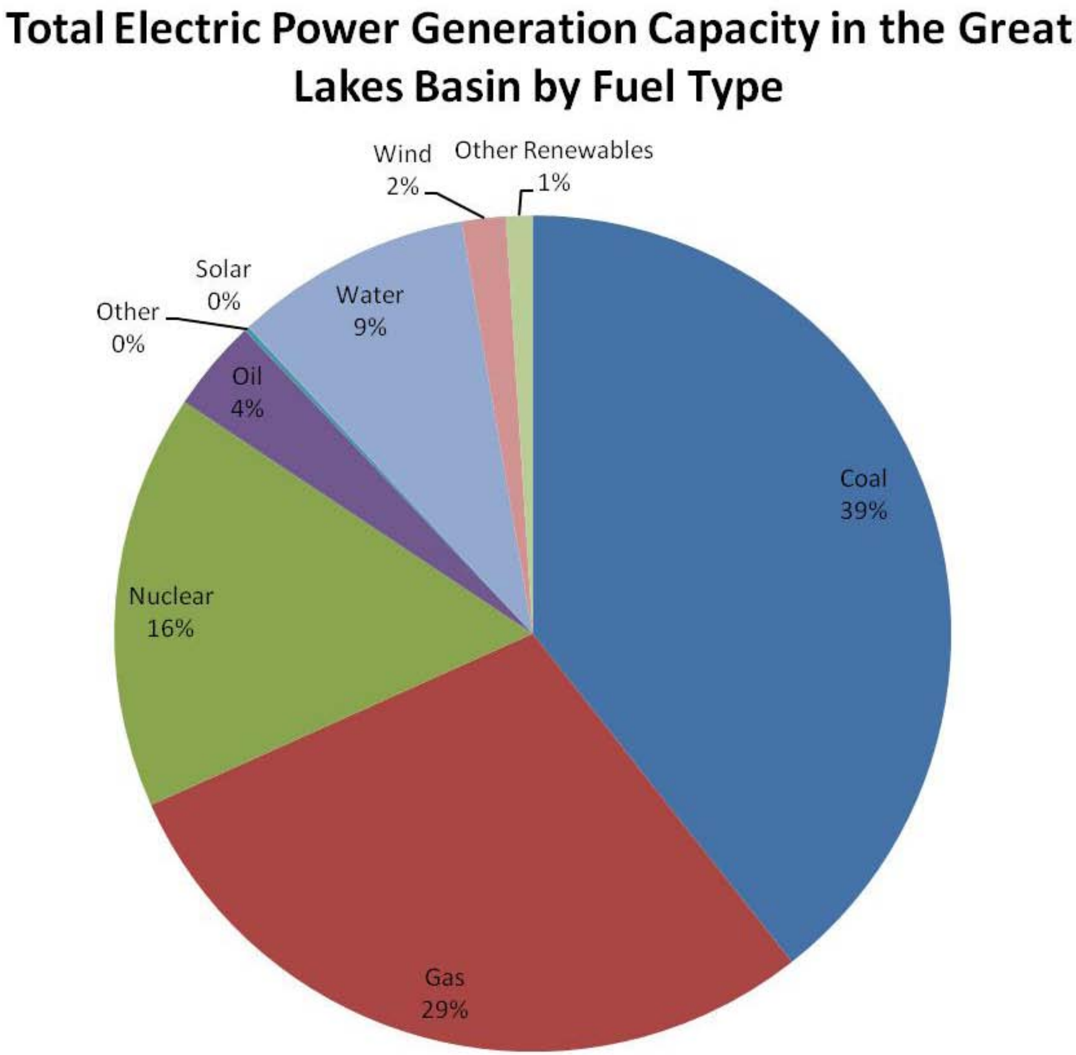
- **4%** of U.S. power generation

- **80%** of municipal costs of water distribution = **energy**

Project Goals and Objectives

- Water and Energy = inextricably linked!
- Thermoelectric Power Production:
  - Great Lakes basin water use
  - Aquatic resource impacts and ecological vulnerabilities **in tributary watersheds**
  - Future power generation scenarios
  - Potential policy & regulatory implications

Great Lakes Power Generation



Thermoelectric Power Production

Fuel →

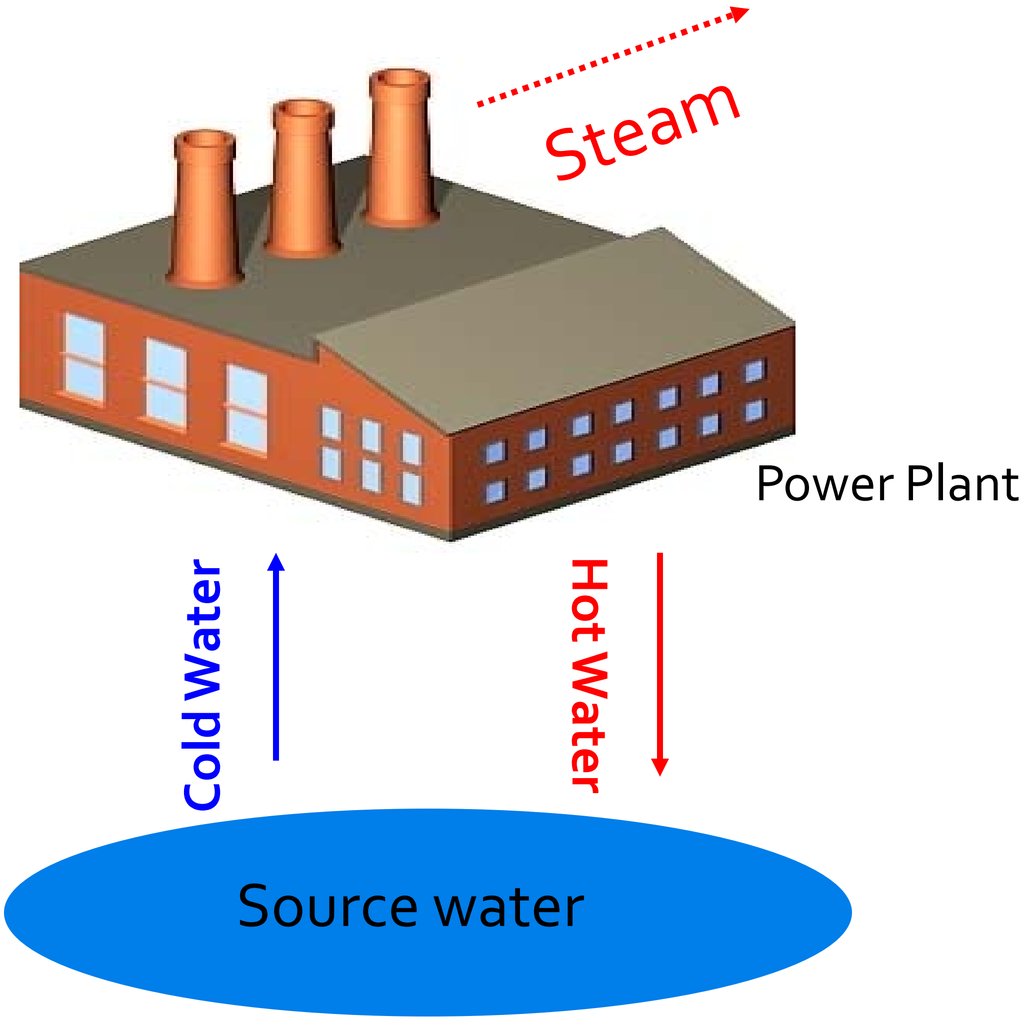
Steam →

Turbine →

POWER

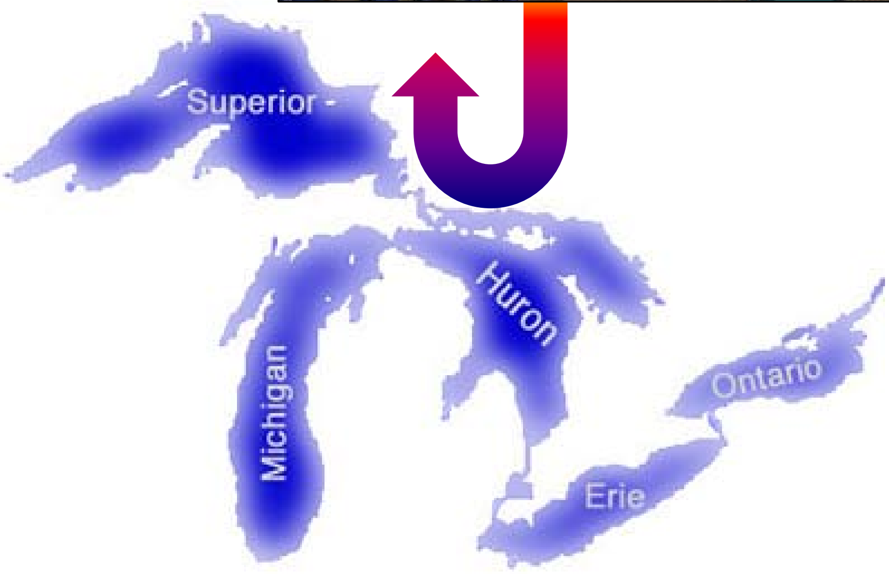
Fuel sources:

- Coal
- Nuclear
- Oil
- Natural gas
- Gas-fired combined cycle
- Biomass



Thermoelectric Power Production in the Great Lakes Basin

- 76% (25.9 BGD) of basin freshwater **withdrawals** (2007)
- 13% (0.4 BGD) of basin freshwater **consumption**
- The difference? Cooling technology
  - Open-loop
  - Closed-loop



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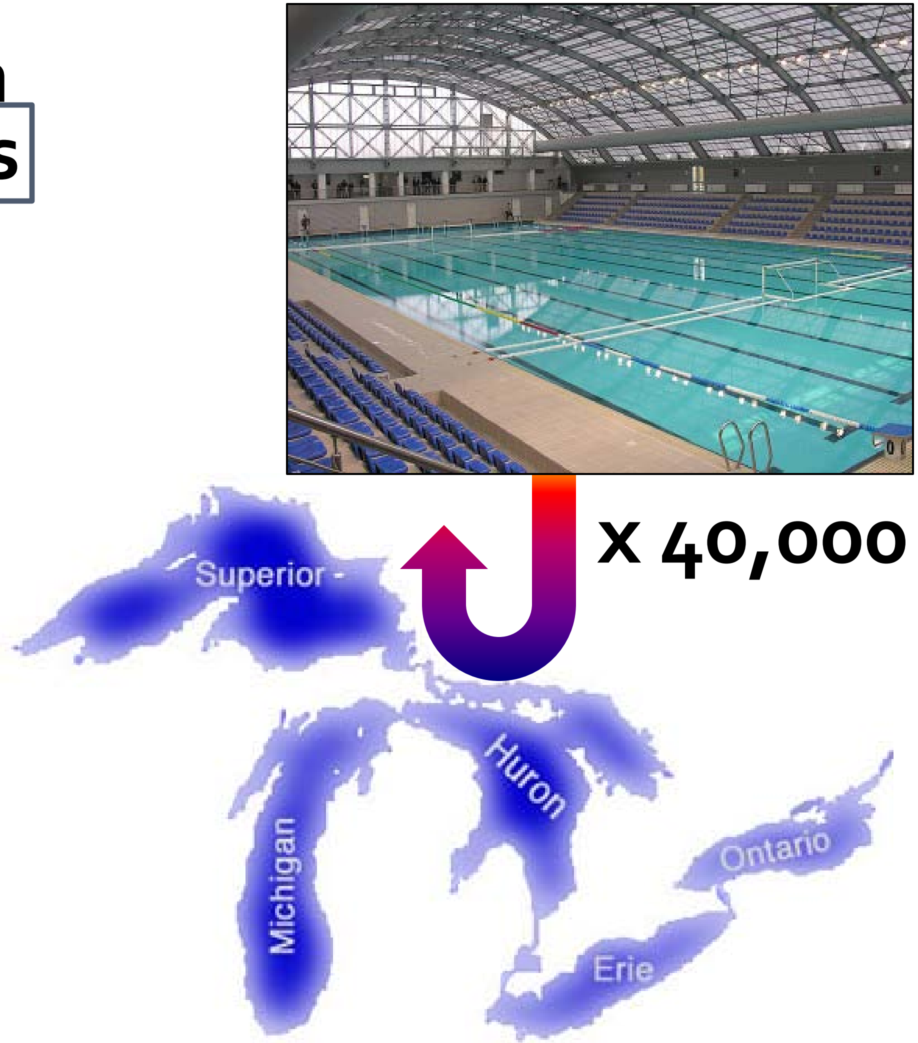

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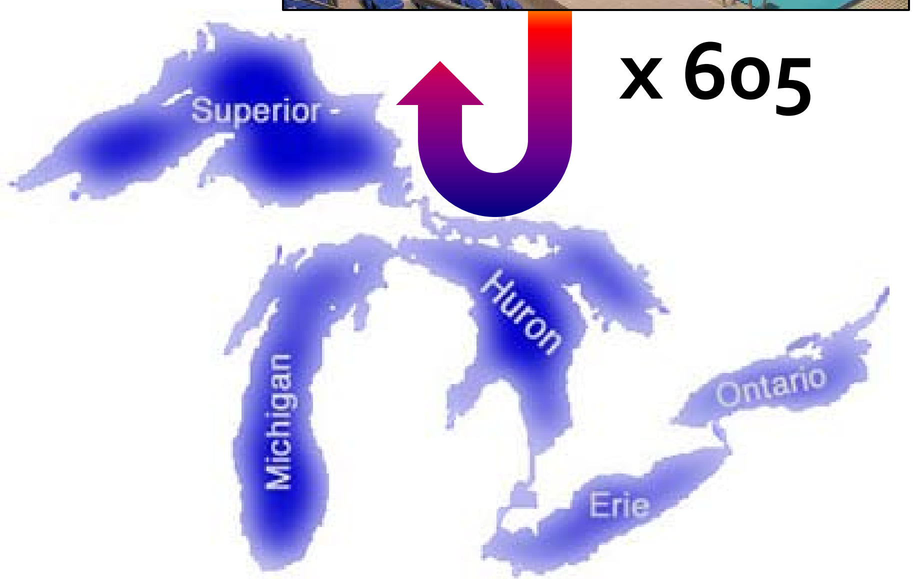

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Cooling Technology

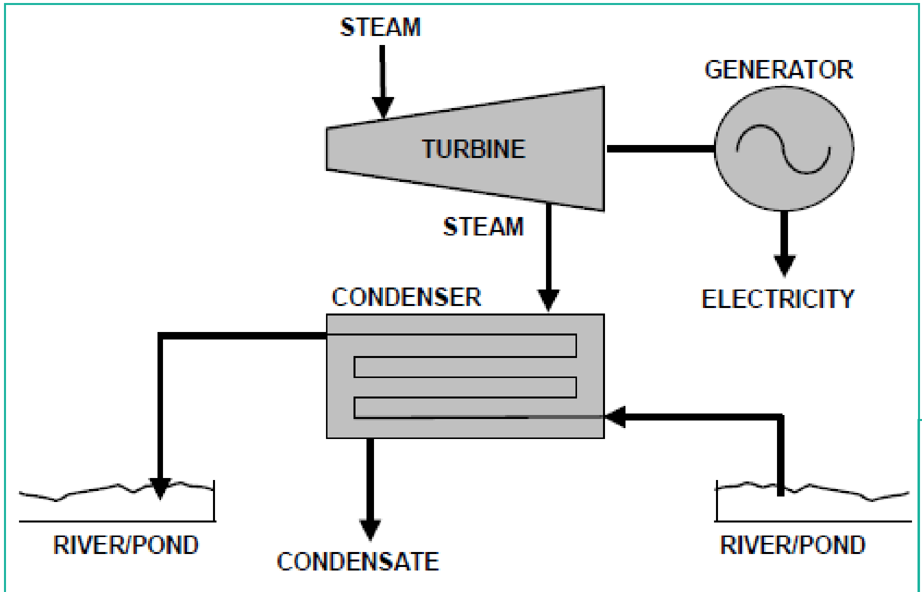


Figure B-1. Diagram of once-through cooling system

- Open-loop cooling

(NREL, 2003)

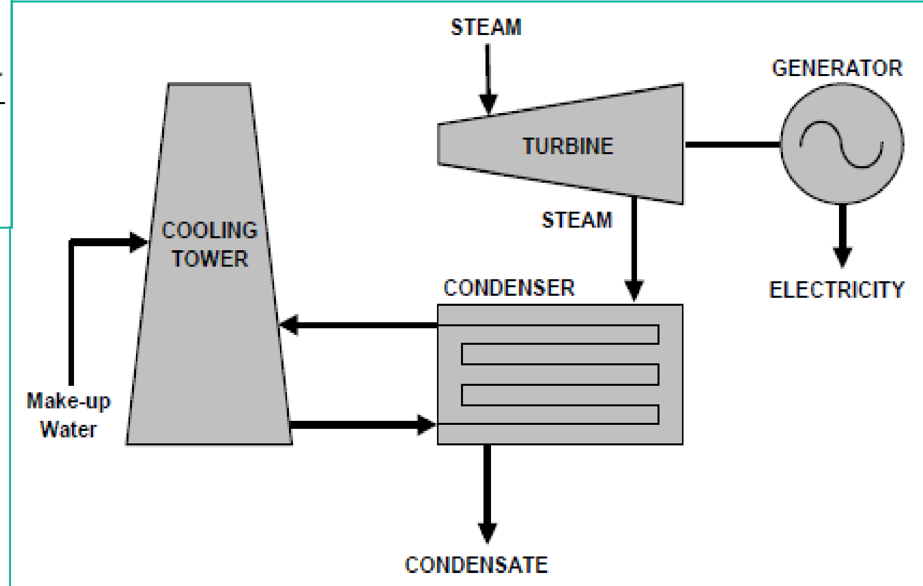


Figure B-2. Diagram of a closed-loop system

- Closed-loop cooling

(NREL, 2003)

Cooling Technology (cont.)

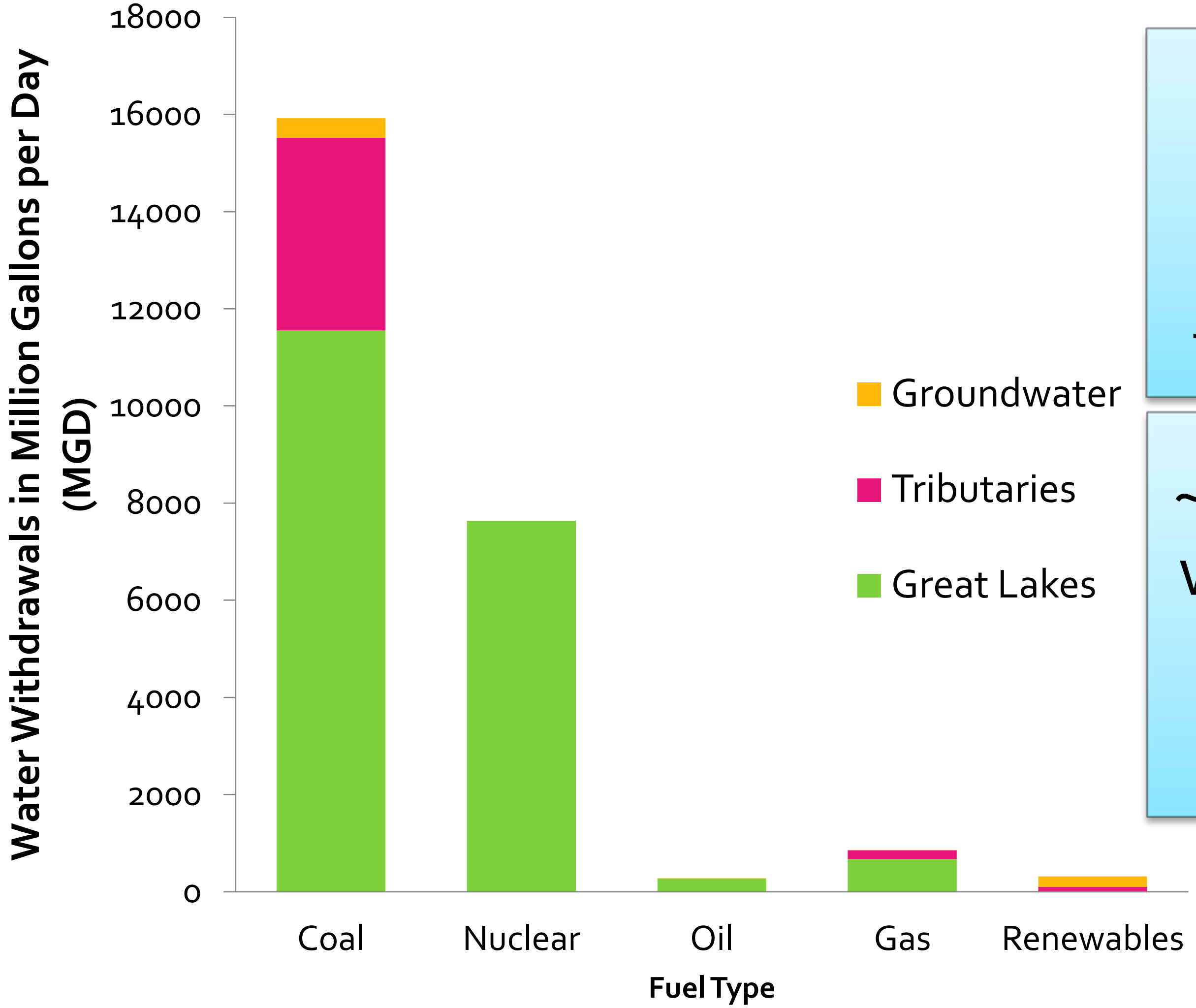
- Withdrawal (MGD)

Fuel Type	Open-Loop	Closed-Loop	TOTAL
Coal	15245	860	**16105**
Nuclear	7020	619	**7639**
Oil	267	0.4	**267.4**
Gas	539	341	**880**
Renewables	N/A	316	**316**
TOTAL	**23071**	**2136.4**	

- Consumption (MGD)

Fuel Type	Open-Loop	Closed-Loop	TOTAL
Coal	151	9	**160**
Nuclear	191	37	**228**
Oil	3	0	**3**
Gas	2	5	**7**
Renewables	N/A	4	**4**
TOTAL	**347**	**55**	

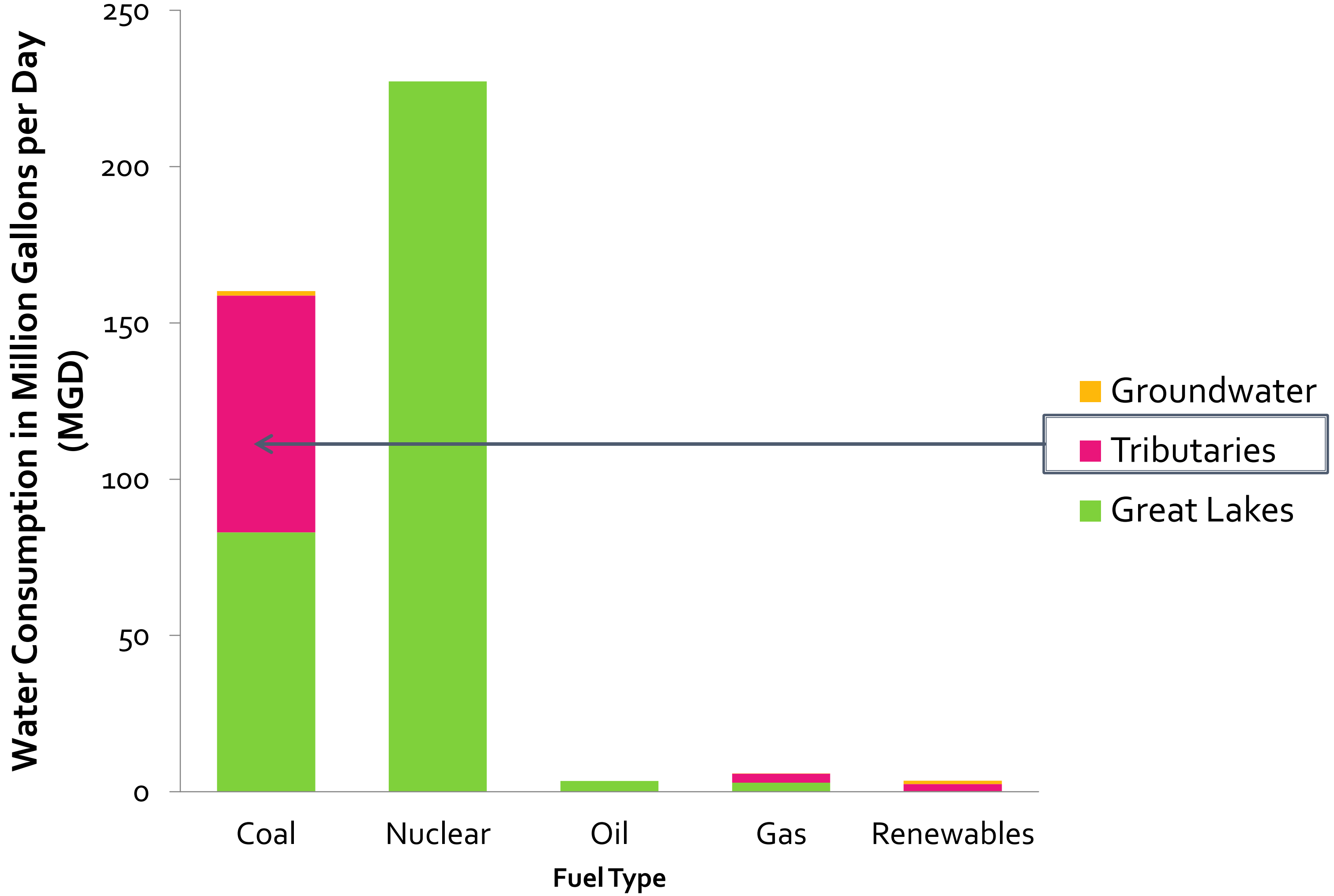
Thermoelectric Water Withdrawal in the Great Lakes Basin



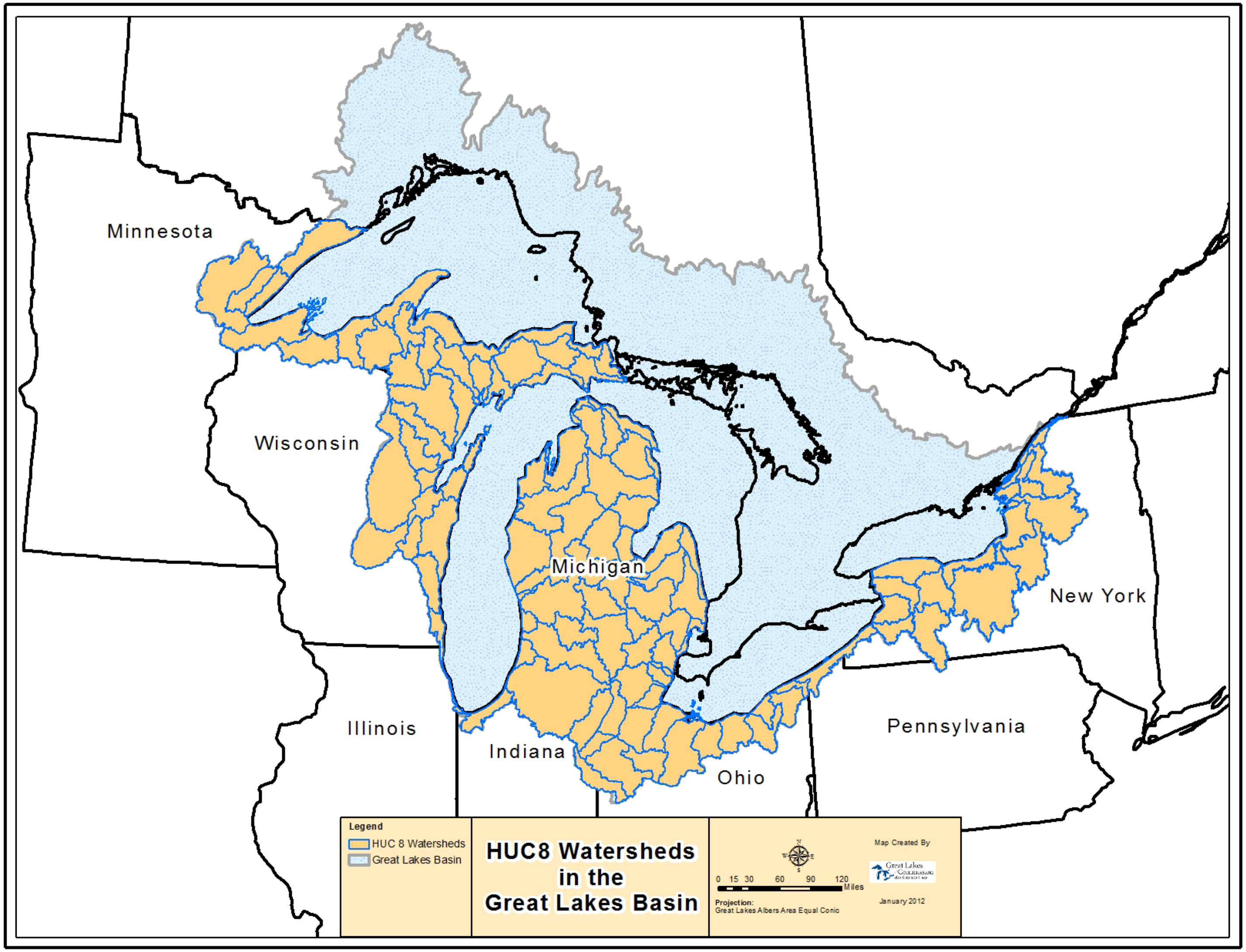
~ ¾ of all power generation withdrawals in the Basin comes directly from the Great Lakes

~25 % of the water withdrawals come from tributaries and groundwater

Thermoelectric Water Consumption in the Great Lakes Basin



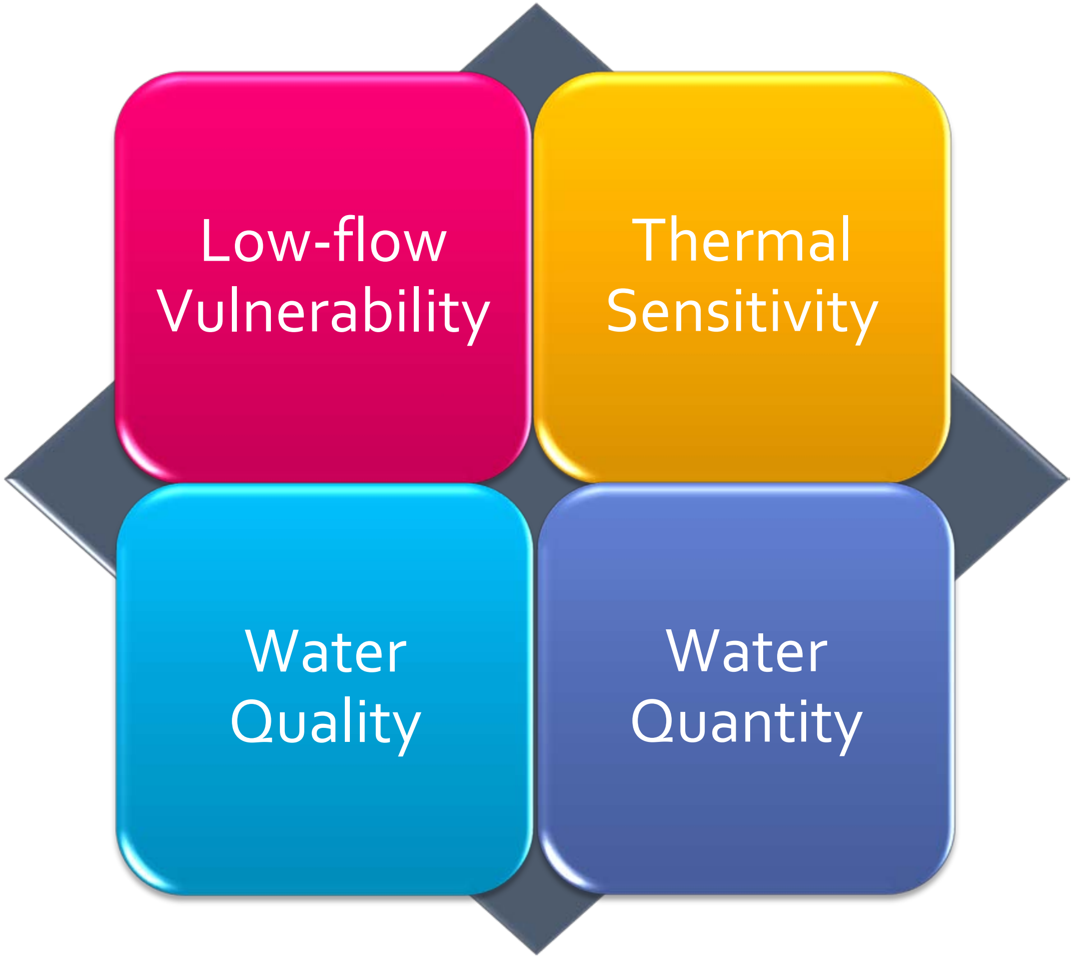
Project Scope



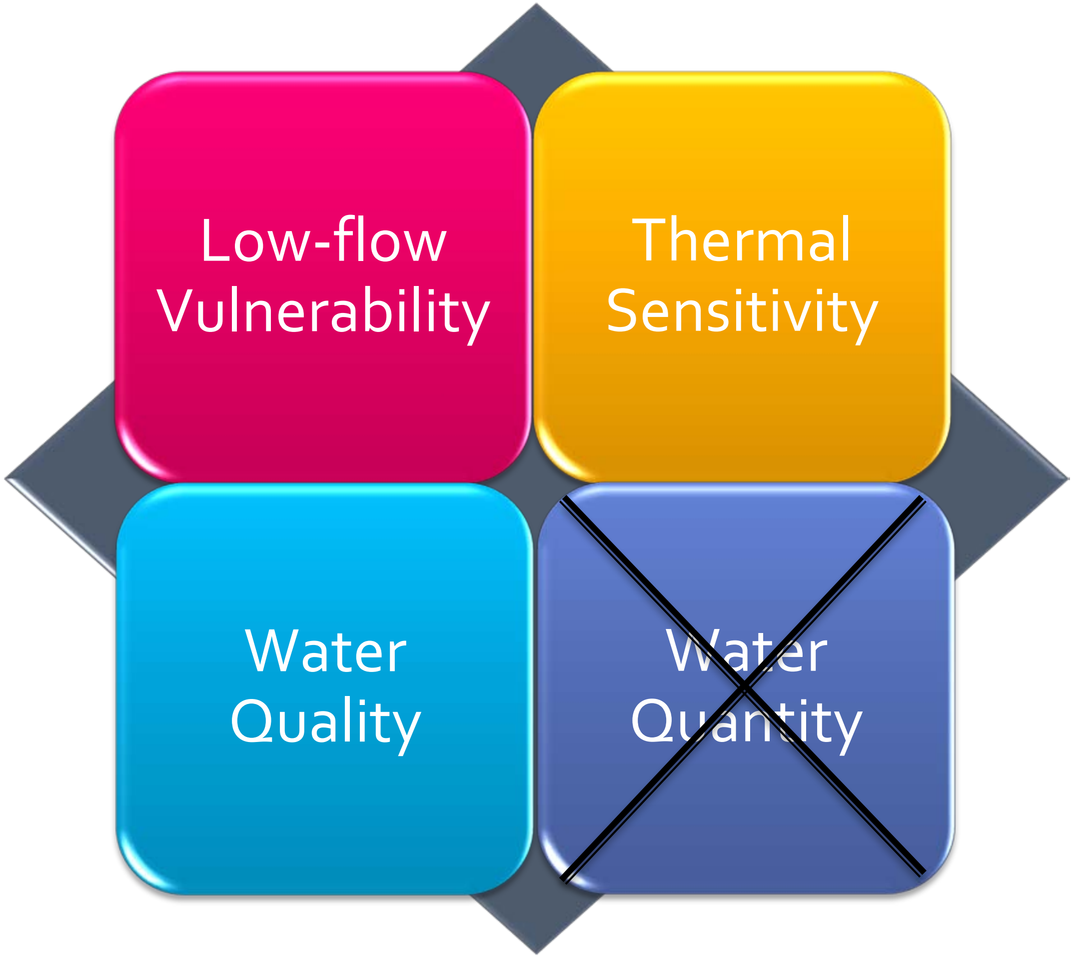
Aquatic Resource Impacts

- Environmental Sensitivity Metrics:
  - General indicators of sensitivity to further energy production development
  - Compatible with Sandia Model, where results were integrated with other information
  - Basin scale: 8-digit HUCs
  - Included four factors (metrics) related to water use and thermal outputs

Aquatic Resource Impacts

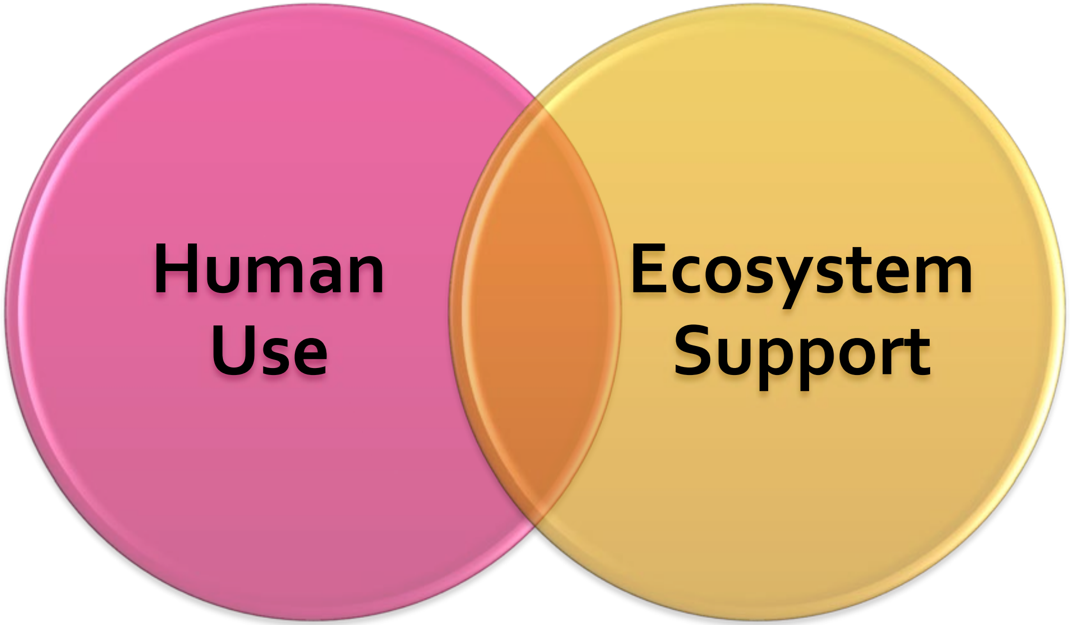


Aquatic Resource Impacts



Metric 1: Low-flow Vulnerability

- When water in short supply:
  - Is use of water in the basin near a level where ecosystem support is jeopardized?
  - How much more use of water is okay?



Metric 1: Low-flow Vulnerability

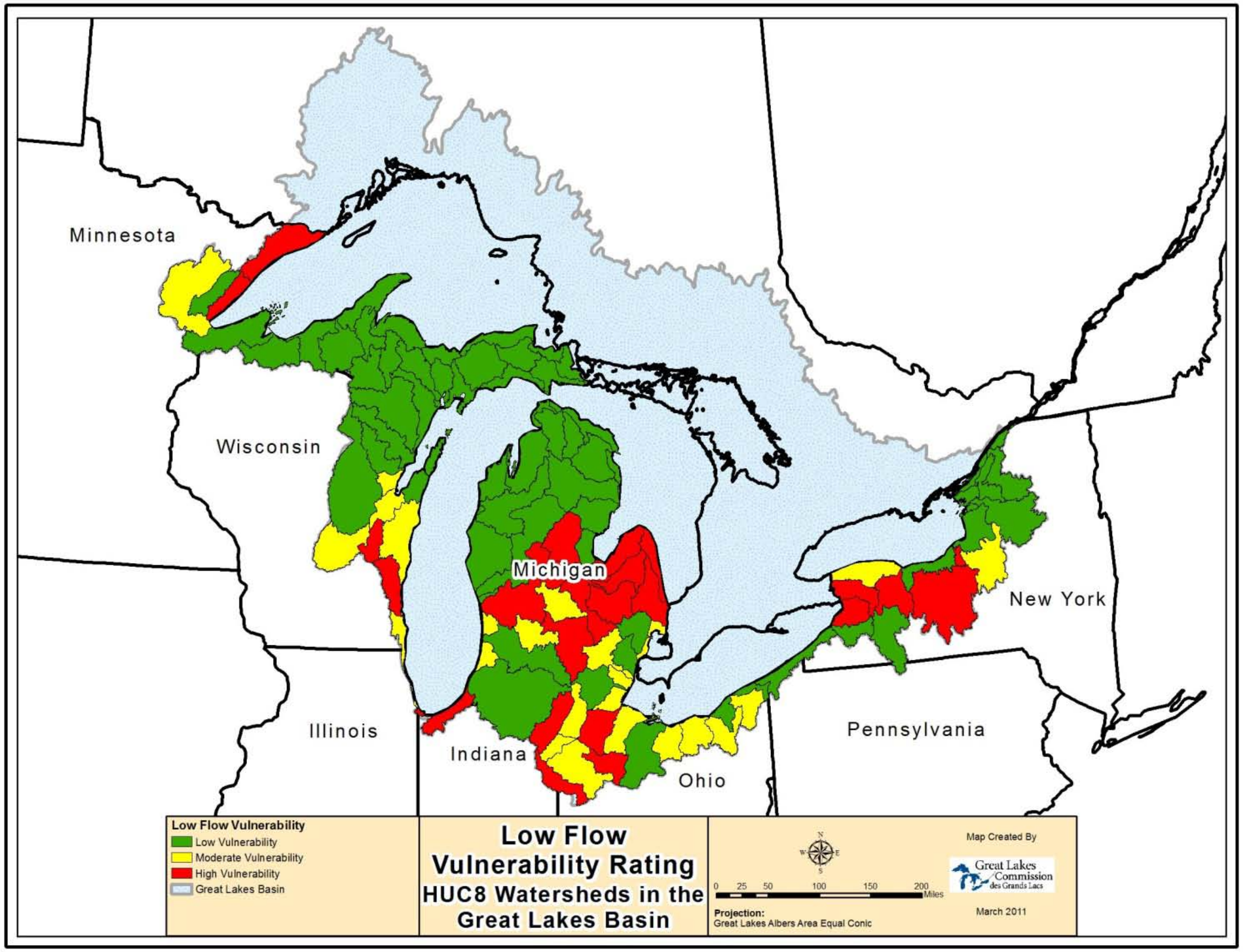
- Reviewed low-flow standards like Michigan's and synthesized this work with emphasis on Michigan standards

$$X\ (\%) = \frac{Mean\ basin\ August\ streamflow\ (MGD)}{((Mean\ basin\ August\ streamflow, MGD) +\ (sum\ of\ water\ uses, MGD))}$$

- < 50%
  - Significant environmental losses
- 50-80%
  - Good environmental conditions
- > 80%
  - Excellent environmental conditions

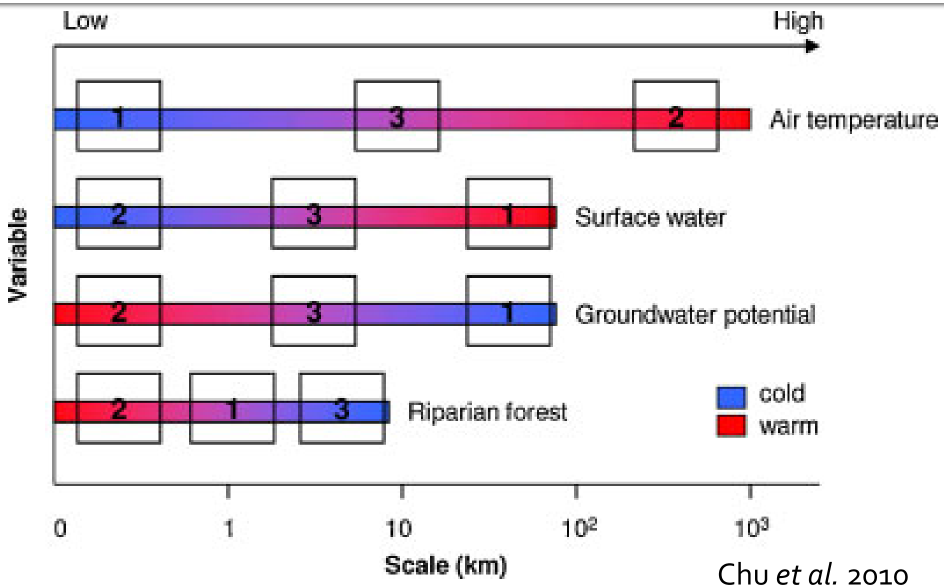
Metric 1: Low-flow Vulnerability

- Scale: 0 (high vulnerability) → 1 (low vulnerability)



Metric 2: Thermal Vulnerability

- How much coldwater resource threatened by change?
  - Warming potential
  - Amount of coldwater resources



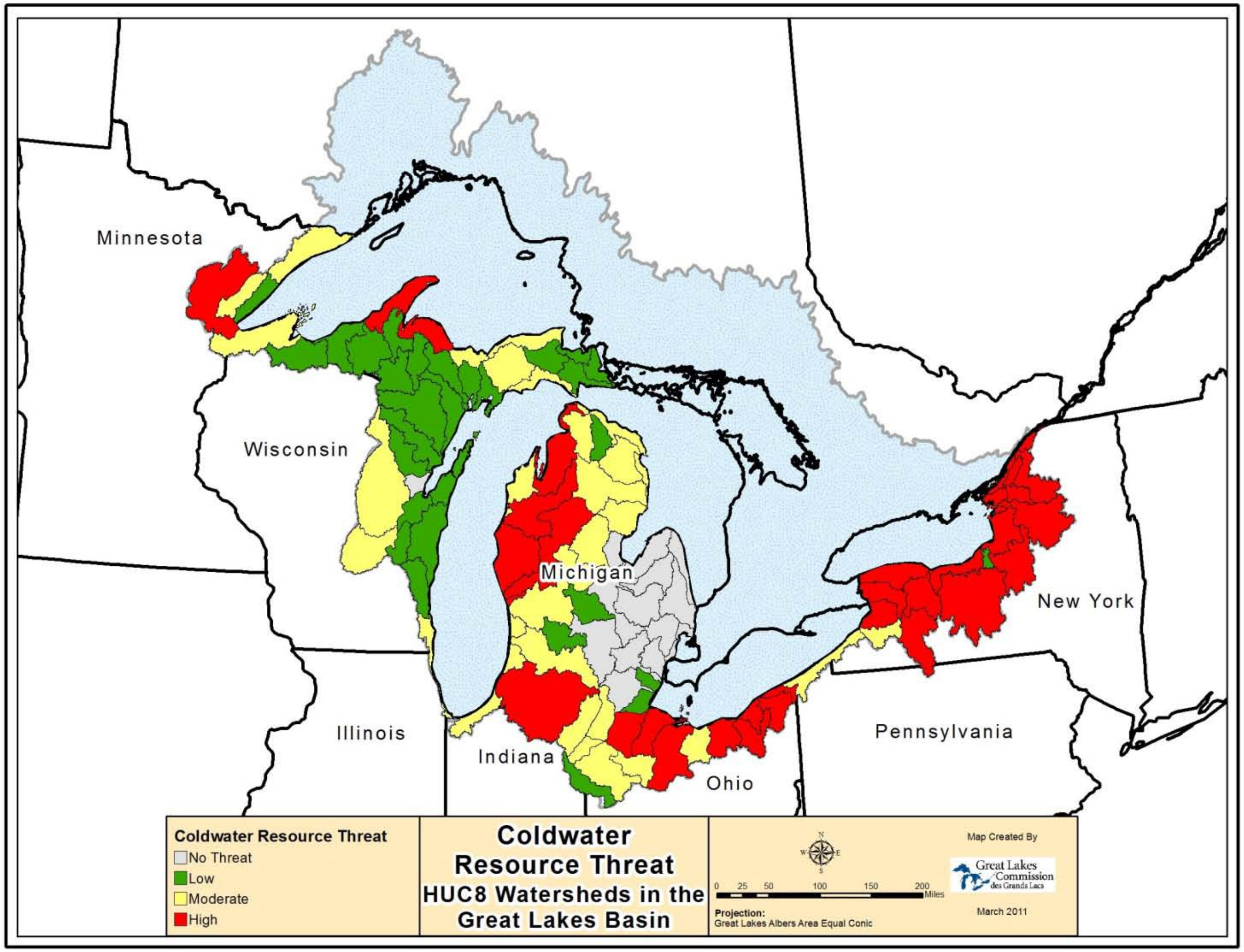
Chu *et al.* 2010

Warming Potential = (**52** (mean annual air temp. rank) +
22 (percent surface water rank) +
18 (percent non-forest cover rank) +
8 (inverse of groundwater potential rank))/100

Coldwater Resource Threat = (Warming potential) * (Miles of coldwater resource)

Metric 2: Thermal Vulnerability

- Scale: 0 (high vulnerability) → 1 (low vulnerability)



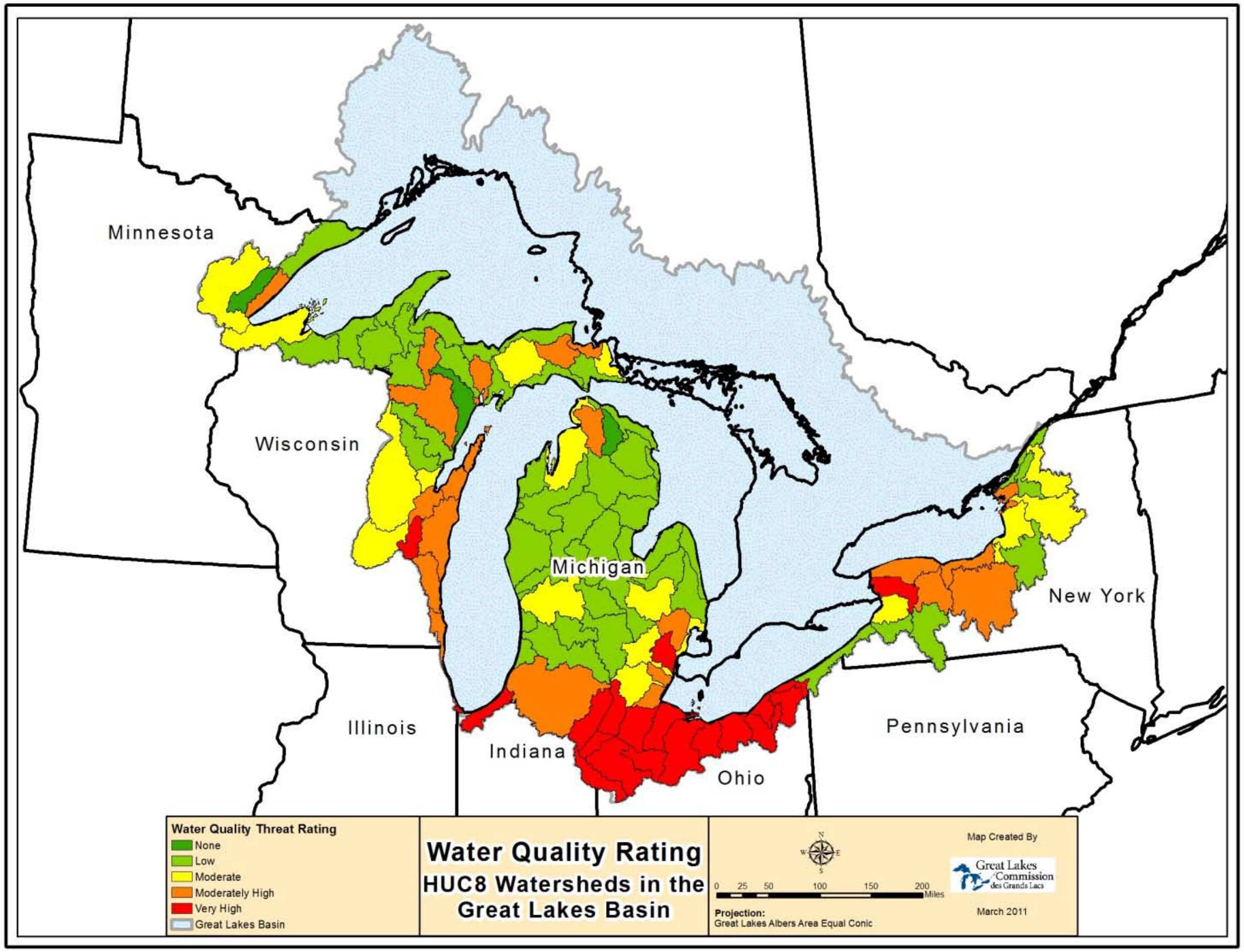
Metric 3: Water Quality Impairment

- Based on EPA data: extent (%) of impaired waters within a given watershed
- Rate vulnerability to further stresses

Table 5: Water Quality Sensitivity		
Percent Impaired Waters	Threat /Vulnerability Ranking	No. of HUC 8 Basins
>25	**Very High**	18
10-25	**Moderately High**	19
5-10	**Moderate**	19
<5	**Low**	43
0	**None**	3

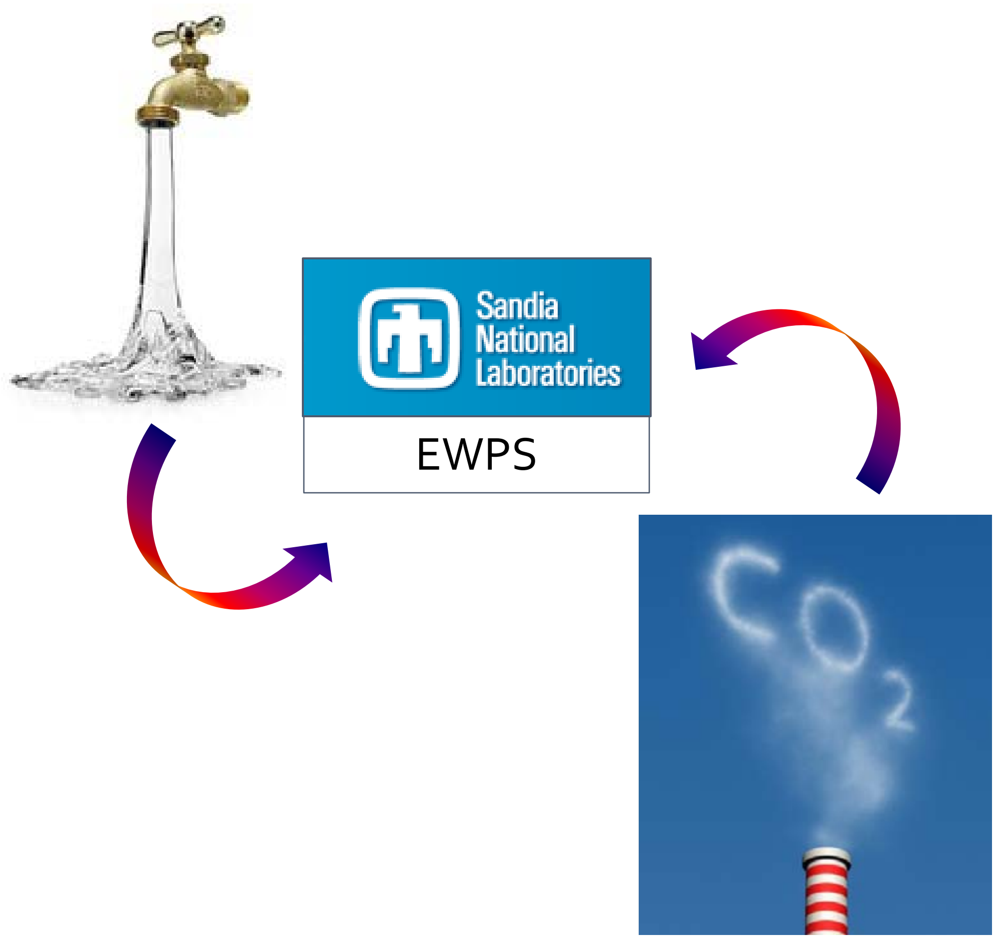
Metric 3: Water Quality Impairment

- Scale: 0 (high vulnerability) → 1 (low vulnerability)



The GLEW Model

- Developed by Sandia National Laboratories and based on the Energy and Water Power Simulation (EWPS) Model
  - Water use
  - Water consumption
  - Greenhouse Gas (GHG) emissions
- 28-year time scale (2007-2035)
- GLEW model additions:
  - Low-flow metric
  - Great Lakes water use
  - HUC-8 level watershed information



Future Power Generation Scenarios

- Business as Usual Case (**BAU**)
- No New Open-loop Cooling (**NNOLC**)
- Open-loop Cooling Prohibited (**OLCP**)
- Renewable Portfolio Standard (**RPS**)
- Carbon Capture and Sequestration (**CCS**)

Population growth demand: ↑ 32%

- U.S. Census Bureau (2004)

Energy production demand: ↑ 25%

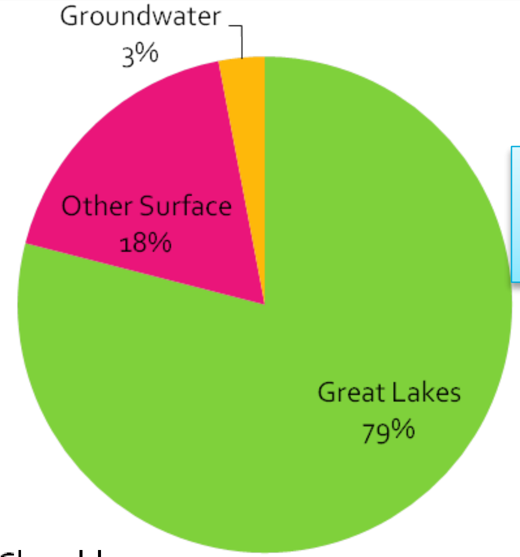
- Energy Information Administration

New plant siting

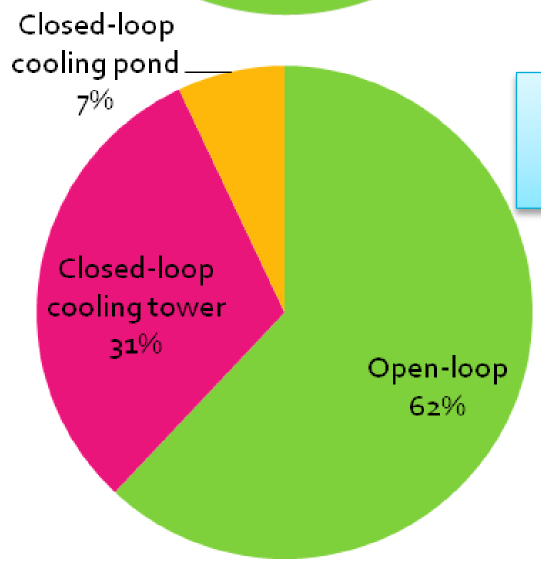
- Assumed 2005 ratio of power facilities in each HUC-8 watershed : overall power production in basin

Business As Usual (BAU)

- Similar fuel mix and cooling mix to 2007
- New plants will also adopt similar mix of source water
- No change in GHG emissions



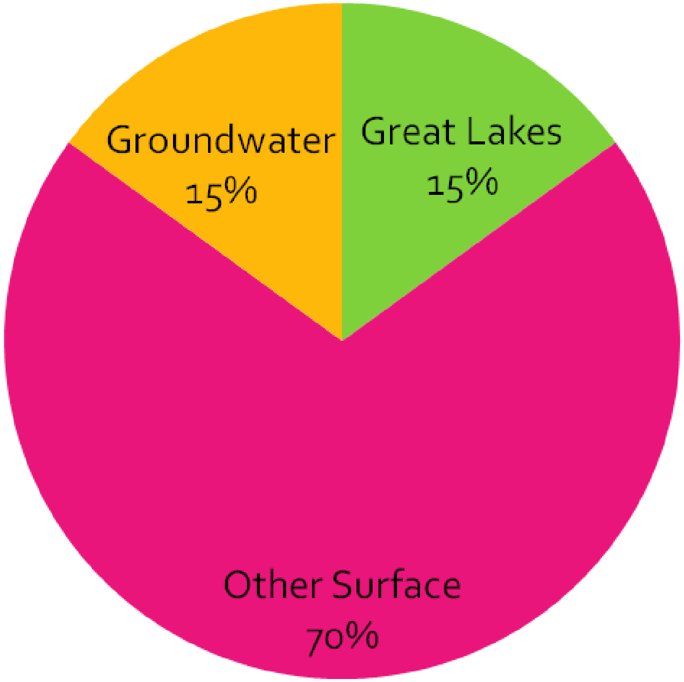
Cooling Water Source



Cooling Water Technology

No New Open-Loop Cooling (NNOLC)

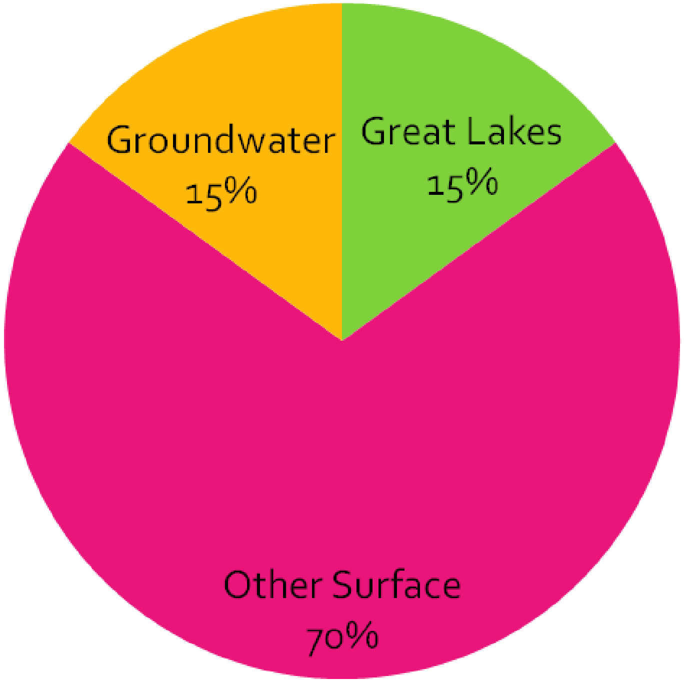
- Same as BAU with two exceptions:
  - No new power plant construction will utilize open loop cooling
  - New construction will depend less on Great Lakes water resources



Cooling Water Source

Open-Loop Cooling Prohibited (OLCP)

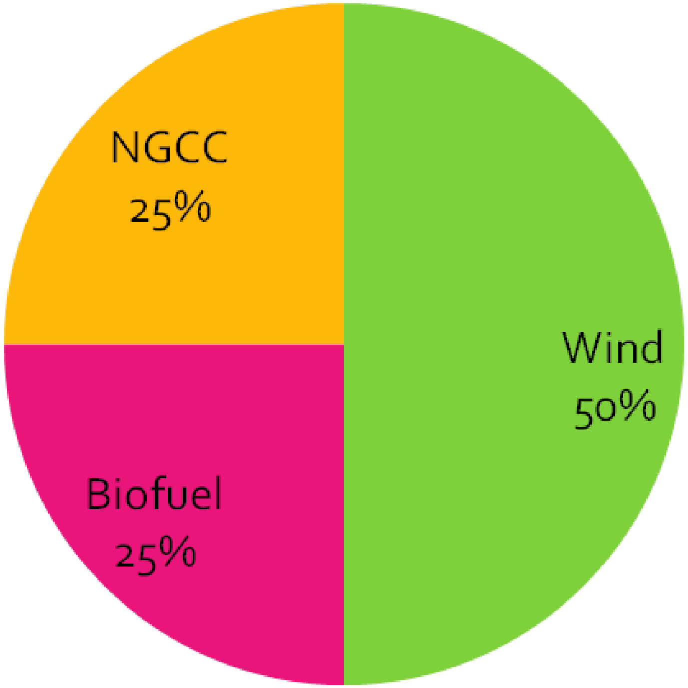
- Same as BAU with four exceptions:
  - No new power plants will utilize open loop cooling
  - Existing plants with open loop cooling = retired or converted to closed loop cooling
  - Plants older than 35 years with a capacity factor of ≤ 20% = retired
  - New construction will depend less on Great Lakes water resources



Cooling Water Source

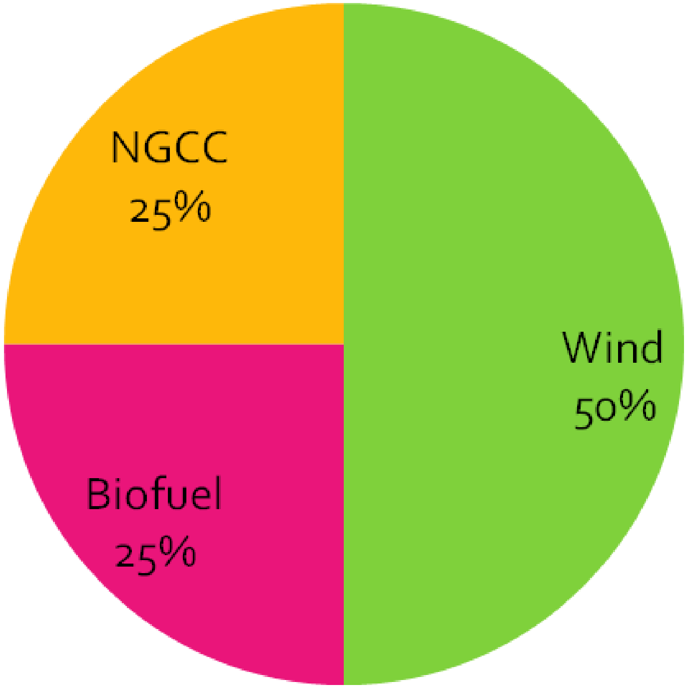
Renewable Portfolio Standard (RPS)

- Same as NNOLC with one exception:
  - Assumed future fuel mix for new plants favors **renewables**

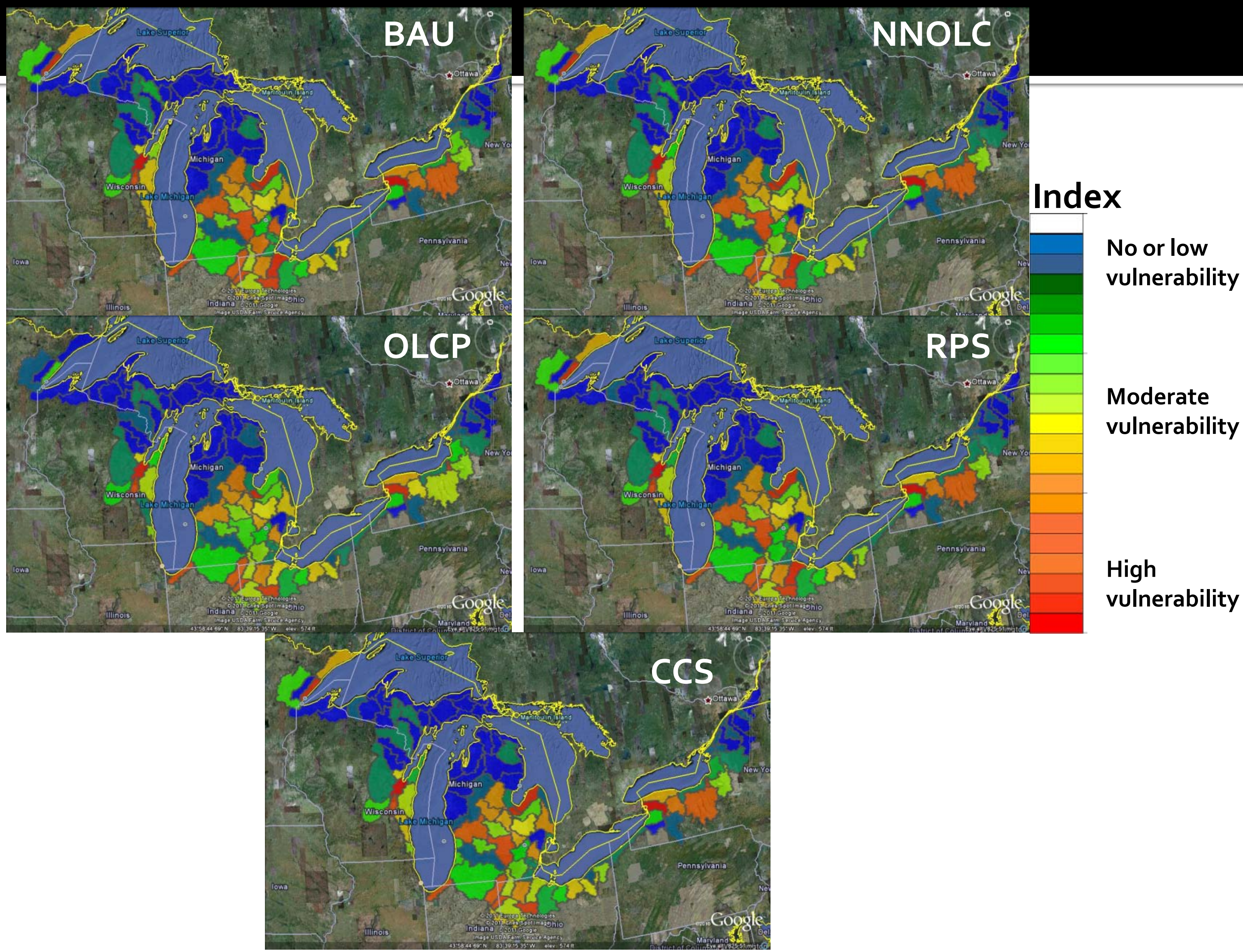


Carbon Capture and Sequestration (CCS)

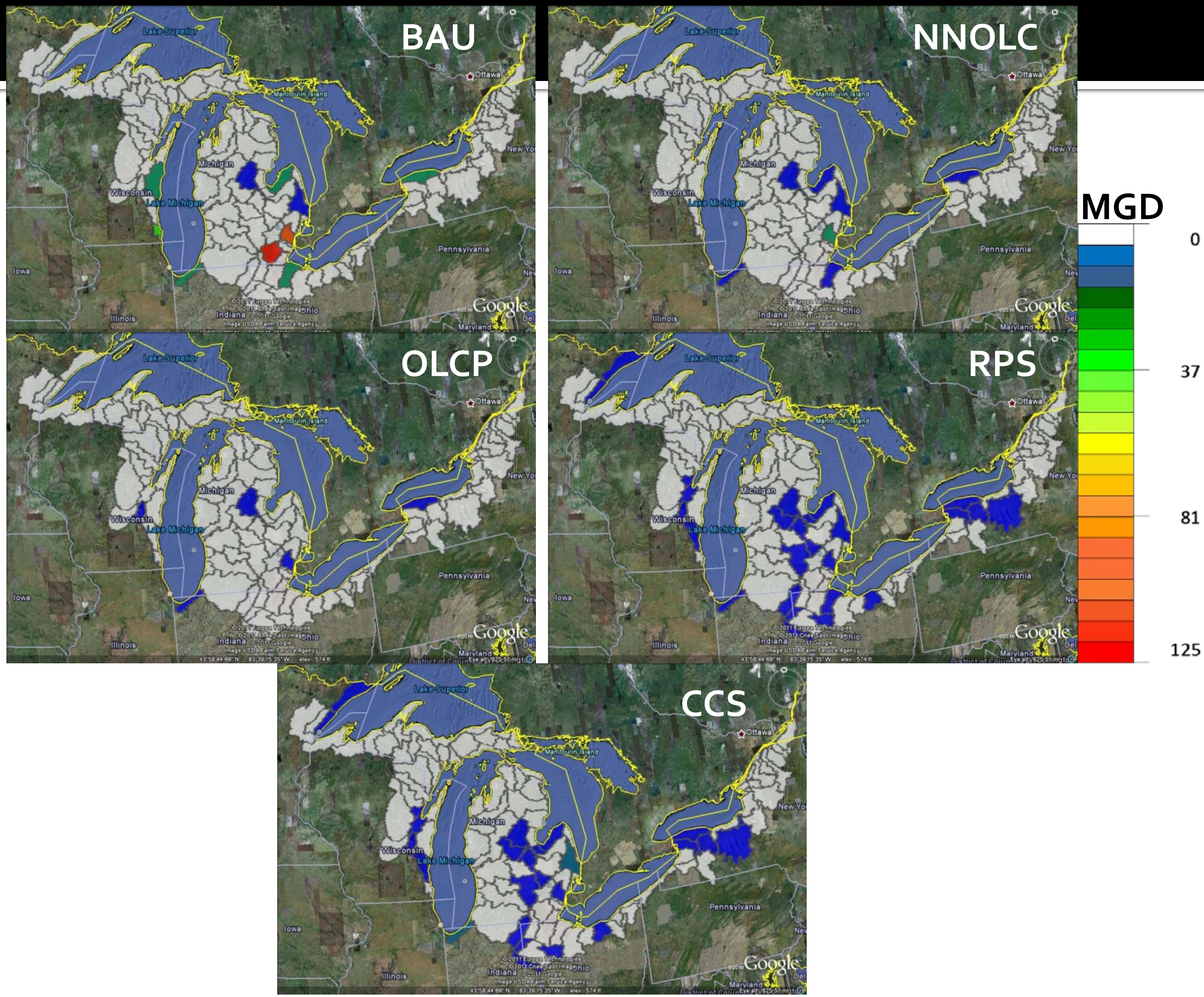
- New plant constructions follow RPS scenario
- New cooling type mix and source water follow NNOLC scenario
- Greenhouse gas levels must be reduced to 20% of 2007 levels



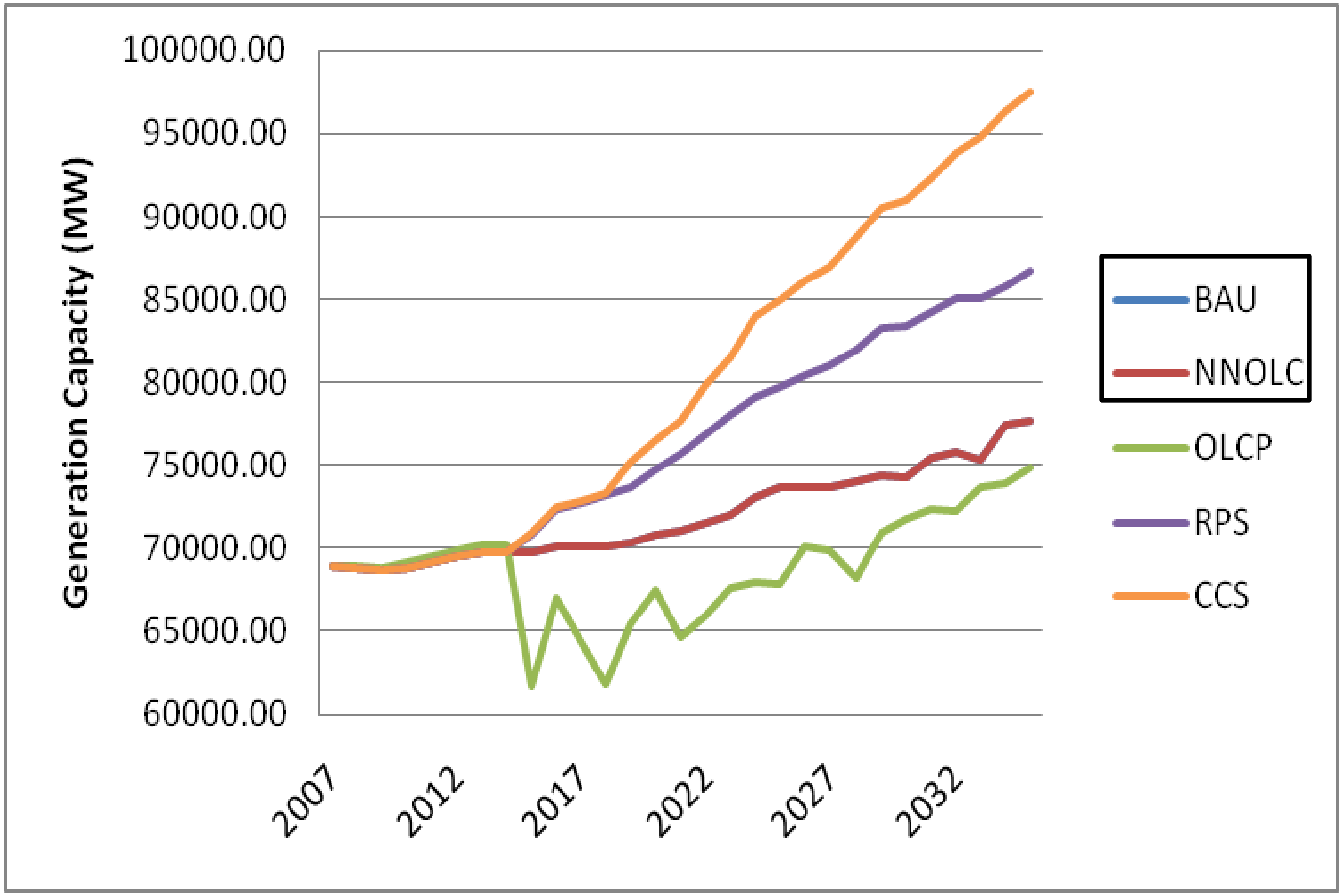
Low-flows (GLEW model)



New Withdrawals from Sensitive Basins



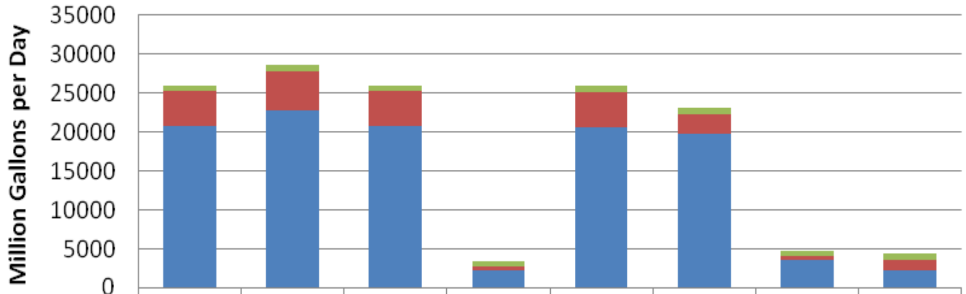
Future Generation Capacity



Tidwell and Moreland, 2011

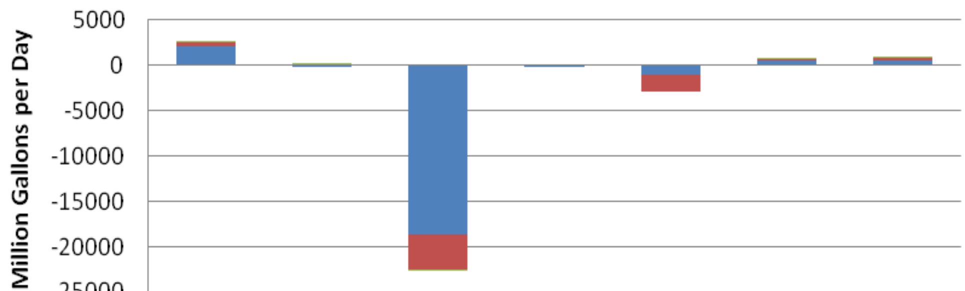
Changes to Regional Withdrawals

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

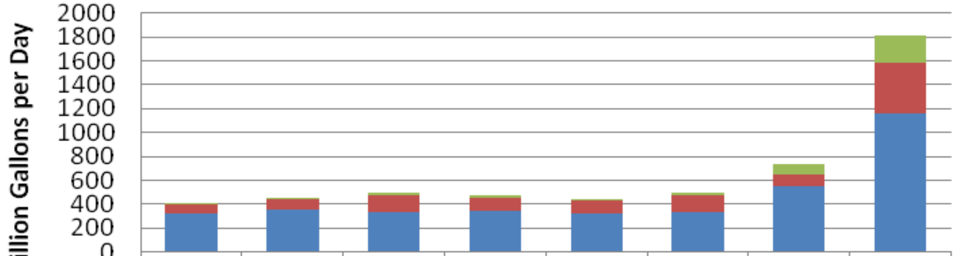


	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
Ground	108	33	-118	23	43	100	171
Stream	504	76	-3945	26	-1833	100	303
Lake	2083	-72	-18608	-83	-1069	603	534

Tidwell and Moreland, 2011

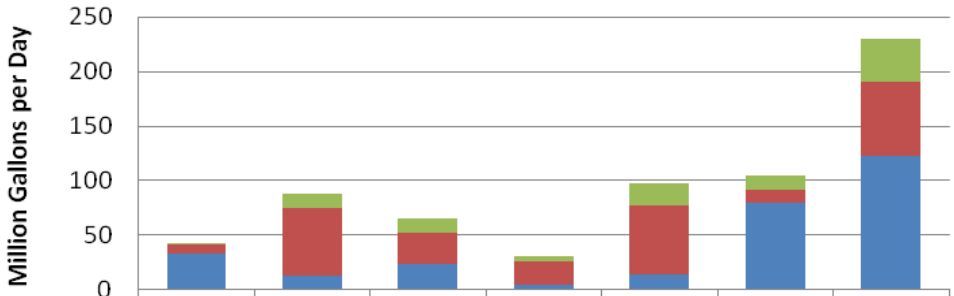
Changes to Regional Consumption

Total Water Consumption



	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

Change in Consumption 2007-2035



	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

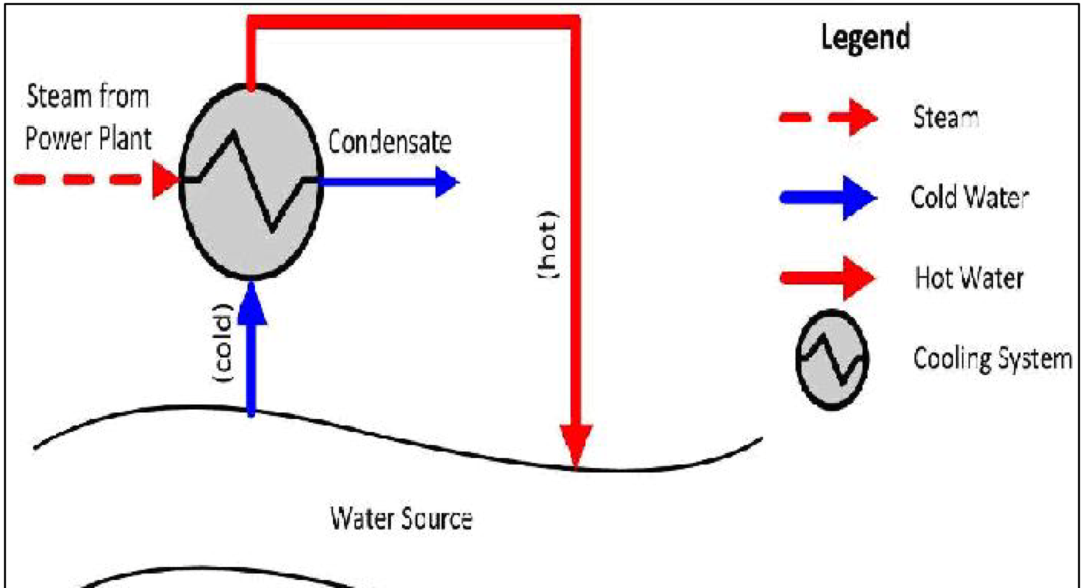
Tidwell and Moreland, 2011

Impacts to Vulnerable Watersheds

Policy Implications

- Clean Water Act Section 316b
  - Cooling technology
  - Impingement
  - Entrainment
- New units required to:
  - Add technology to reduce intake flows equiv. to **closed-loop**

Open-Loop Cooling System



Environmental Defense Fund, 2010

Almost **60%** of plants in the GL Basin utilize open-loop cooling!

↓

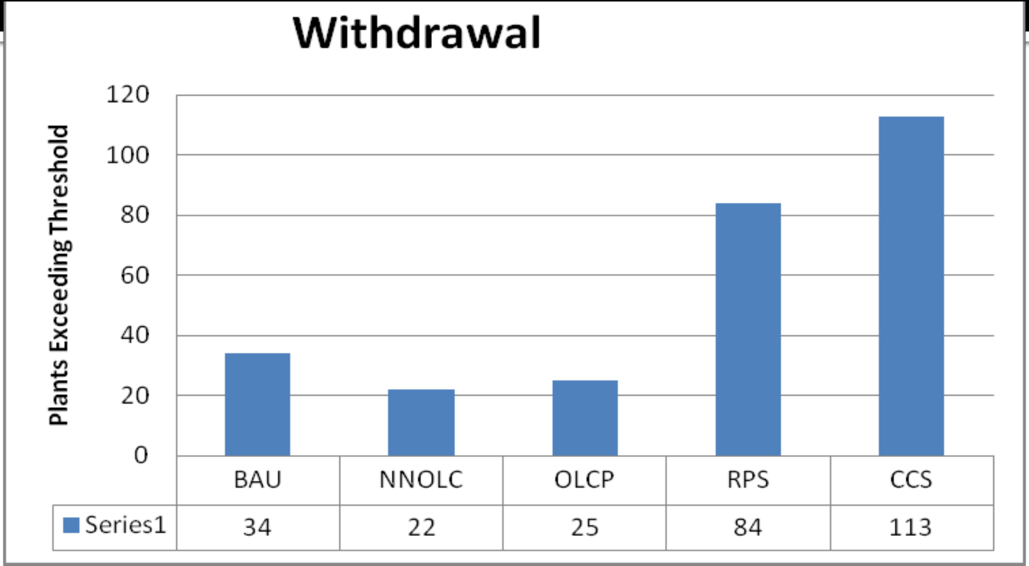
Policy (and water use) changes may impact **ecological health** of watersheds

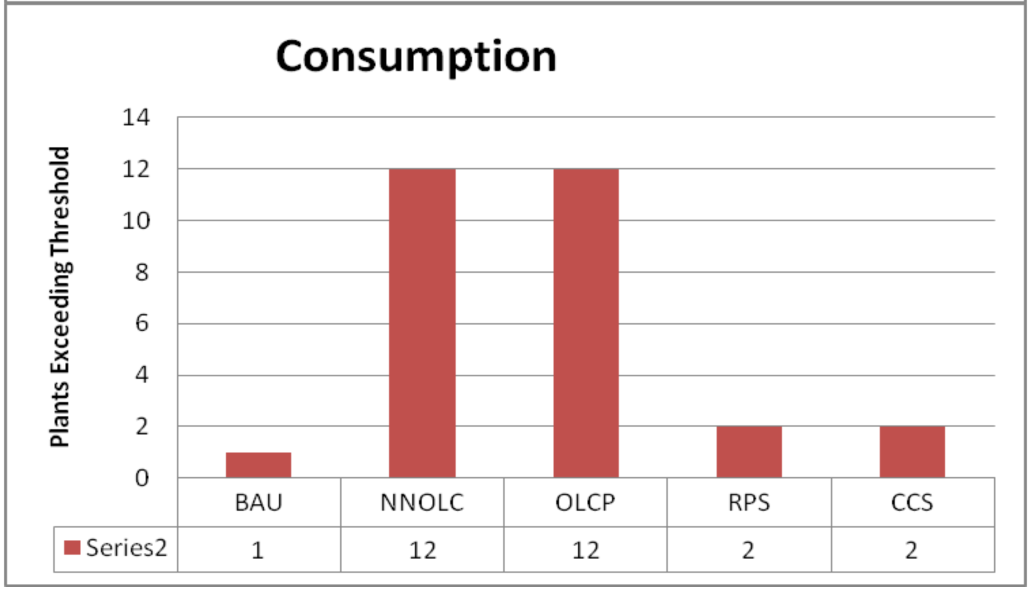
Policy Implications, cont.

The Great Lakes and St. Lawrence River Basin Water Resources Compact

- Enacted in 2008 by Great Lakes states and provinces to establish guidelines for water conservation
- Thresholds for Reporting and Registration:
  - Withdrawal: **100,000 GPD**
  - Consumption: **5 MGD** (subject to regional review)
    - States may set their own thresholds!
- GLEW Scenarios:
  - Result in varying projections of water use and, thus, varying implications for compliance with **Compact** guidelines…

Policy Implications, cont.





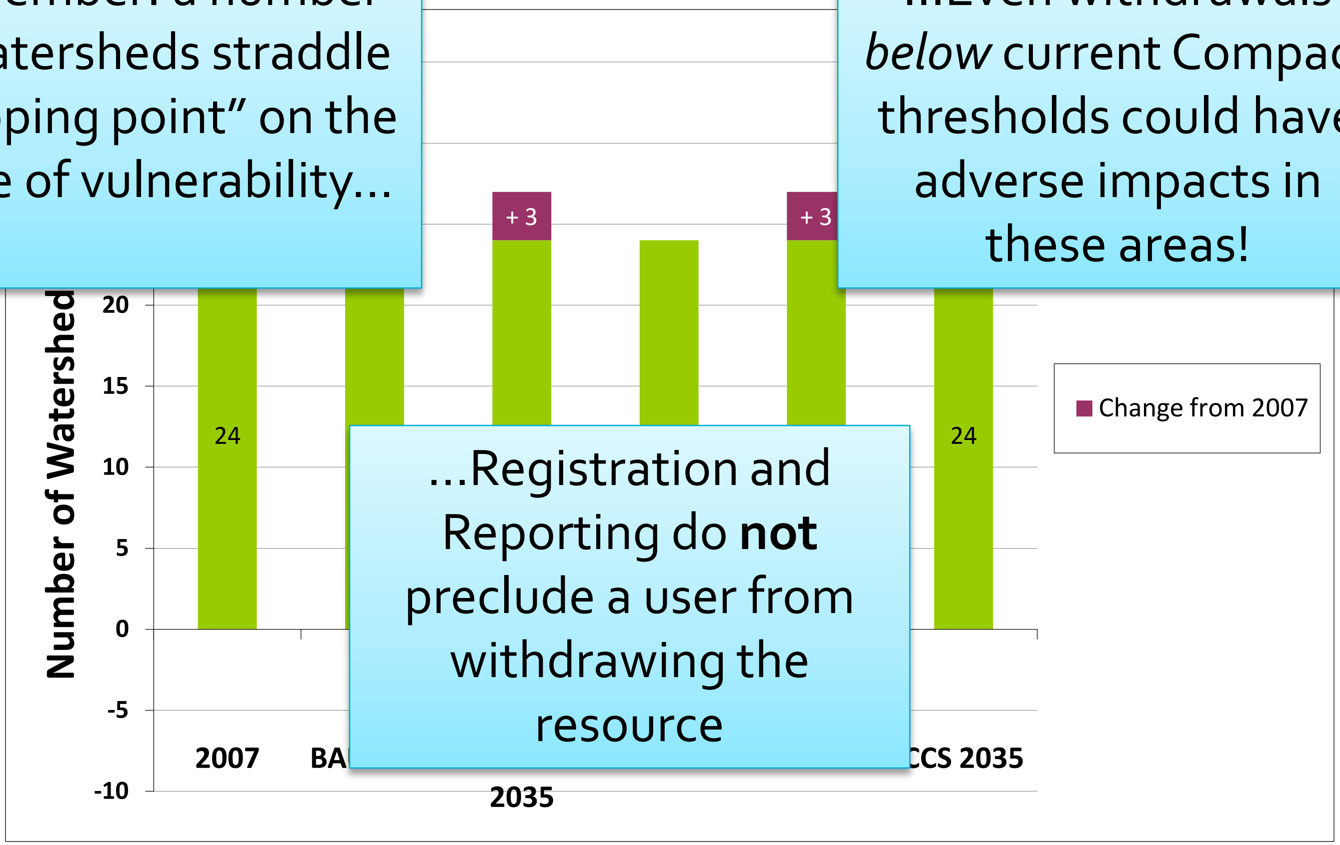
Tidwell and Moreland, 2011

Policy Implications, cont.

- Compact threshold violations vs. vulnerable watersheds
  - What's the connection?

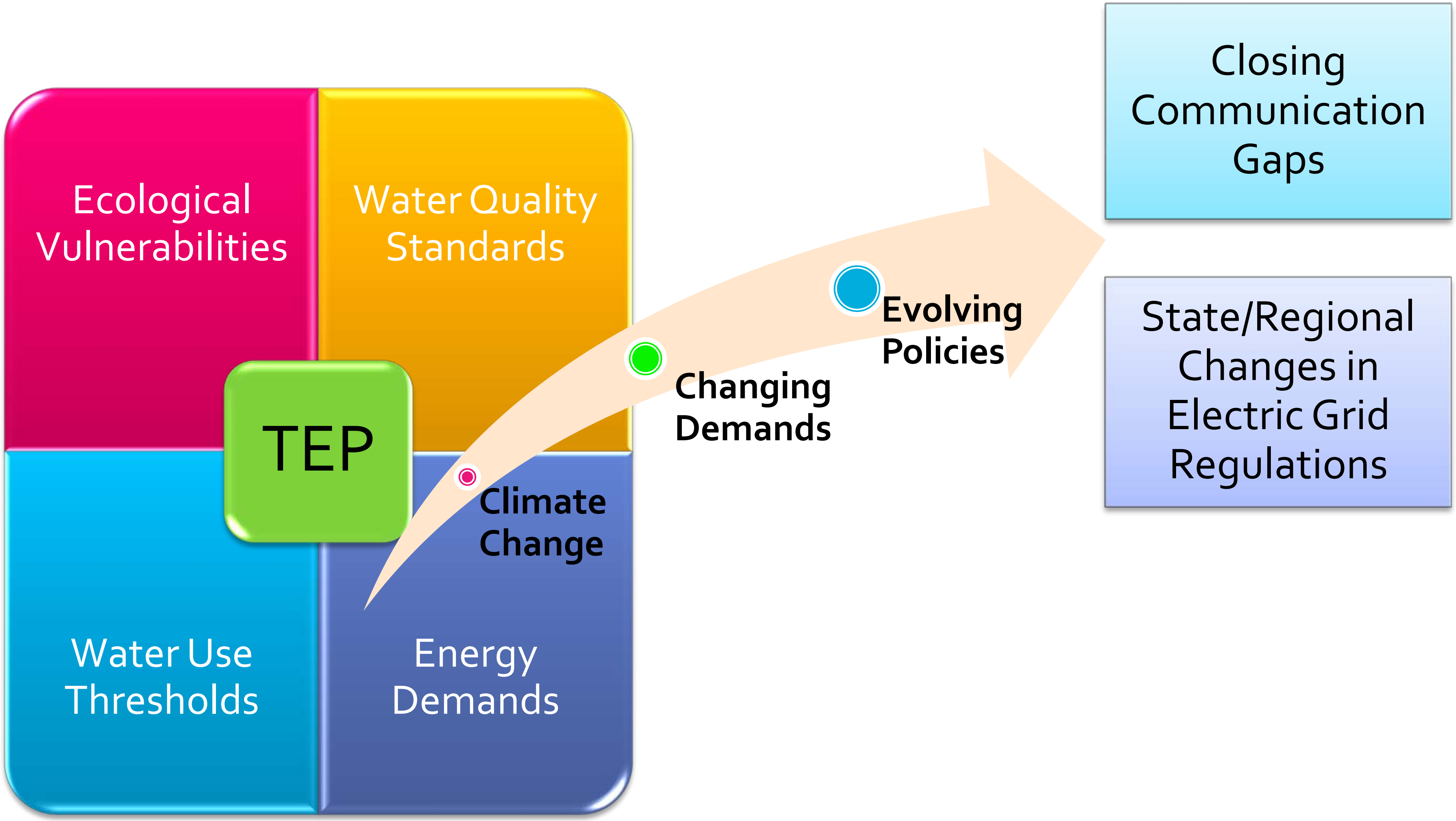
Remember: a number of watersheds straddle a "tipping point" on the verge of vulnerability…

…Even withdrawals *below* current Compact thresholds could have adverse impacts in these areas!



…Registration and Reporting do **not** preclude a user from withdrawing the resource

Electric Market Planning & Regulation



Electric Market Planning & Regulation: State Level

State Departments of Natural Resources

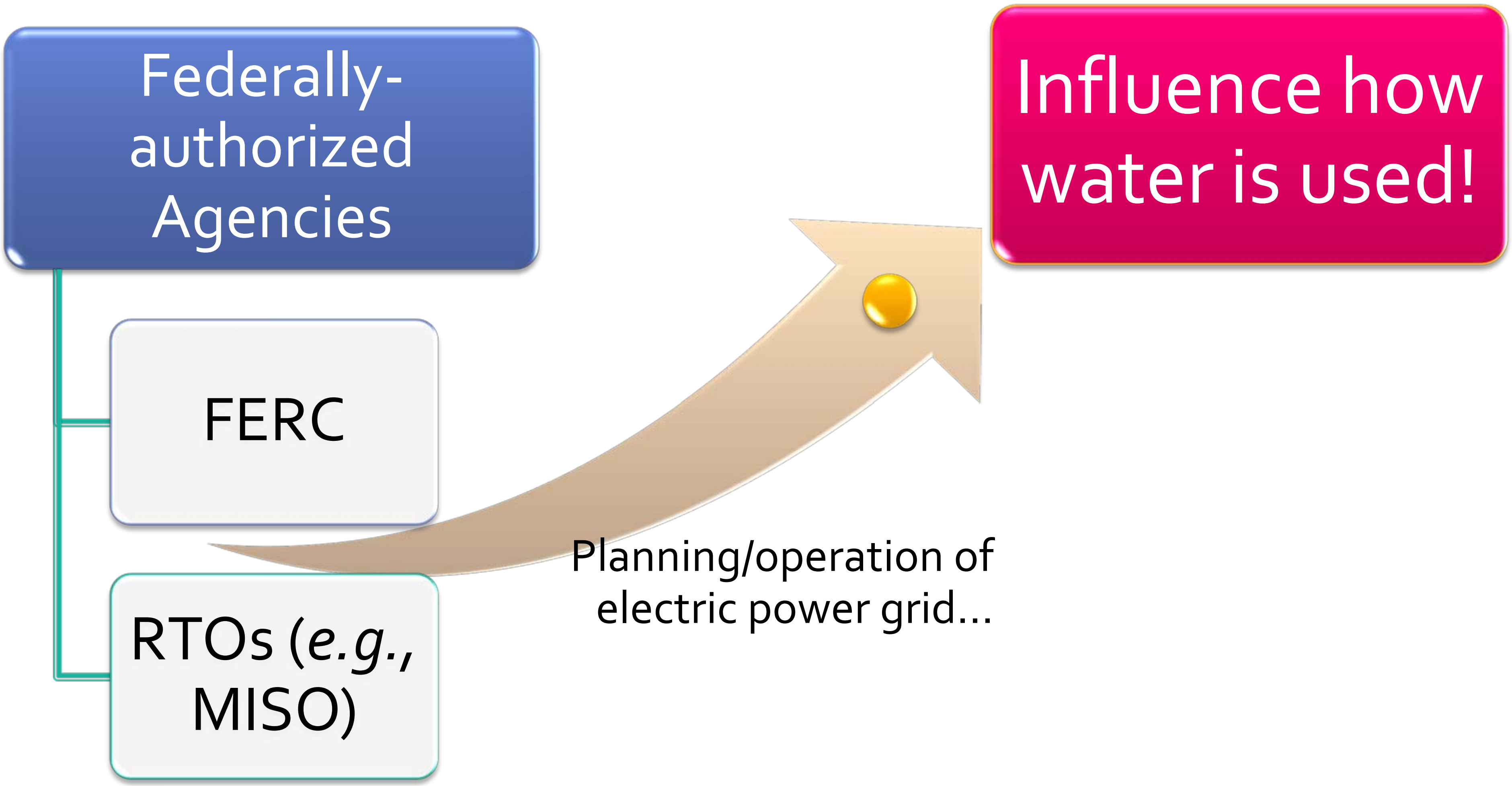
- Reporting procedures require disclosure of power plant water use/consumption

State Public Utility Commissions

- Key decision makers about where new power production facilities are sited

Minimize Adverse Impacts

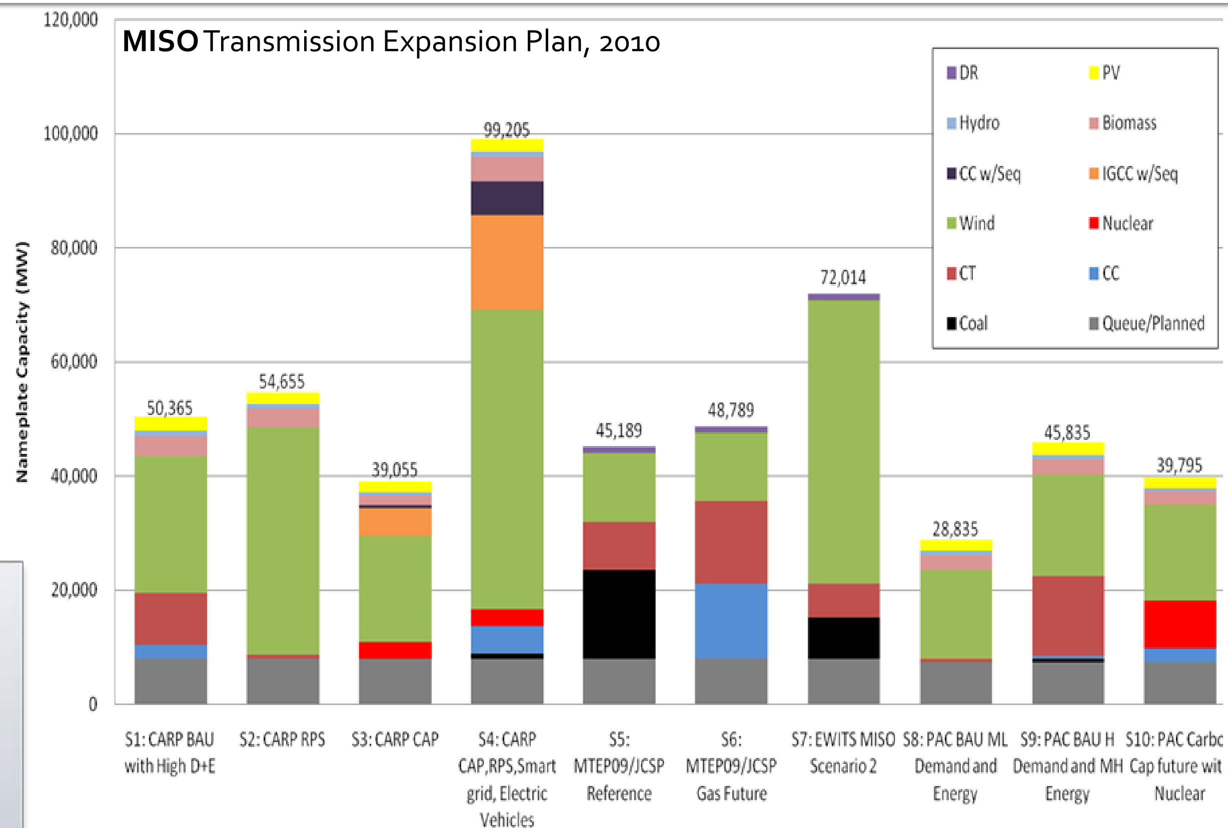
Electric Market Planning & Regulation: Regional Level



Electric Market Planning & Regulation: Regional Level

- RTO modeling exercises show varying future energy generation mixes

Water??



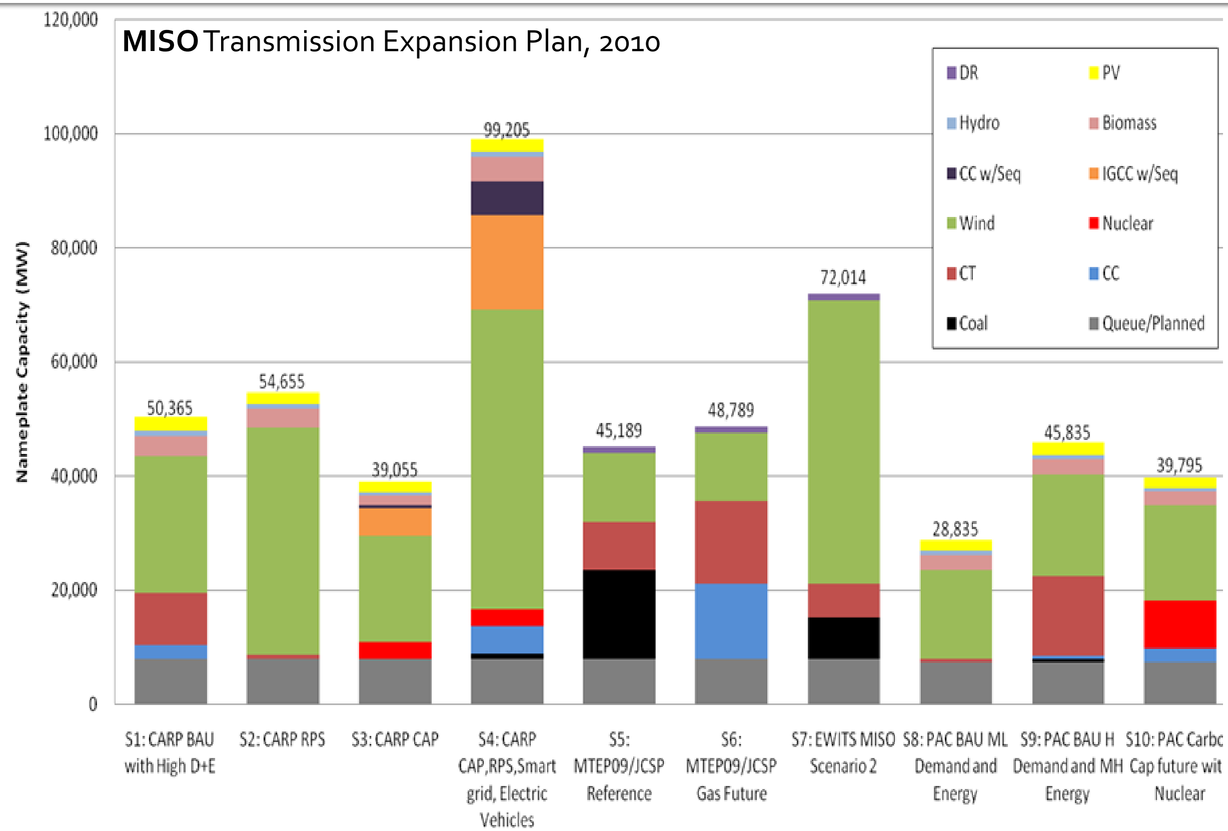
Cost

Reliability

GHG Emissions

Electric Market Planning & Regulation: Regional Level

- RTO modeling exercises show varying future energy generation mixes
- GLEW model: First time **water resources** are considered in future power projection scenarios for the Great Lakes basin

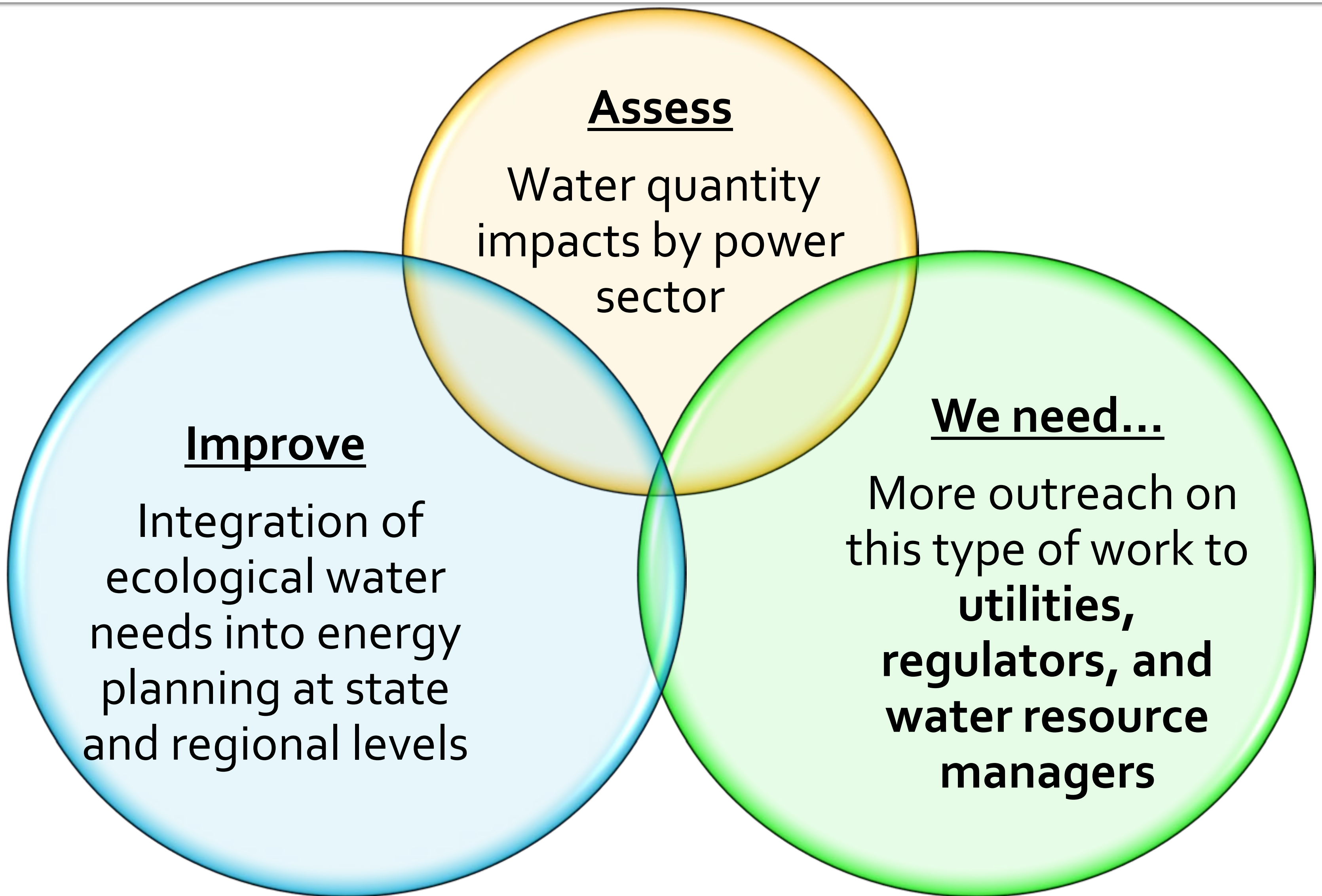


Cost

Reliability

GHG Emissions

Application of Results: Market Planning & Regulation



Key Findings

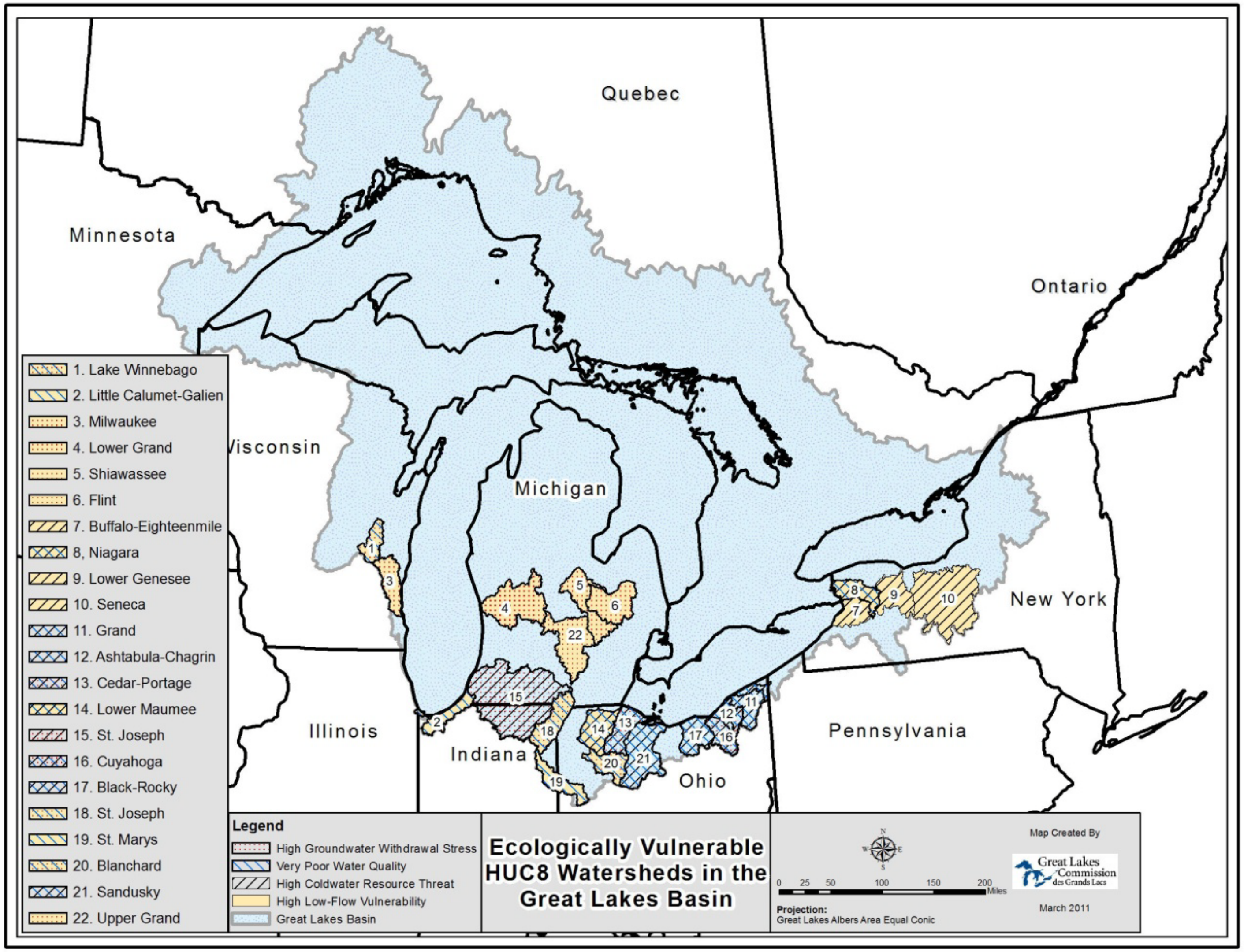
- TEP= dominant water user in GL Basin
  - 76% of total **withdrawals**
  - 13% of total **consumption**
- Future thermoelectric scenarios result in vastly different water resource use and impacts by 2035:
  - Increase in withdrawals by 2,695 MGD (**BAU**)
    - OR
  - Decrease in withdrawals by 22,671 MGD (**OLCP**)

- Drivers assessed:
  - Vulnerable watersheds (↑, ↓)
  - Non-thermoelectric sector(s)
  - Infrastructure (CWA 316b)
  - Policy (GL Compact)

Key Findings (cont.)

- Changes in thermoelectric water use = more significant impact on tributary watersheds than changes to municipal/industrial uses
- Impacts vary across basin
  - Greater impacts in vulnerable areas
- Results will differ depending on where new power generation occurs
- ...Location matters!

Key Findings (cont.)



Supporting Documents

Supporting Documents

- ***Energy and Water in the Great Lakes*** (V. Tidwell and B. Moreland. 2011. Sandia National Laboratories)
- ***Environmental Rules to Classify Basins for Sensitivity from Future Energy Development*** (M. Bain. 2011. Cornell University)
- ***The Confluence of Power and Water: How Regulation of the Electric Power Grid Affects Water and Other Natural Resources*** (N. Schroeck. 2011. Great Lakes Environmental Law Center)
- ***Electric Power Planning, Regulations, and Water Resources*** (J. Moore. 2011. Environmental Law and Policy Center)

Website:

http://www.glc.org/energy/glew/

Questions?

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Acknowledgements

- Great Lakes Protection Fund

- GLEW Project Advisors:
  - Alliance for Water Efficiency
  - DTE Energy
  - Edison Electric Institute
  - Electric Power Research Institute
  - Illinois Dept. of Natural Resources
  - Mich. Dept. of Energy, Labor, and Economic Growth
  - NY Power Authority
  - Ontario Power Generation
  - Penn. Dept. of Env. Protection
  - Recycled Energy Development
  - U.S. Dept. of Energy (National Energy Technology Laboratory)
  - University of Texas, Austin
  - We Energies
  - Wisc. Dept. of Natural Resources
  - Wisconsin Public Services Commission

- GLEW Core Team:
  - Cornell University
  - Sandia National Laboratories
  - Great Lakes Environmental Law Center
  - Environmental Law and Policy Center