

Water-Energy Nexus
Integrating Water and Energy
Systems for Sustainable
Development

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Integrated Energy-Water Planning

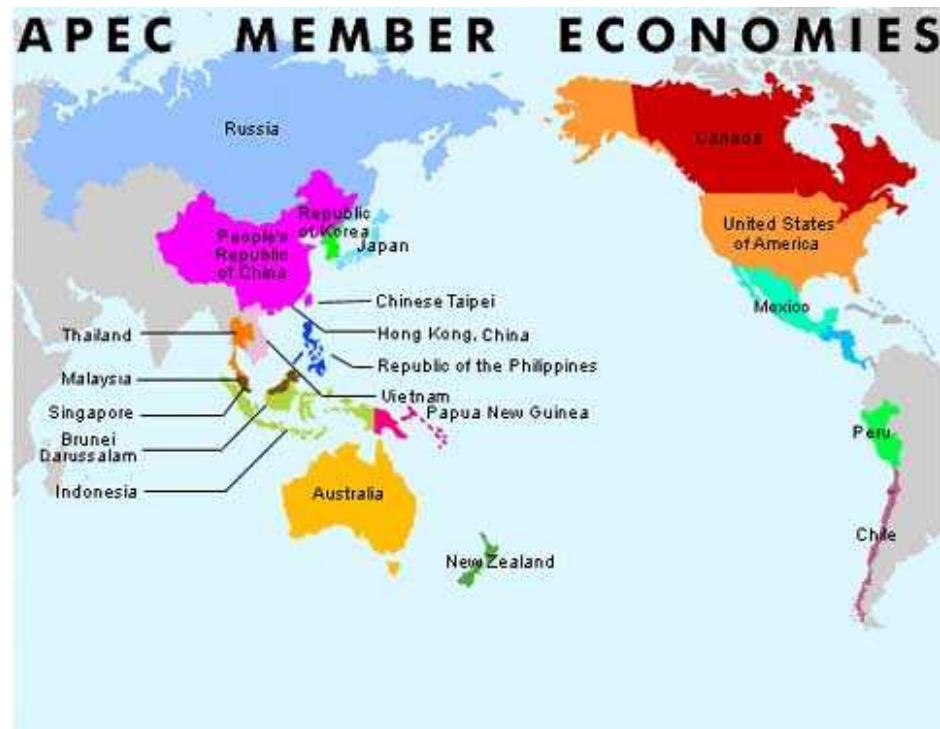
Vincent Tidwell
Sandia National Laboratories
APEC Water-Energy Nexus Expert Workshop
Atlanta, Georgia
October 31, 2017

Take-Aways

- Modeling and analysis key to managing the Energy-Water Nexus
- Multi-modal, multi-scale approach is needed:
 - Multinational Scale: High-level analysis aimed at recognizing and communicating the problem,
 - Regional Scale: Moderate detail capturing linkages between energy and water supporting integrated planning, and
 - Asset Scale: Detail sufficient to model operations of key assets to quantify vulnerabilities and adaptive measures.

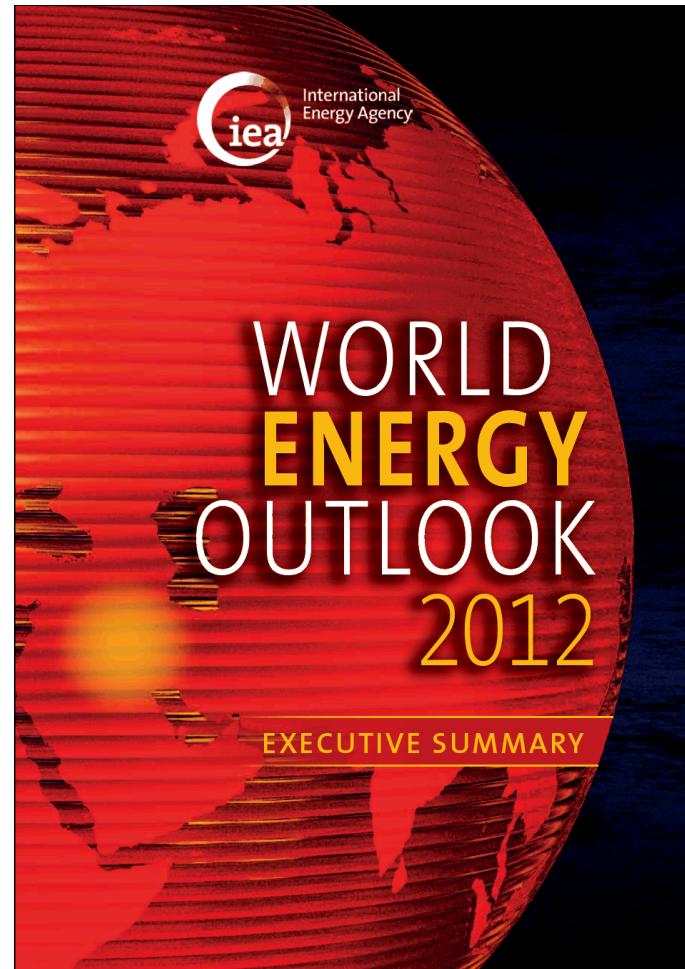
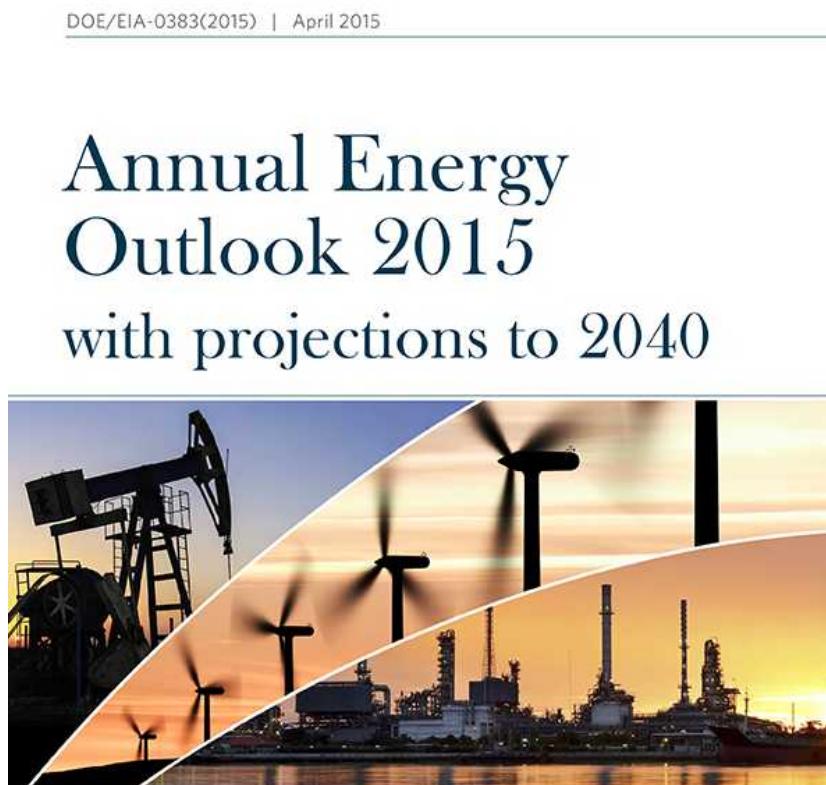
Multinational: Identifying Hot Spots

- Support the Asia-Pacific Economic Cooperation by investigating the Energy-Water Nexus in each member economy:
 - Map water use for energy
 - Map energy use for water
 - Perform mapping at a regional level
 - Compare to measures of water stress



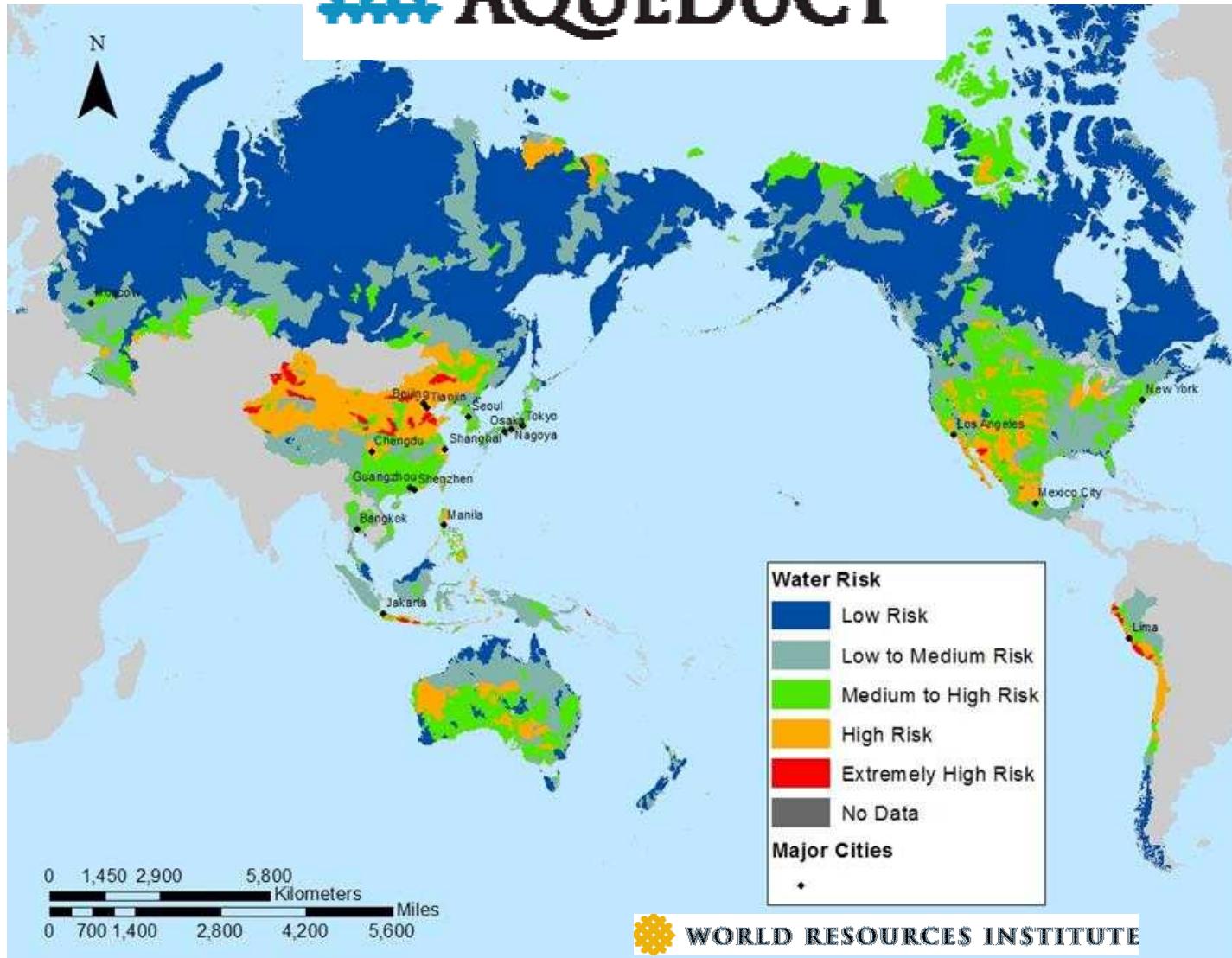
Methods

- Utilized publically available data



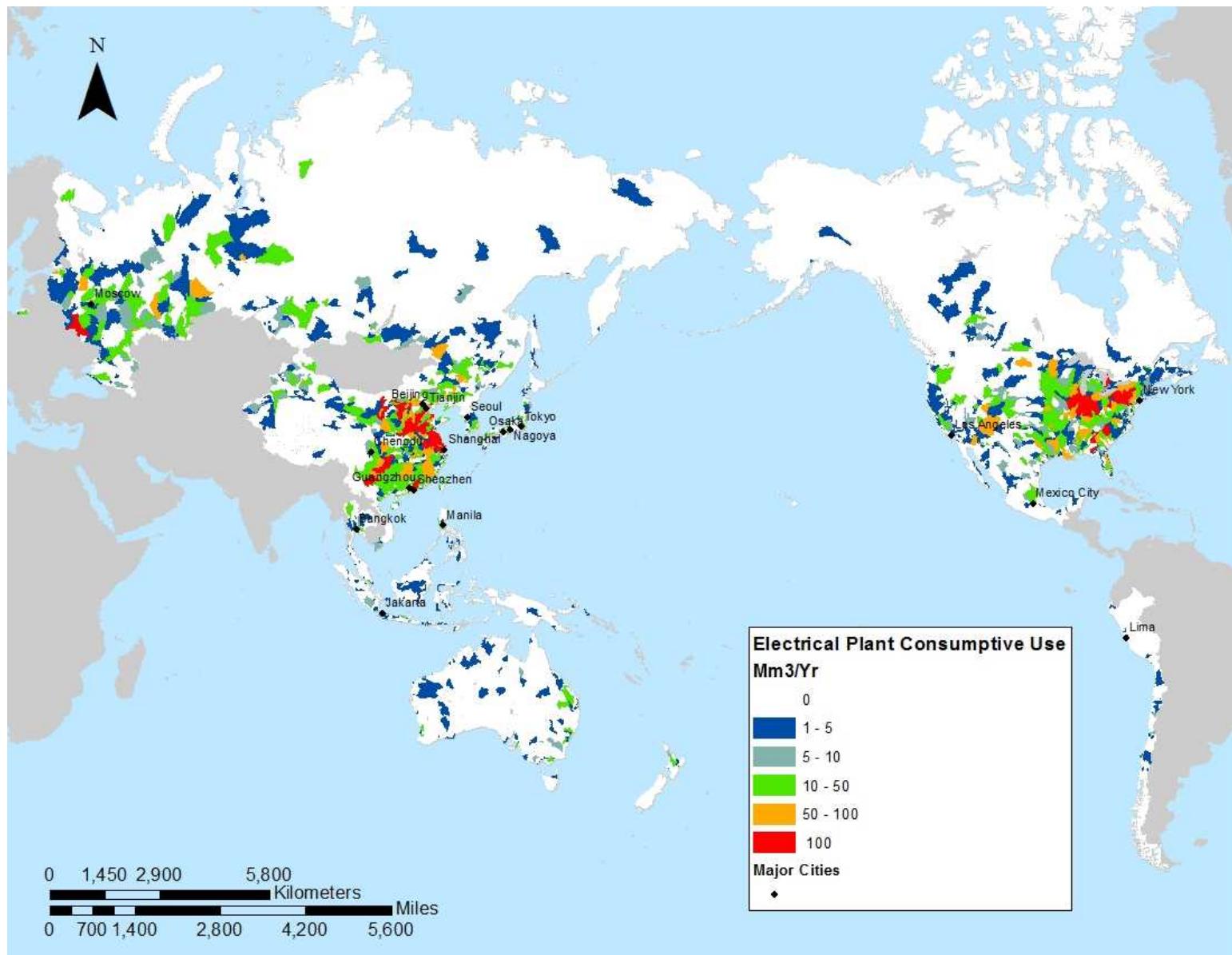
Global Water Risk Mapping

 AQUEDUCT

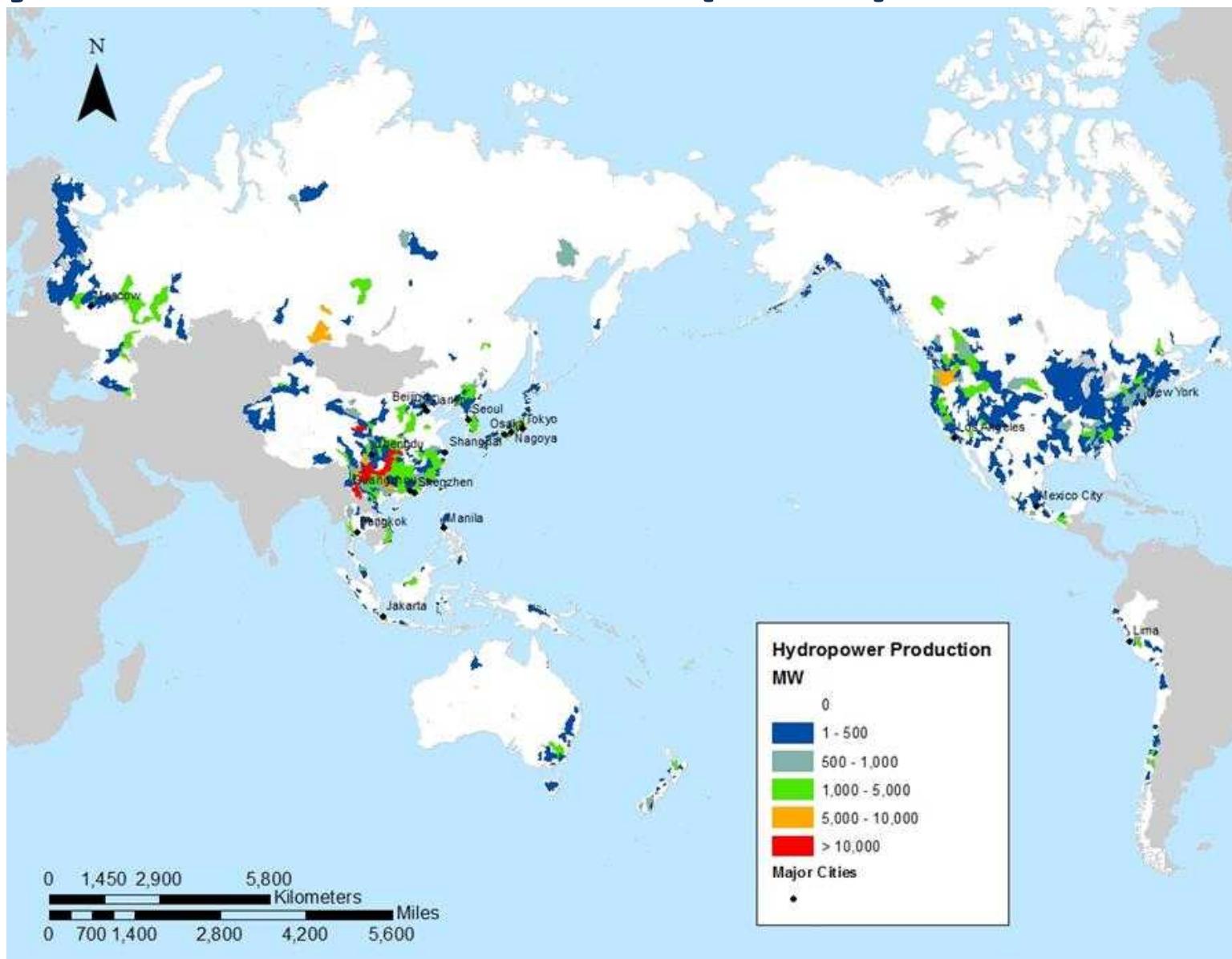


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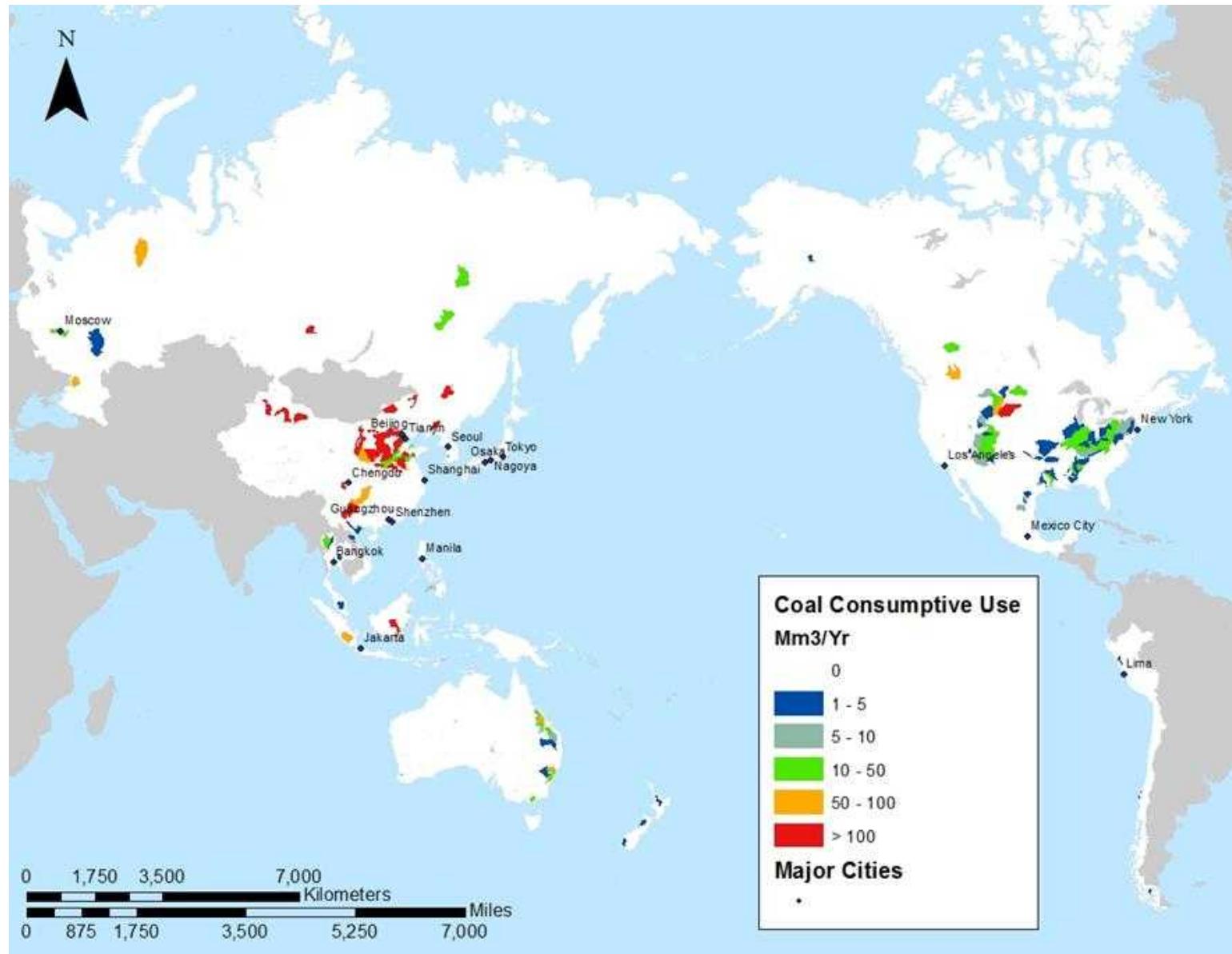
Water for Thermoelectric Power



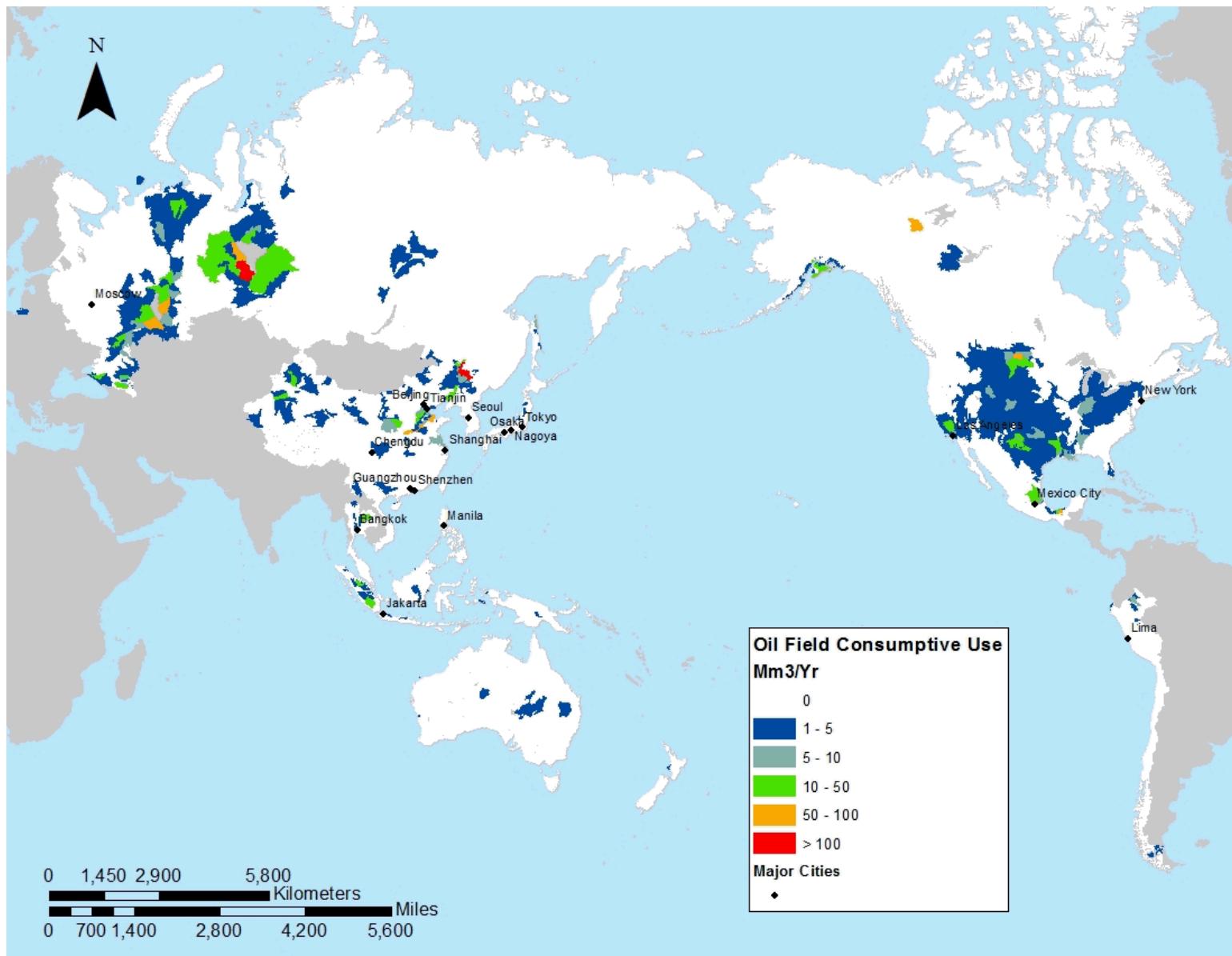
Hydroelectric Power (MW)



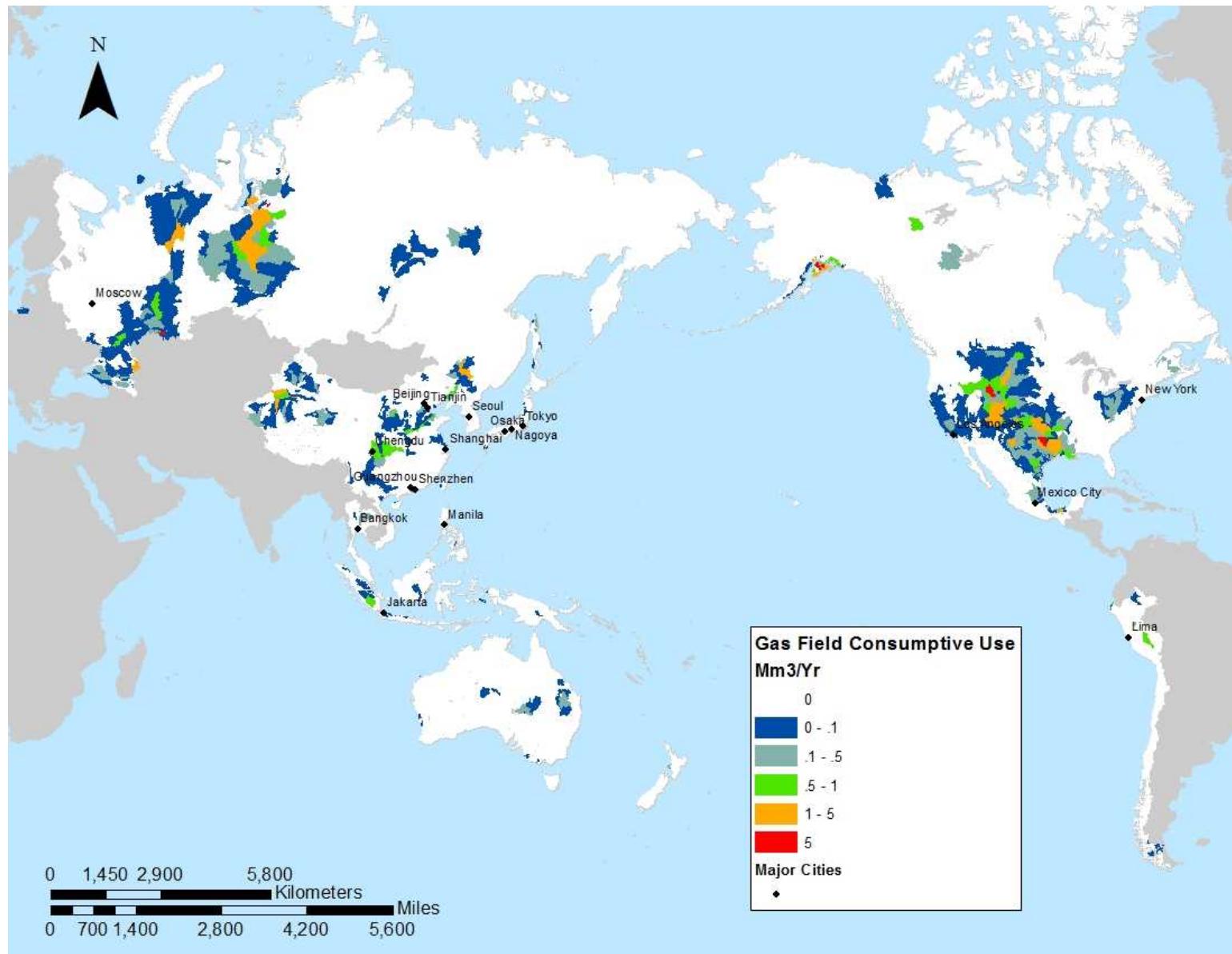
Water for Coal Extraction



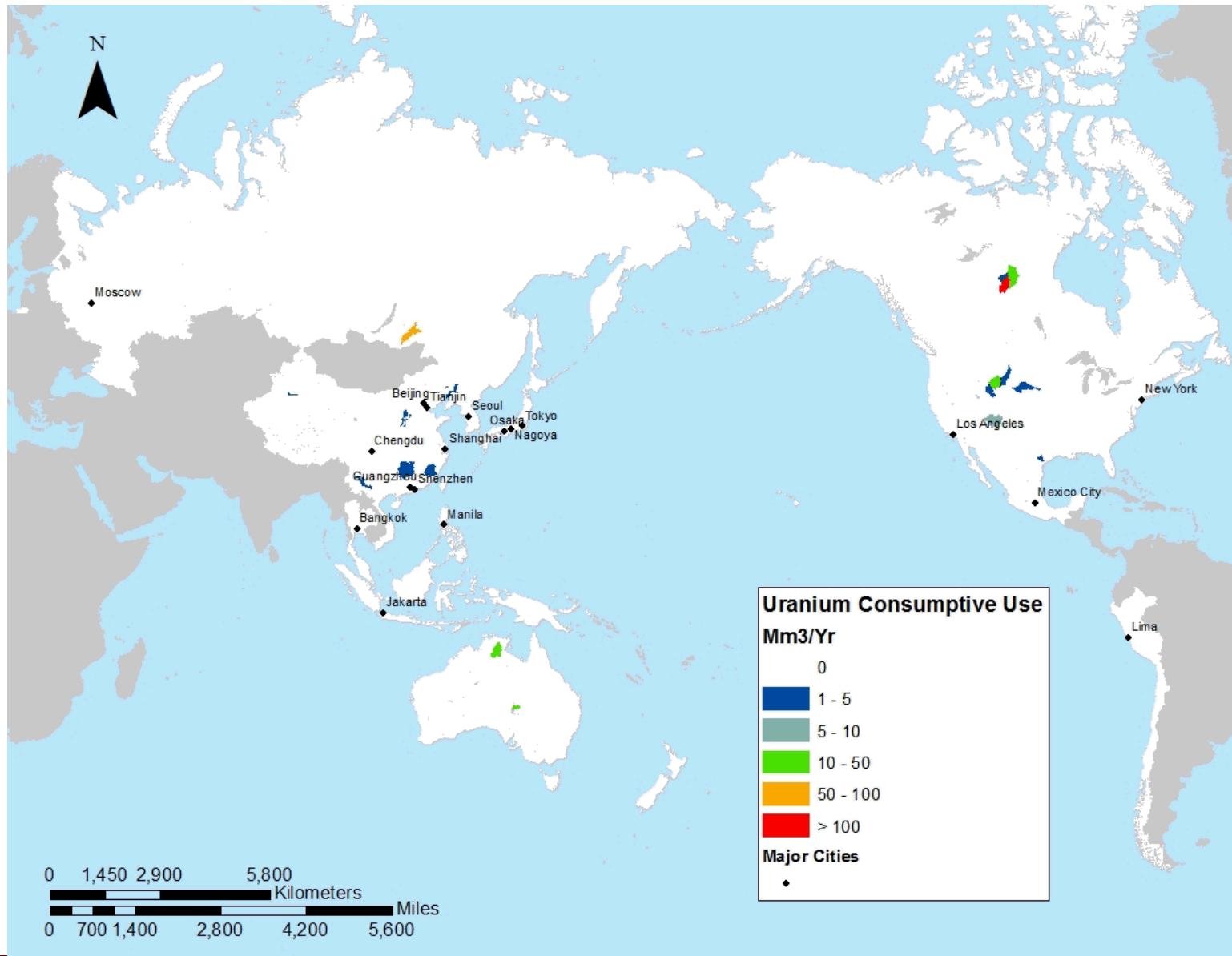
Water for Oil Extraction



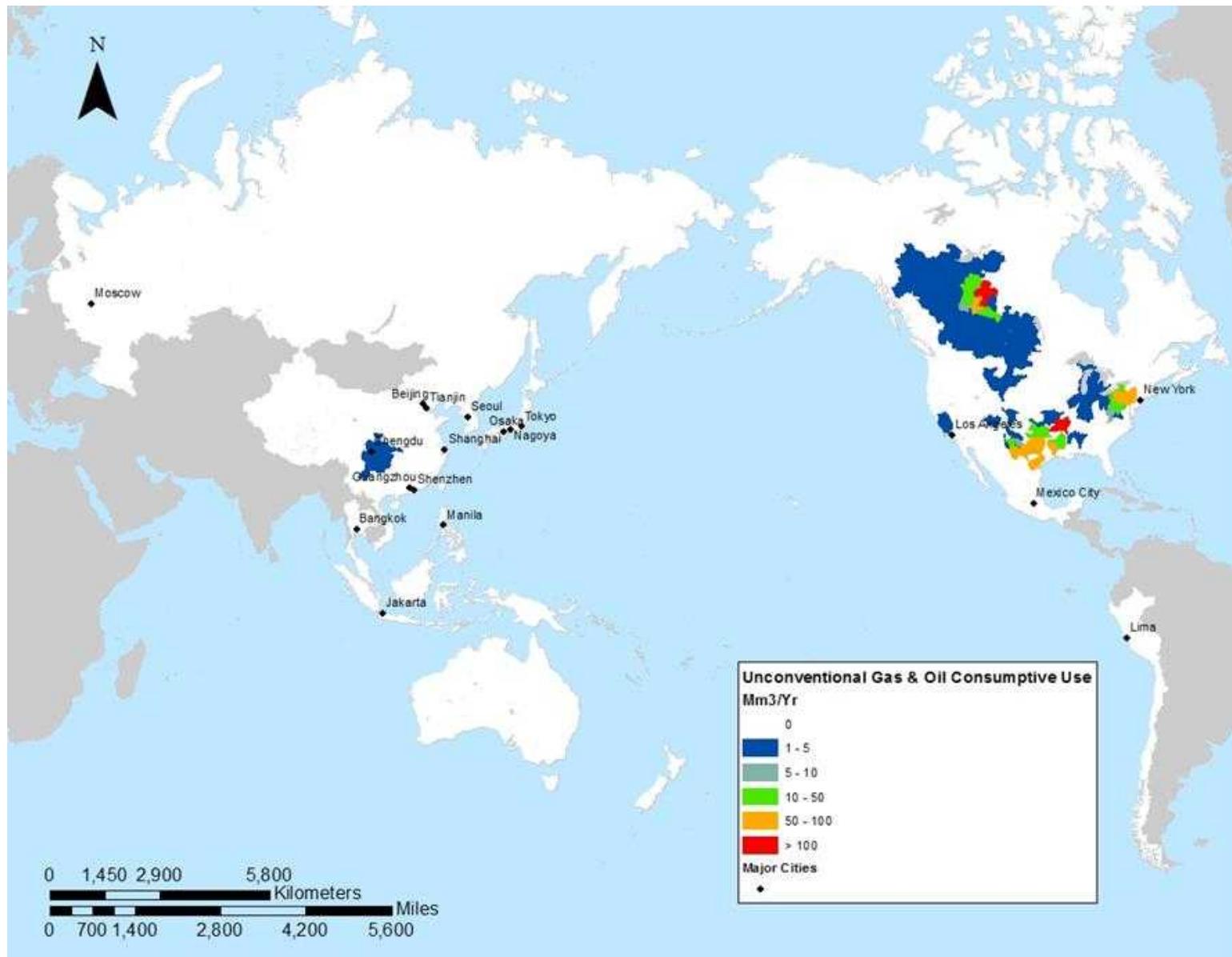
Water for Natural Gas Extraction



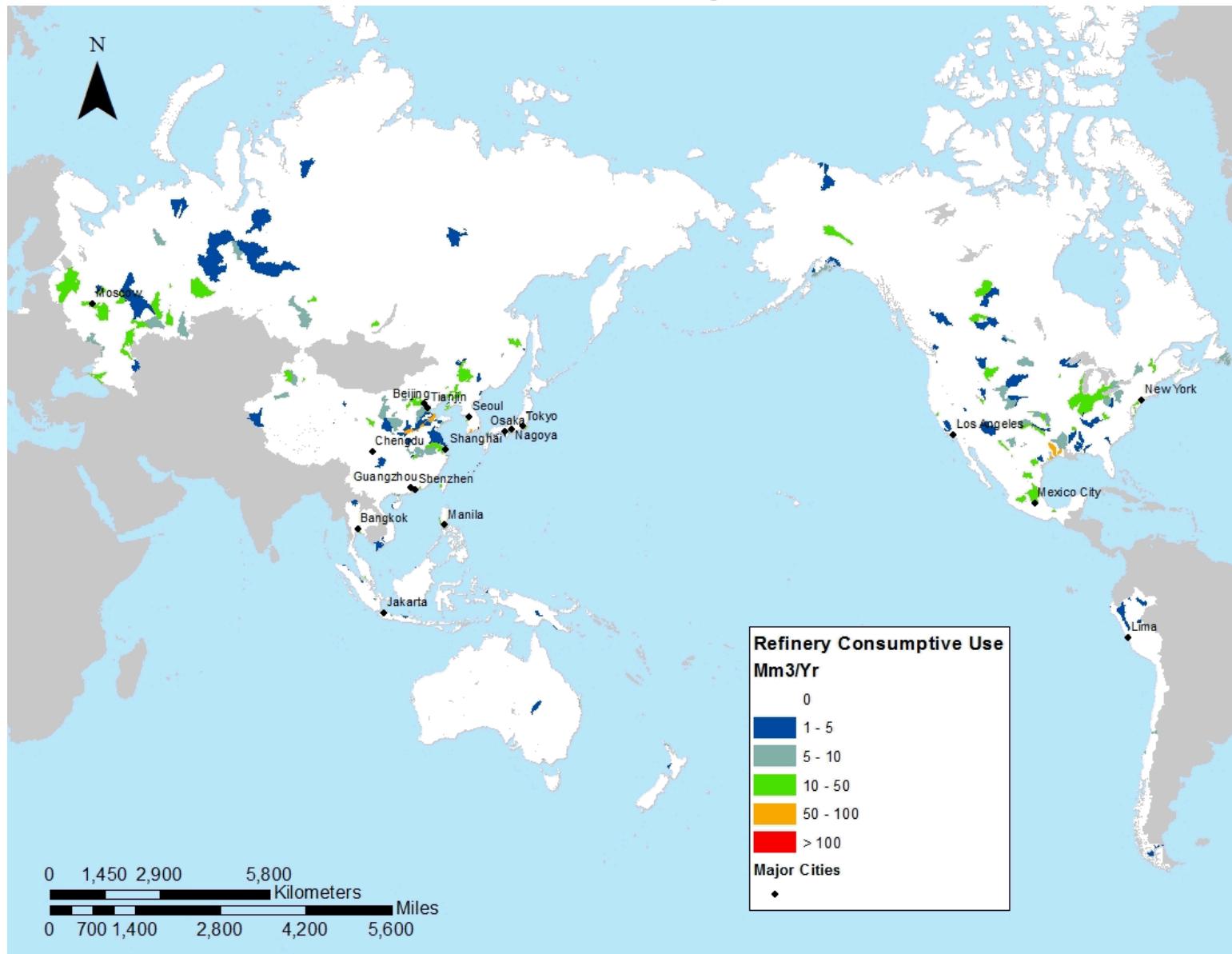
Water for Uranium Extraction



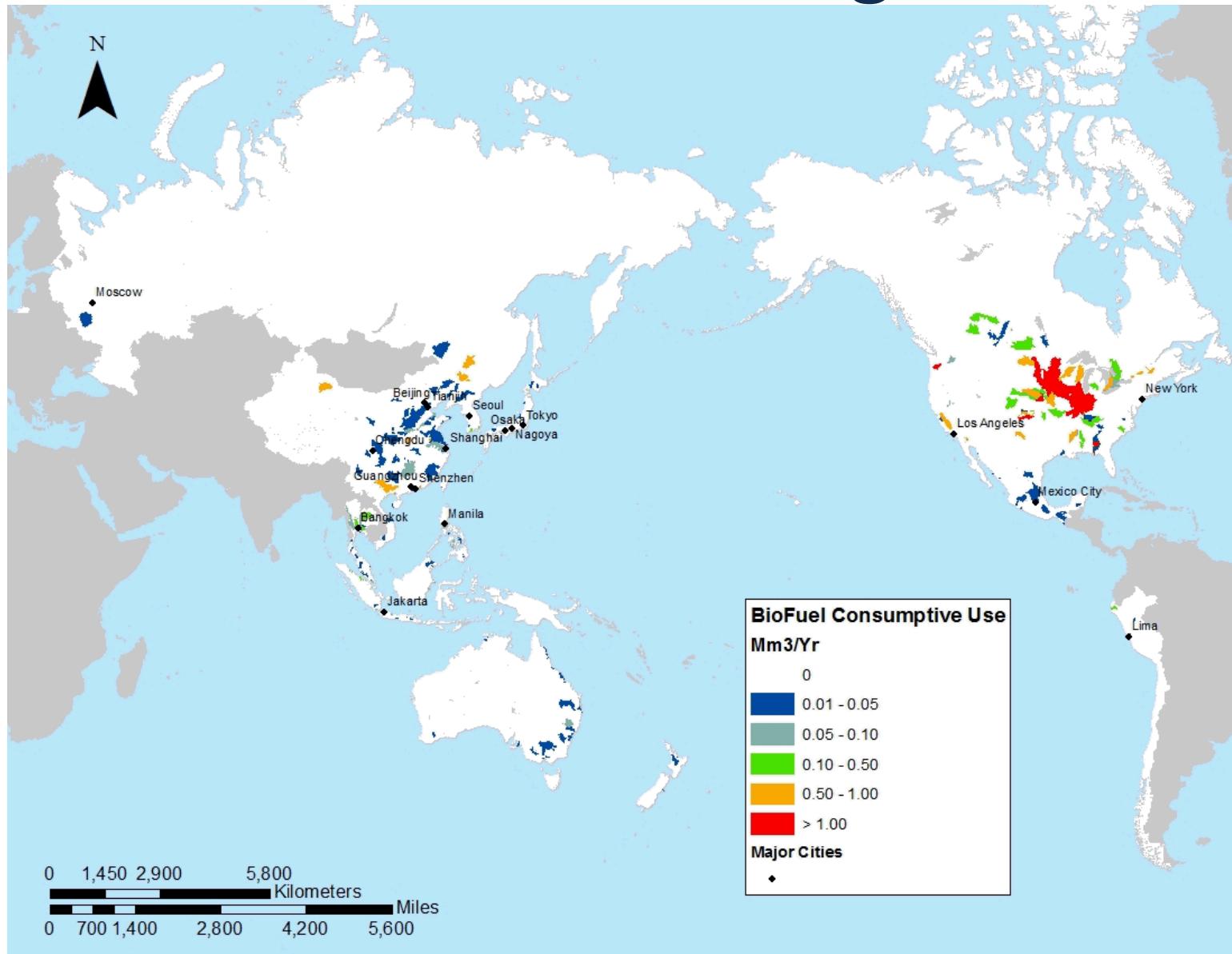
Water for Unconventional Oil and Gas



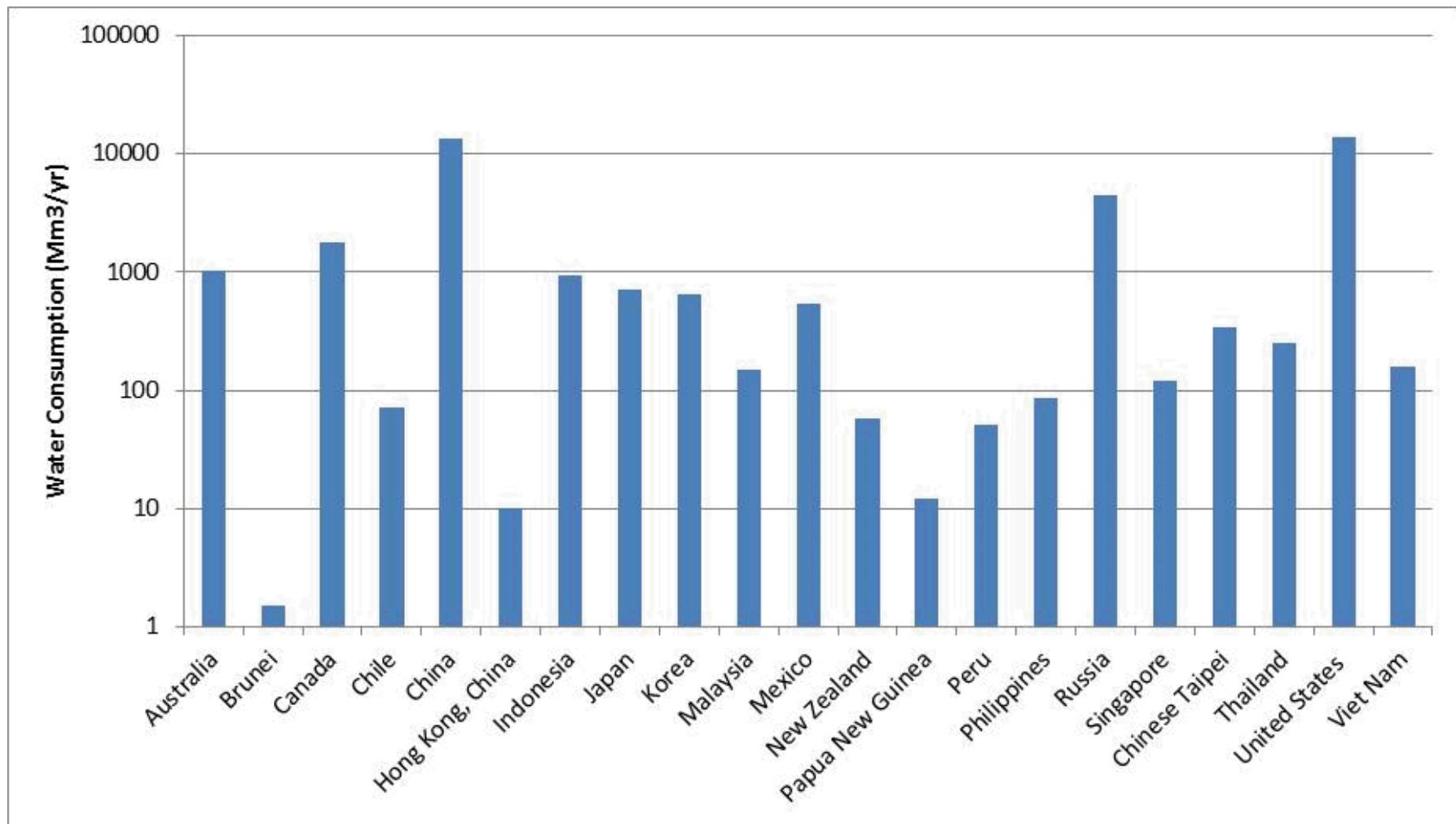
Water for Oil Refining



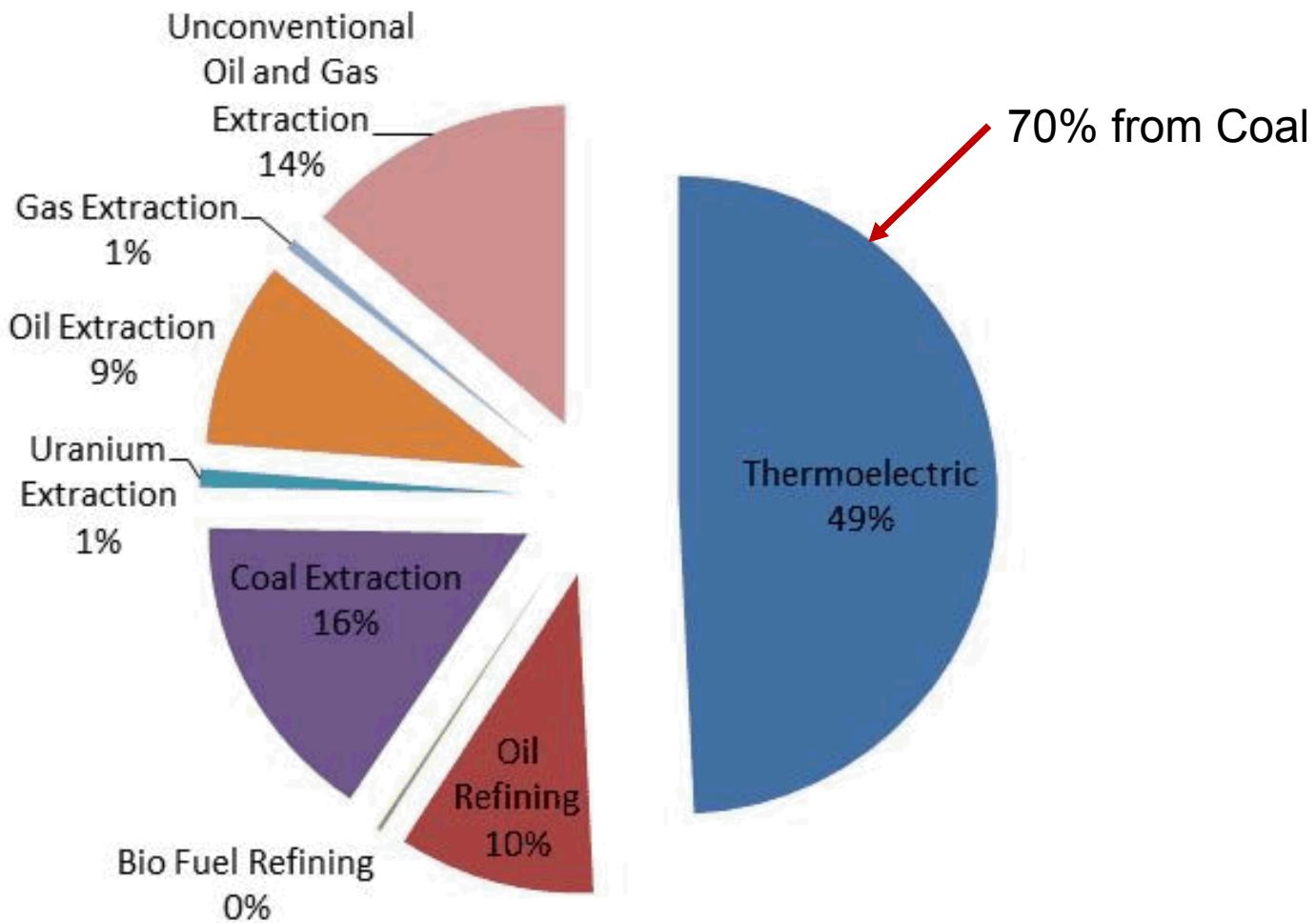
Water for Biofuel Refining



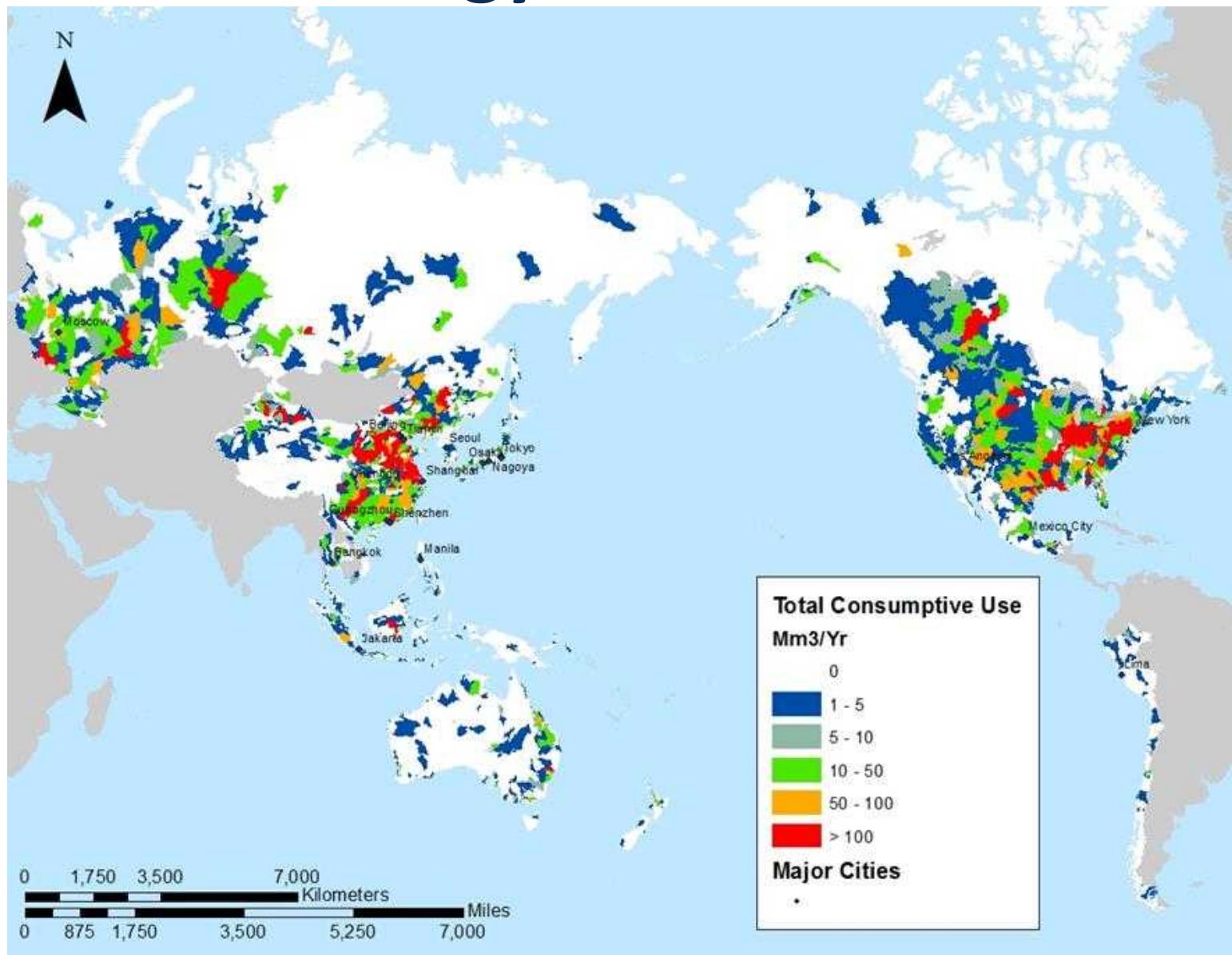
Water for Energy by Economy



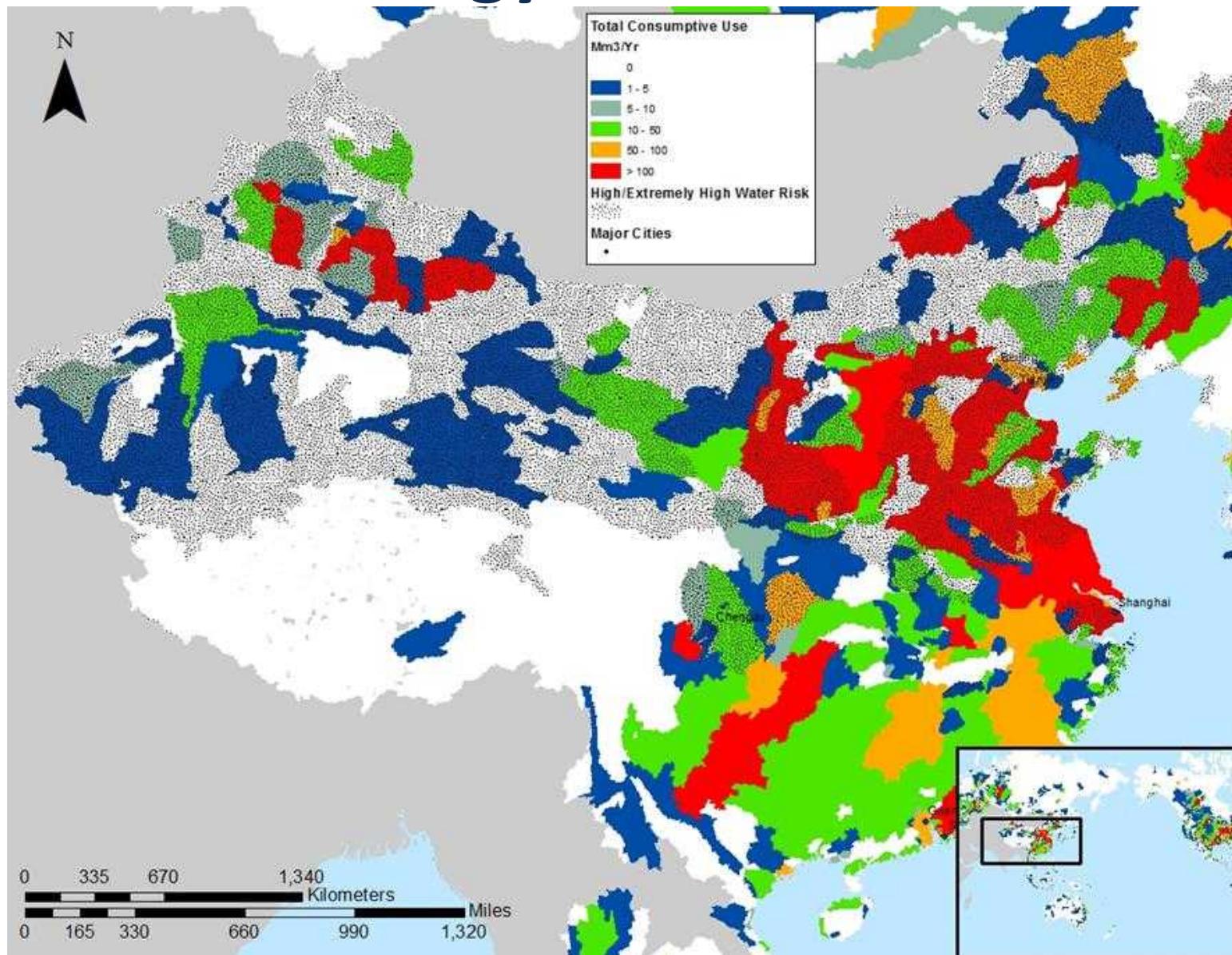
Water for Energy by Sector



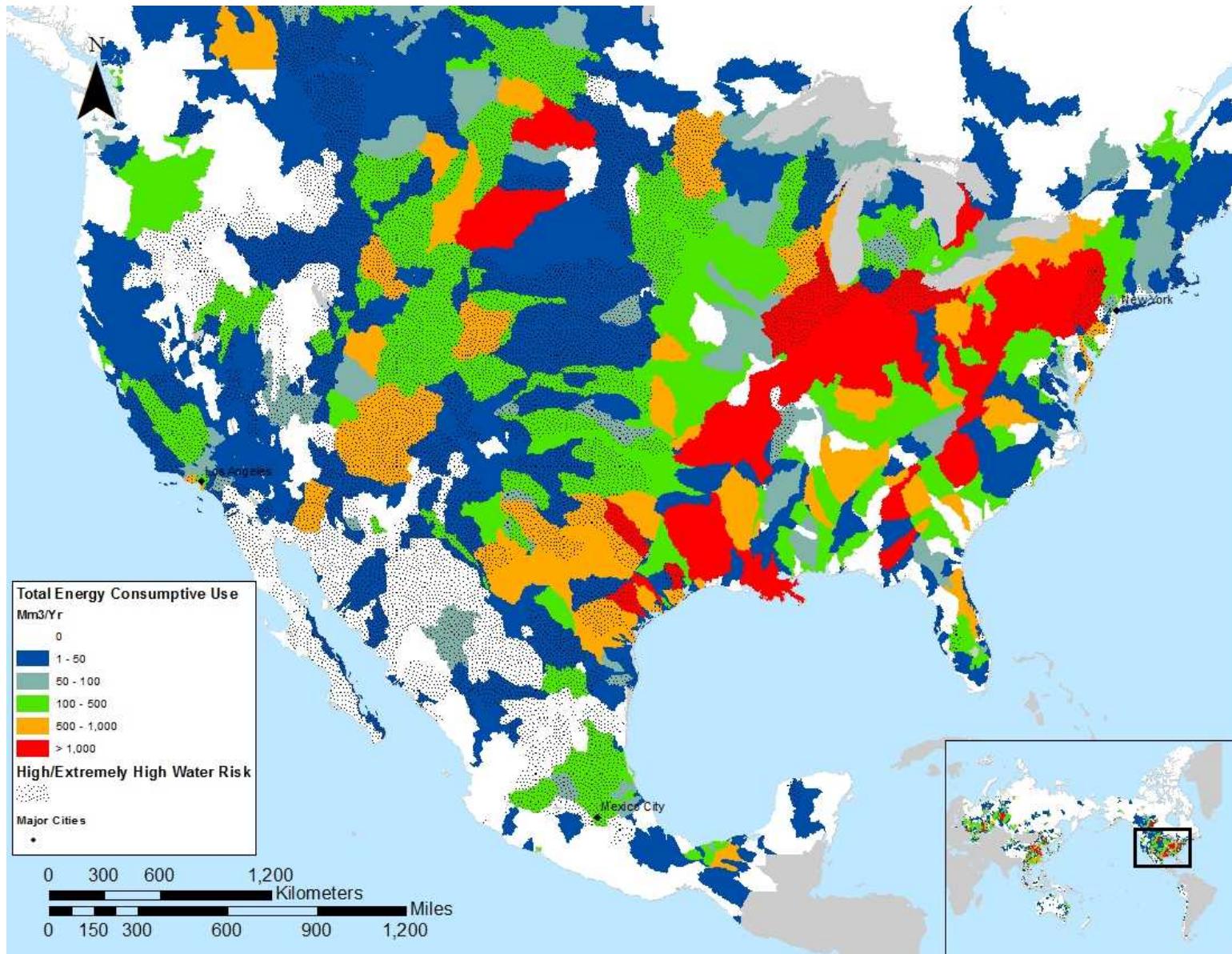
Water for Energy with Water Stress



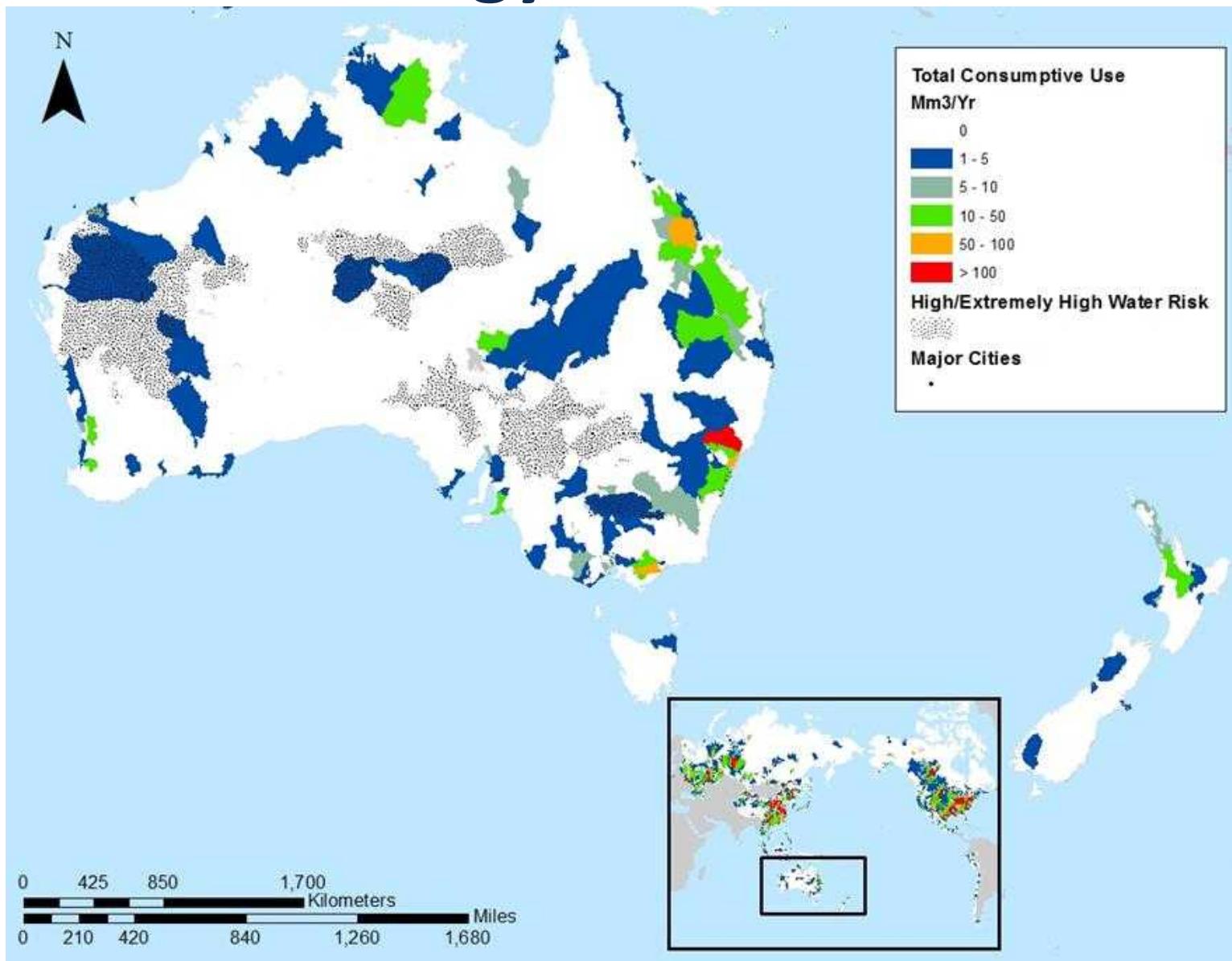
Water for Energy: Detail China



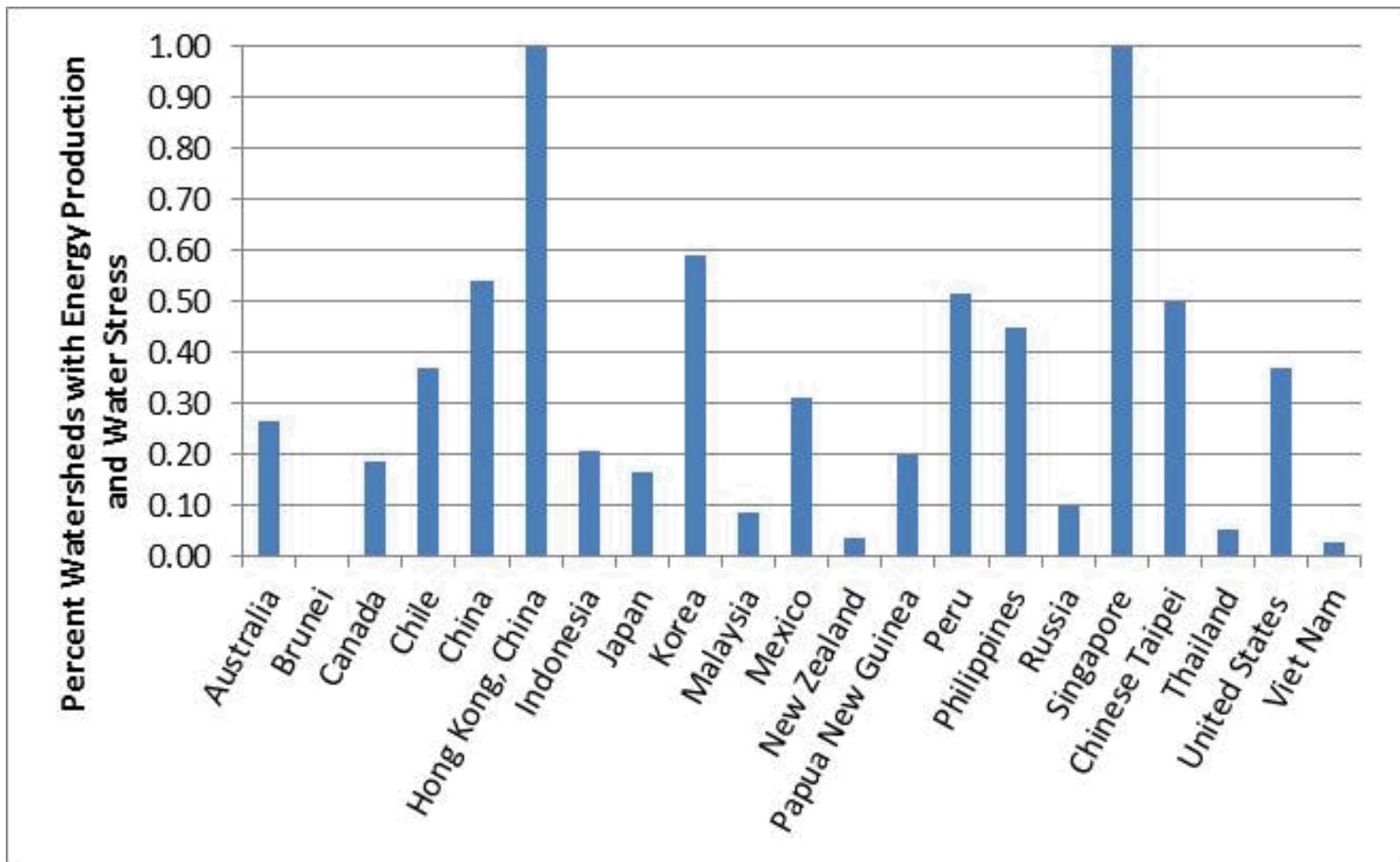
Water for Energy: Detail United States



Water for Energy: Detail Australia

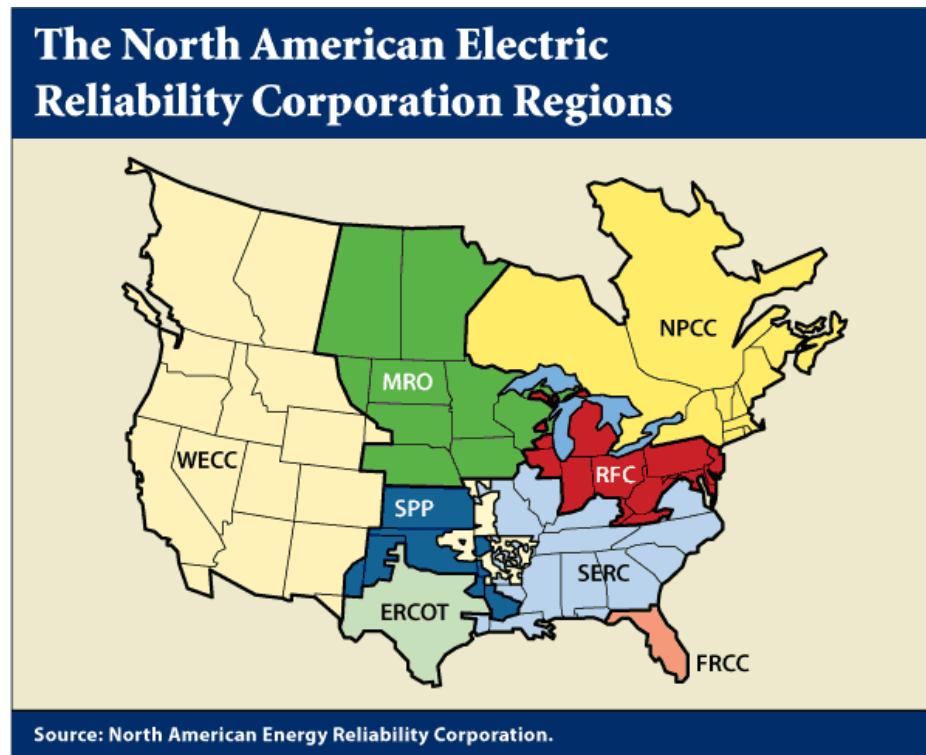


Energy-Water Risk



Regional: Integrated Planning

- Integrate water related concerns into long-range transmission expansion planning (20 yrs.) of WECC:
 - Siting of new power plants
 - New transmission capacity



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WECC

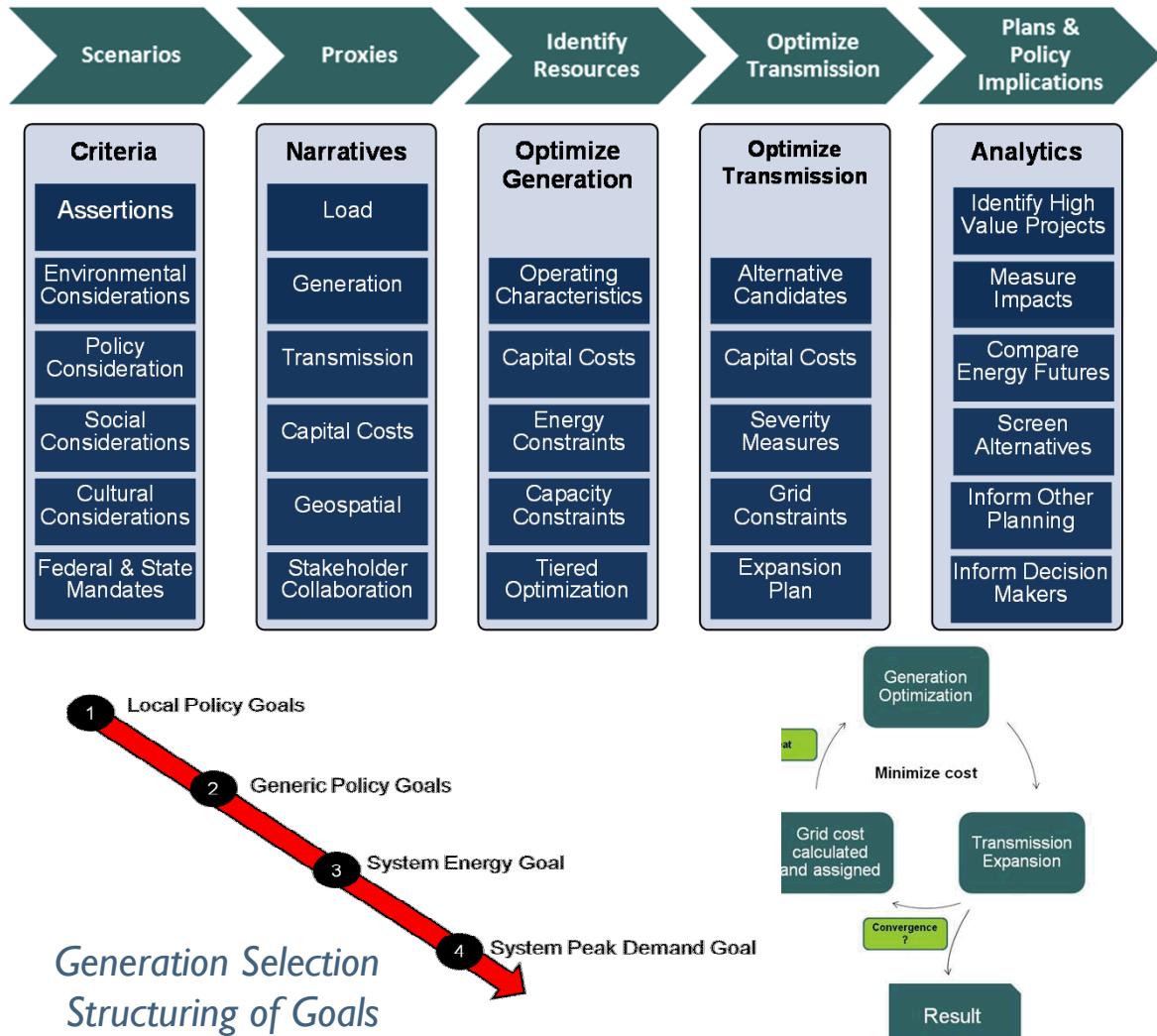


WSWC
Western States Water Council

Methods: Capital Expansion

Source: WECC 2013

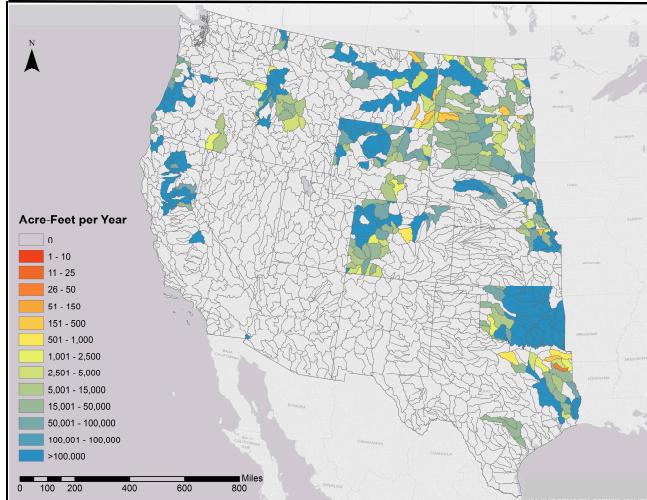
- Co-optimize generation and transmission additions.
- Least cost solution subject to goal related constraints:
 - Energy,
 - Policy,
 - Environmental, and
 - Societal conditions.
- Water is one of many considerations.



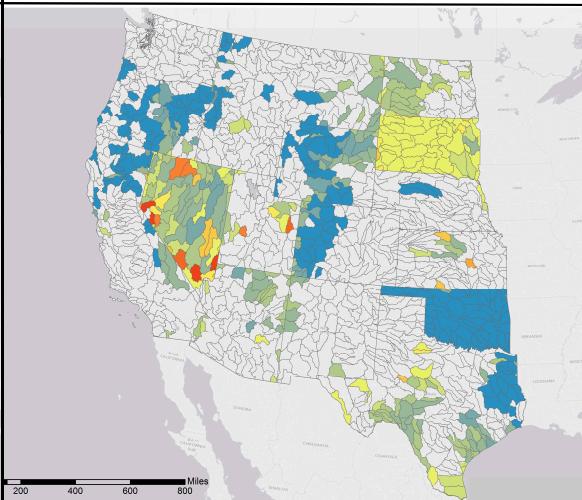
Optimization Iteration

Results: Water Supply Availability

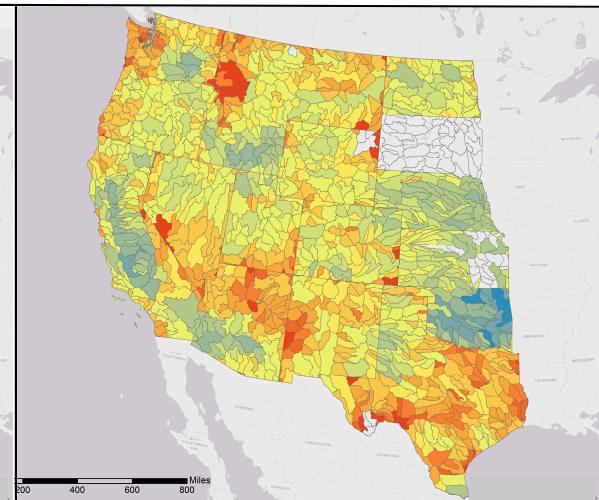
Unappropriated Surface Water



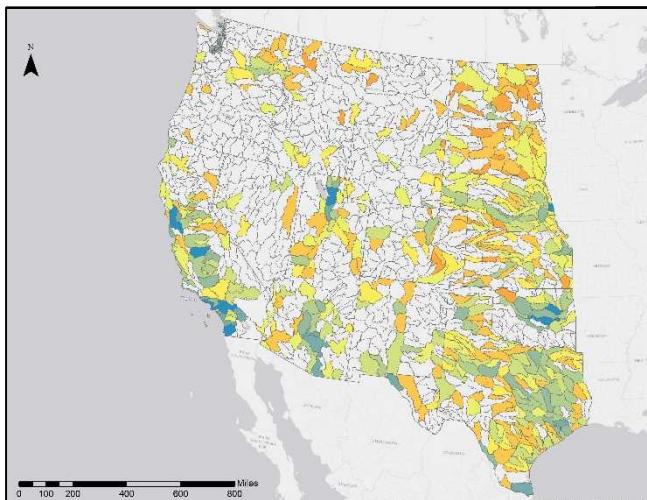
Unappropriated Groundwater



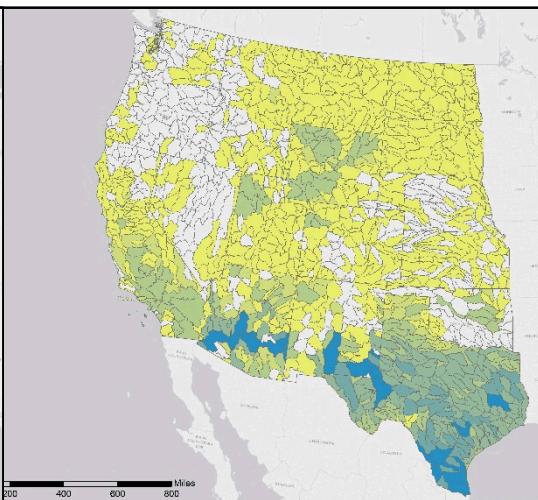
Appropriated Water



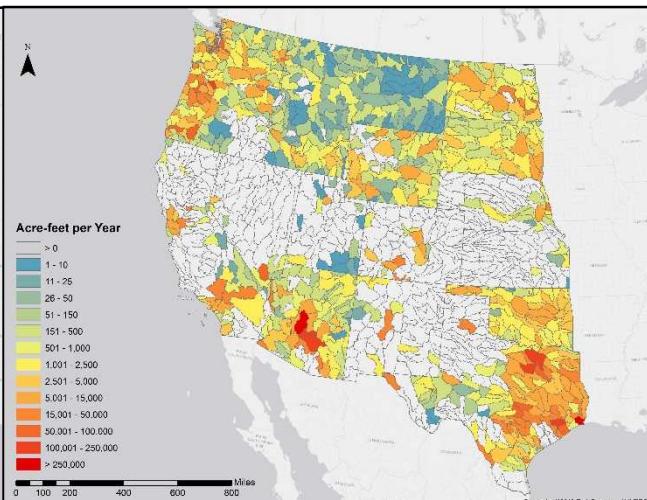
Municipal Wastewater



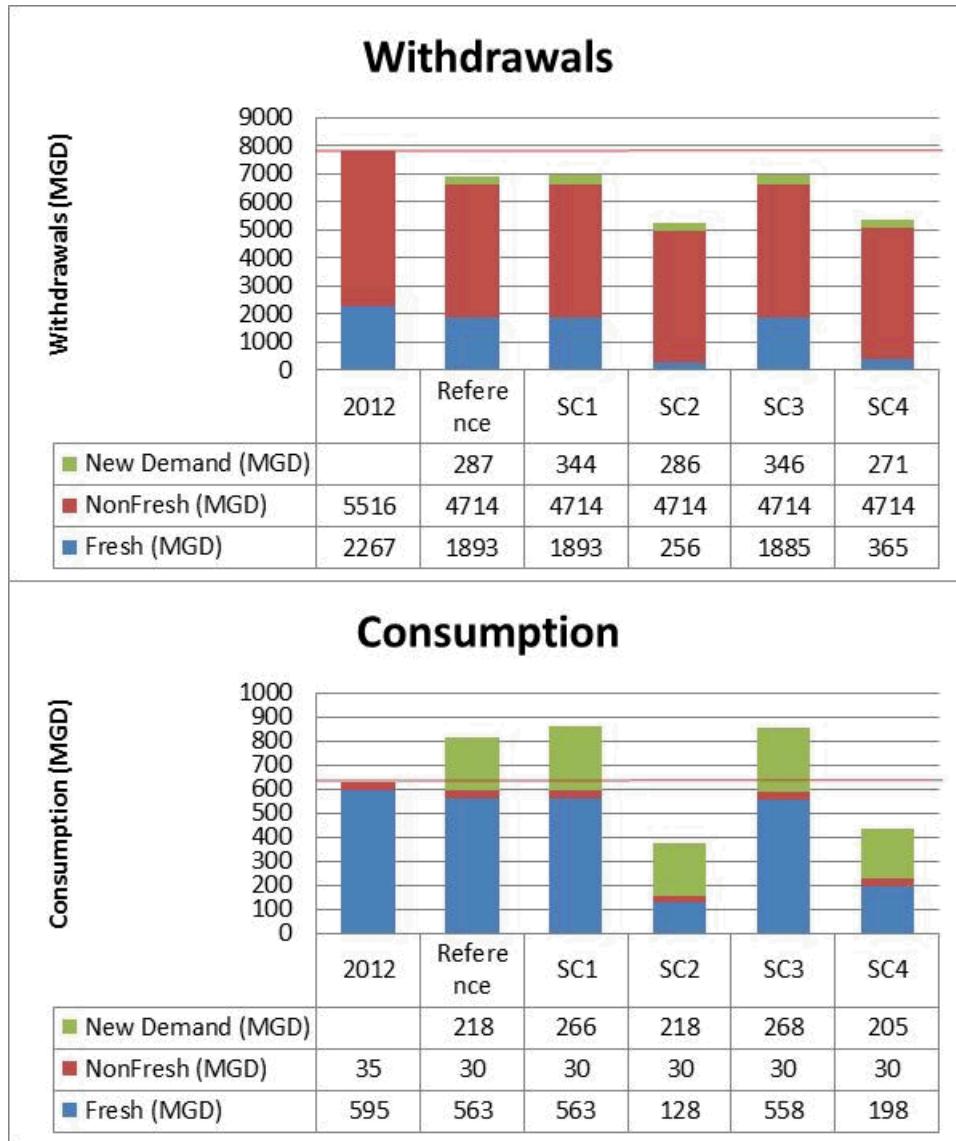
Brackish Groundwater



Consumptive Demand 2010-2030

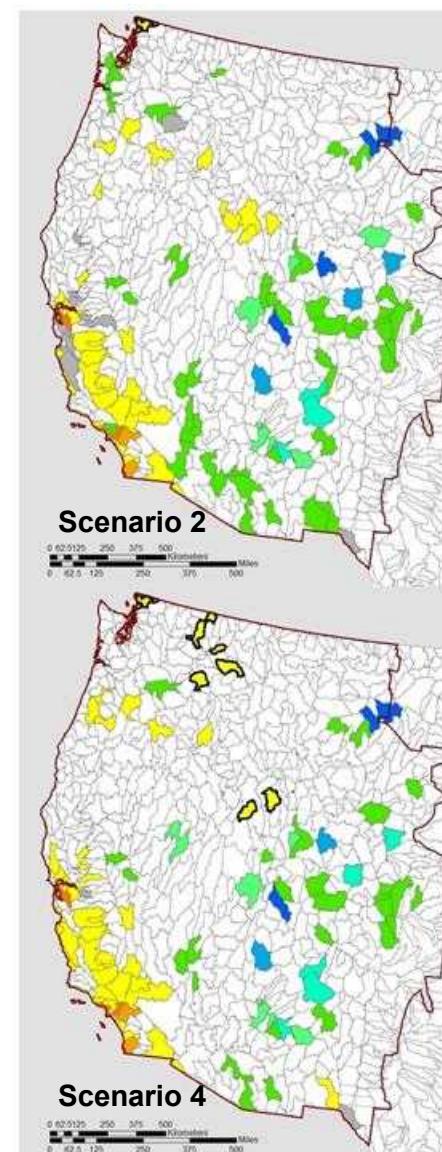
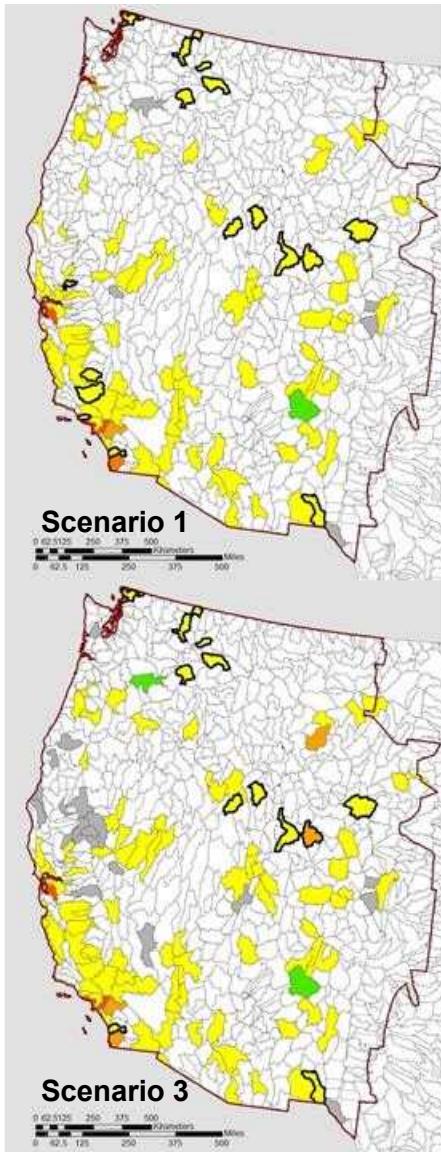
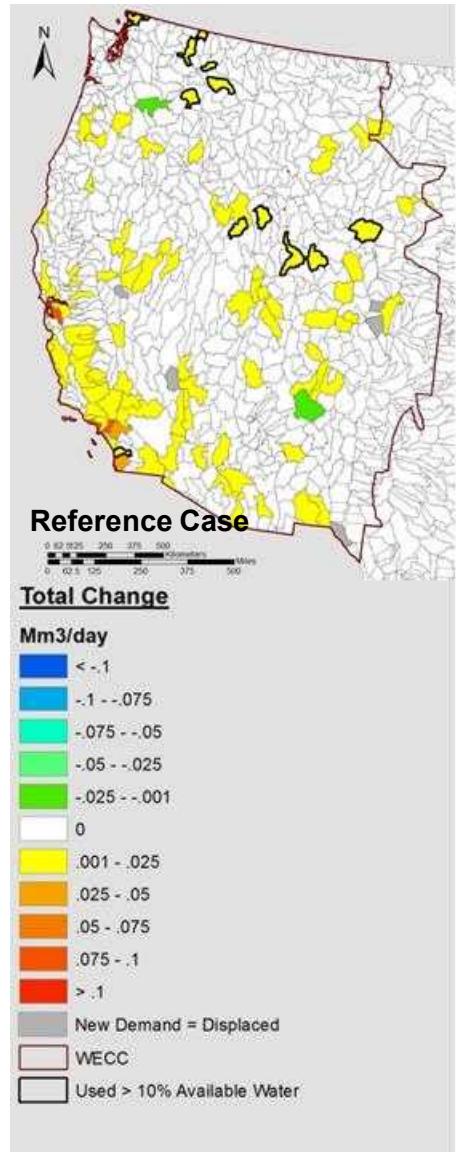


Results: Water Use

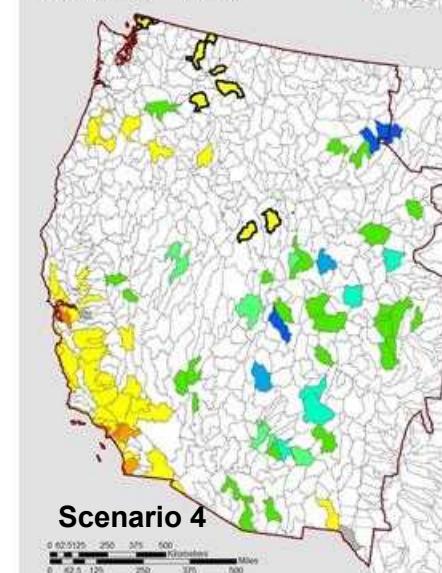
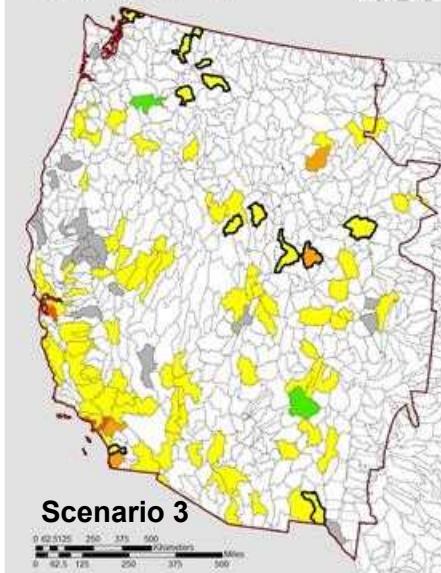


- Uniform reductions in withdrawals:
 - Similar additions across scenarios,
 - Retirements of 14% of seawater and 4 % freshwater withdrawals,
 - >70% displacement of freshwater withdrawal in scenarios 2 and 4
- Consumption varies by scenario:
 - Uniform additions,
 - >30% decrease for scenarios 2 and 4 (displaced coal)
 - >30% increase for other scenarios

Results: Watershed Impacts

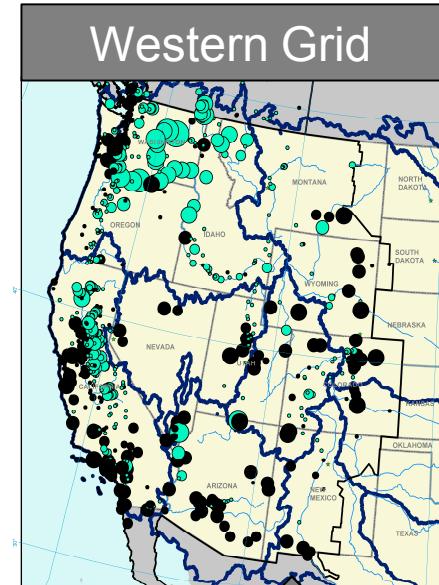
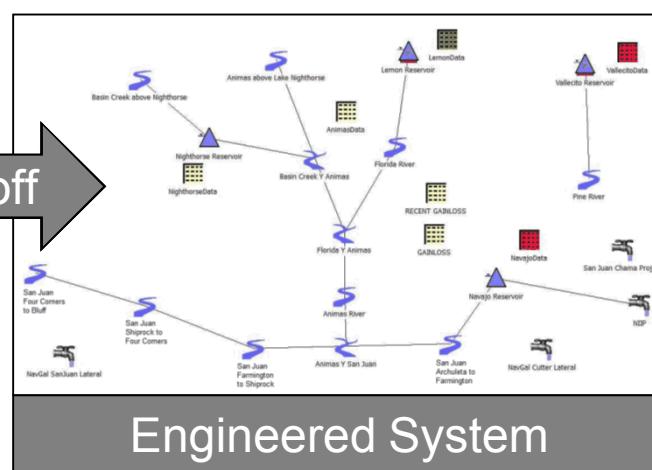
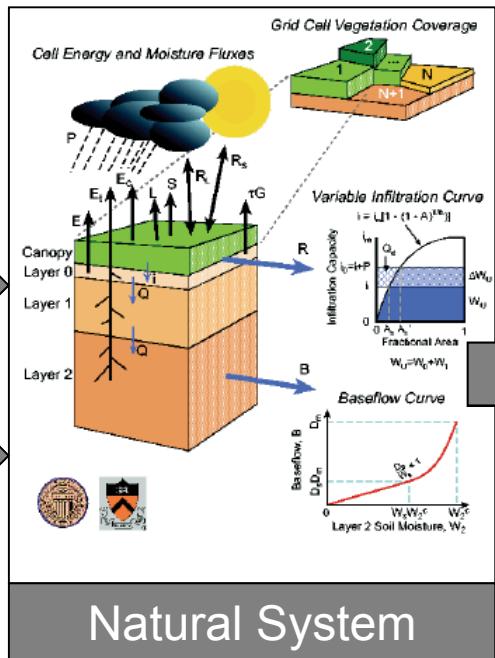


- Few instances where new demands exceed 10% of available water (outlined watersheds).
- Two scenarios free up considerable water (2 and 4).



Asset-Level: Vulnerability Analysis

- Framework that links natural and engineered systems to evaluate climate vulnerabilities and adaptive measures at the *asset level*:
 - Multiple interacting sectors,
 - Multiple forcings, and
 - Multiple interacting scales.



Deliveries

- Electric Power
- Agriculture
- Environment

San Juan Basin



Four Corners Region



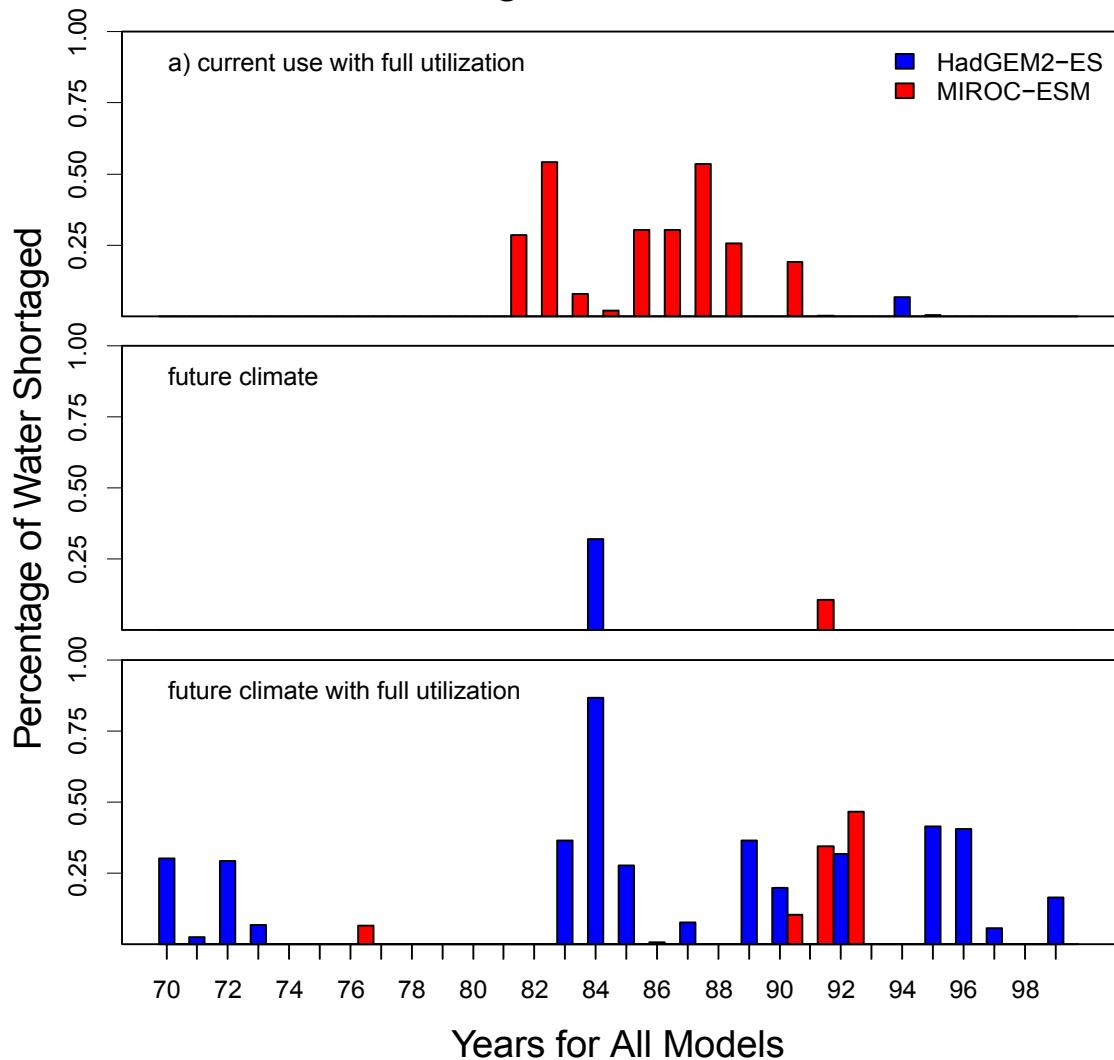
- Colorado River basin
- Snow melt dominated system

Water Users

- Native American
- Irrigation
- Multiple power plants and limited hydropower
- Municipalities
- Instream flows
- Interbasin transfers

Water Delivery Shortages

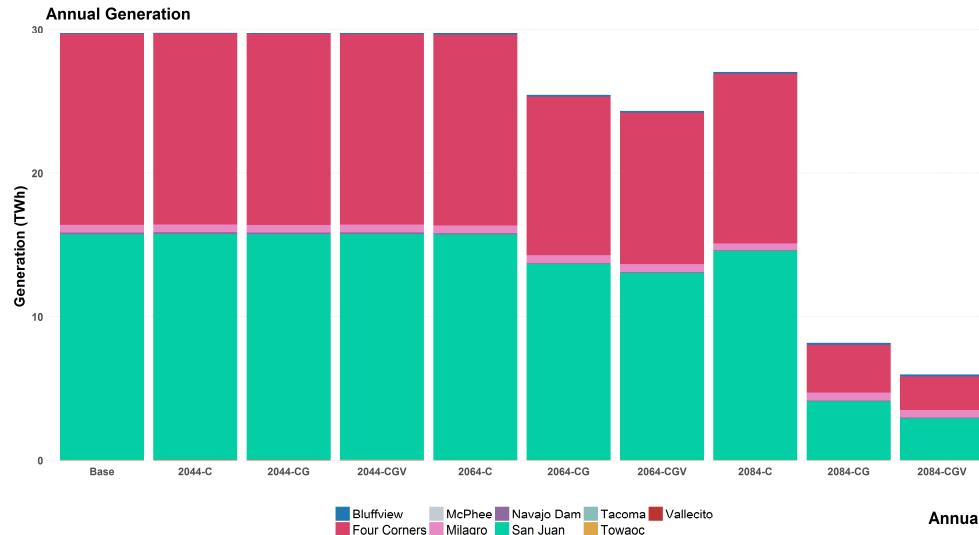
Shortages: 2080-2099



- Expose vulnerabilities to climate change, growth and other forcings.
- Expose differences among assets.
- Basis for evaluating adaptive measures.

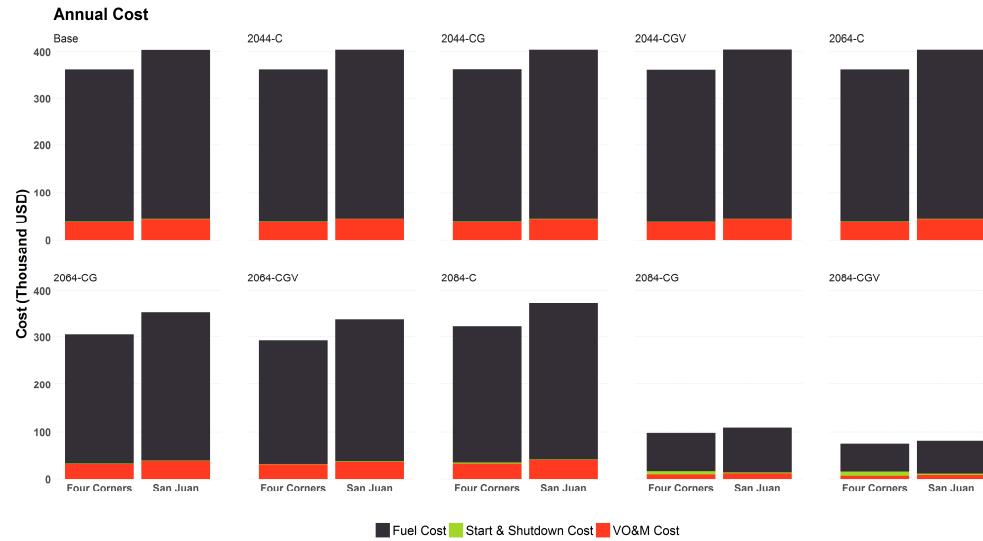
Generation Vulnerability

Impact on Generation by Year and Scenario



- Combined effects of climate on electricity demand and water supply.
- Impacts increase in time.
- Impacts to generation and costs to generate.

Impacts on Operational Cost by Year, Plant and Scenario



Take-Aways

- Modeling and analysis is key to managing the Energy-Water Nexus
- Multi-modal, multi-scale approach is needed:
 - Multinational Scale: High-level analysis aimed at recognizing and communicating the problem,
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 - Asset Scale: Detail sufficient to model operations of key assets to quantify vulnerabilities and adaptive measures.

- Project data available at:

http://energy.sandia.gov/?page_id=1741

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Energy and Climate

RENEWABLE SYSTEMS CLIMATE/ENVIRONMENT ENERGY INFRASTRUCTURE ENERGY RESEARCH ABOUT EC

Energy and Climate • Climate/Environment • Water Security Program • Energy and Water in the Western and Texas Interconnects

Energy and Water in the Western and Texas Interconnects

Background Objectives Tasks Benefits/Outcomes Collaborators Links Documents Data Portal

Water Scarcity Impacts Energy Production

In the United States the energy sector accounts for approximately 41% of daily fresh water withdrawals and 49% of total overall daily water withdrawals for the following energy-related uses:

- Hydroelectric power generation
- Thermoelectric power plant cooling and air emissions control
- Energy-resource extraction, refining, and processing

The Energy Information Administration projects the U.S. population will grow by **70 million people** between 2005 and 2030, increasing electric power demand by **50 percent** and transportation fuel demand by **30 percent**. This will require more water. Unfortunately, this growth in water demand is occurring at a time when the nation's fresh water supplies are seeing increasing stress from:

- Limitations of surface-water storage capacity
- Increasing depletion and degradation of ground water supplies
- Increasing demands for the use of surface water for in-stream ecological and environmental uses
- Uncertainty about the impact of climate variability on future water fresh surface and ground water resources

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Last Updated: August 7, 2014

WATER SECURITY PROGRAM

- Water Infrastructure Security
- Water, Energy, and Natural Resource Systems
- Energy and Water in the Western and Texas Interconnects
 - Energy and Water Data Portal
 - Electric Power Generation and Water Use Data
 - Water Availability, Cost, and Use

ENERGY-WATER DATA PORTAL

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