

Integrated Energy-Water Planning

Vincent Tidwell



# *Integrated Energy-Water Planning*

**Vincent Tidwell**

**Sandia National Laboratories**

**APEC Water-Energy Nexus Expert Workshop**

**Atlanta, Georgia**

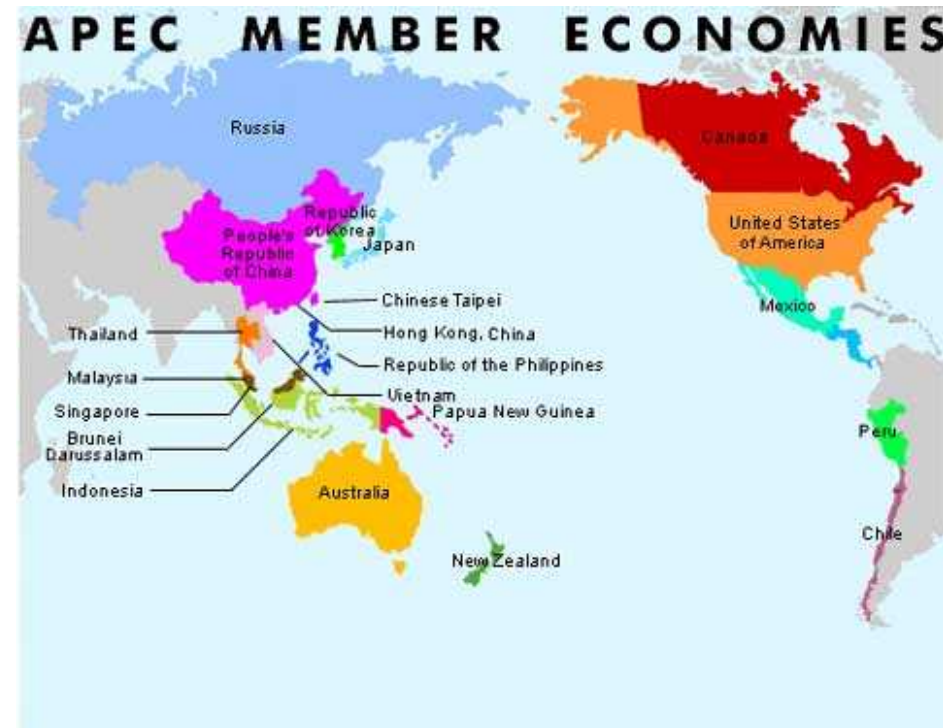
**October 31, 2017**

# 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

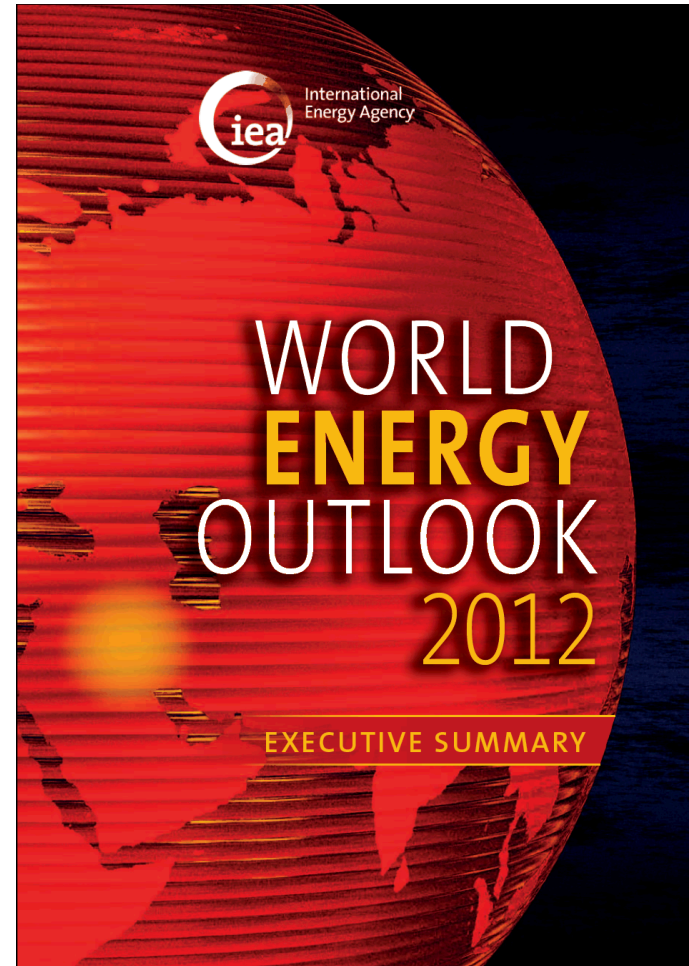
- Utilized publically available data

DOE/EIA-0383(2015) | April 2015

## Annual Energy Outlook 2015 with projections to 2040

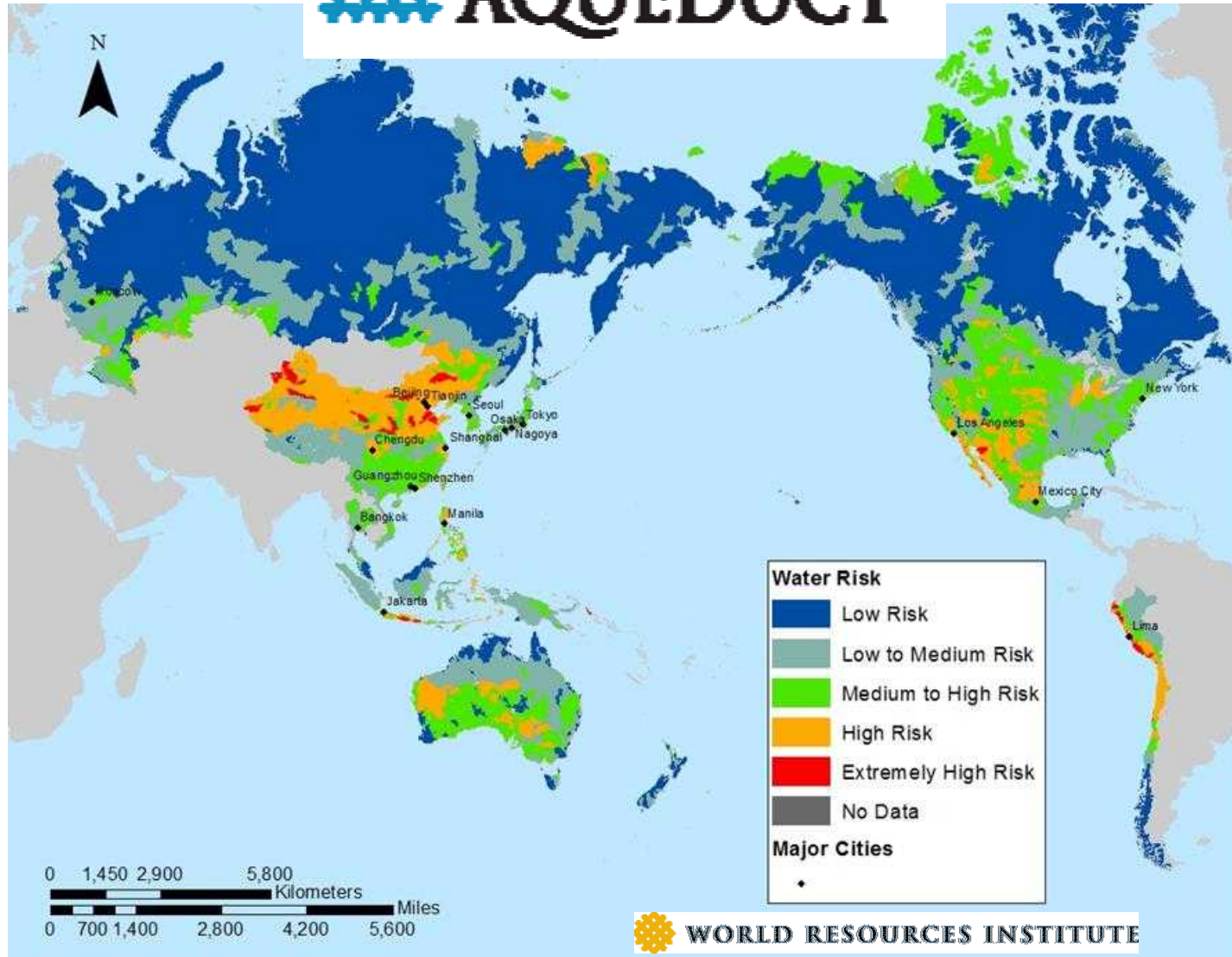


 *Independent Statistics & Analysis*  
U.S. Energy Information  
Administration

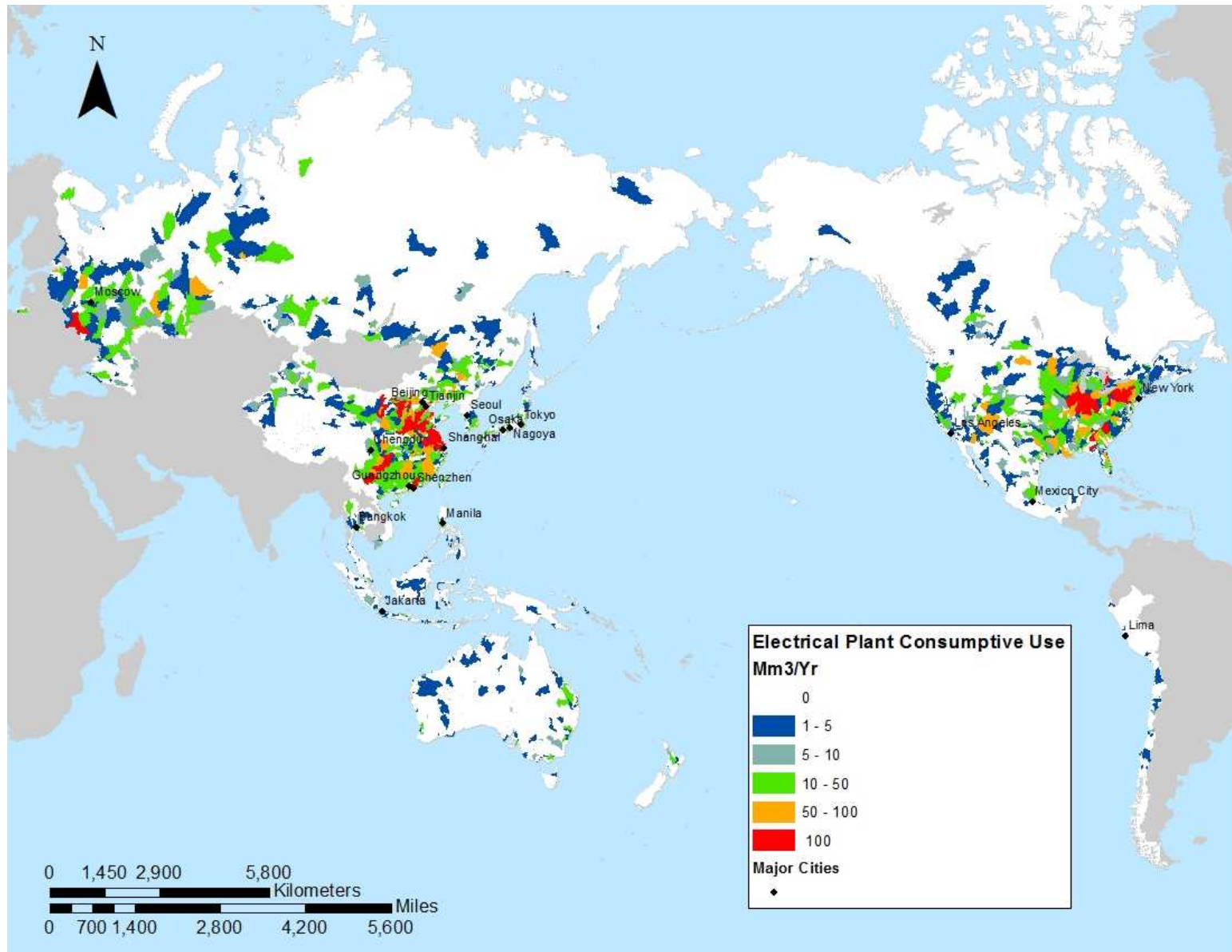




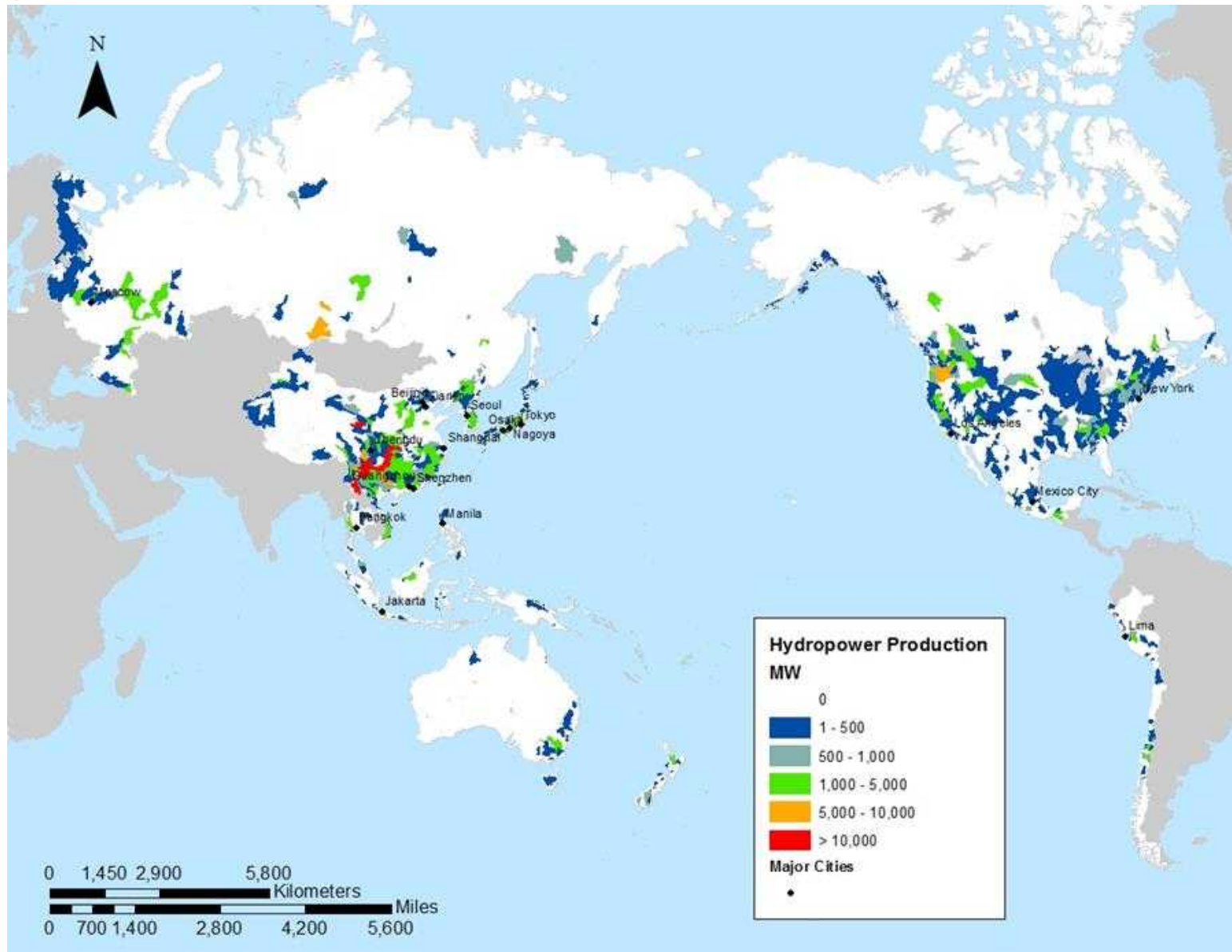
# Global Water Risk Mapping



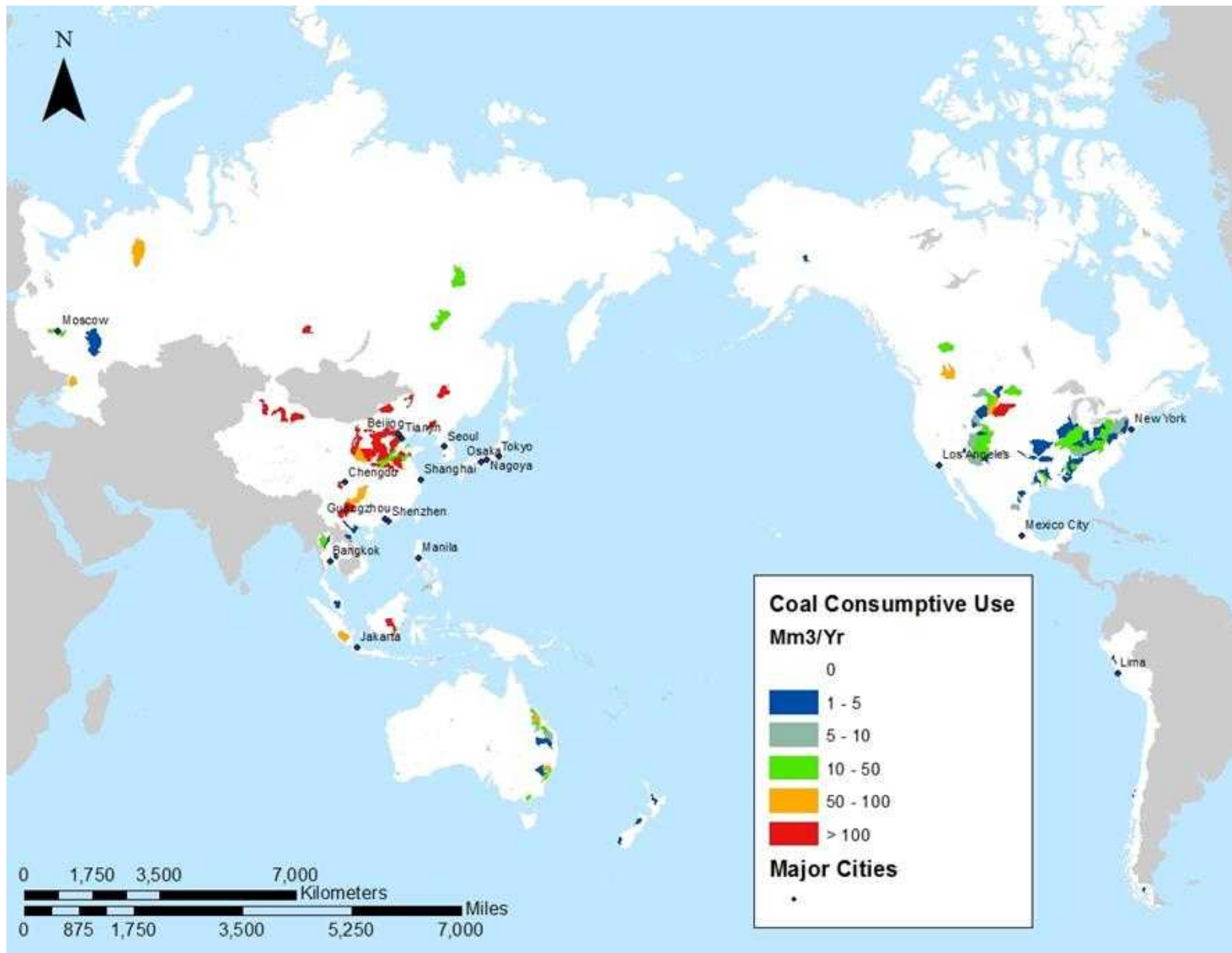
# Water for Thermoelectric Power



# Hydroelectric Power (MW)

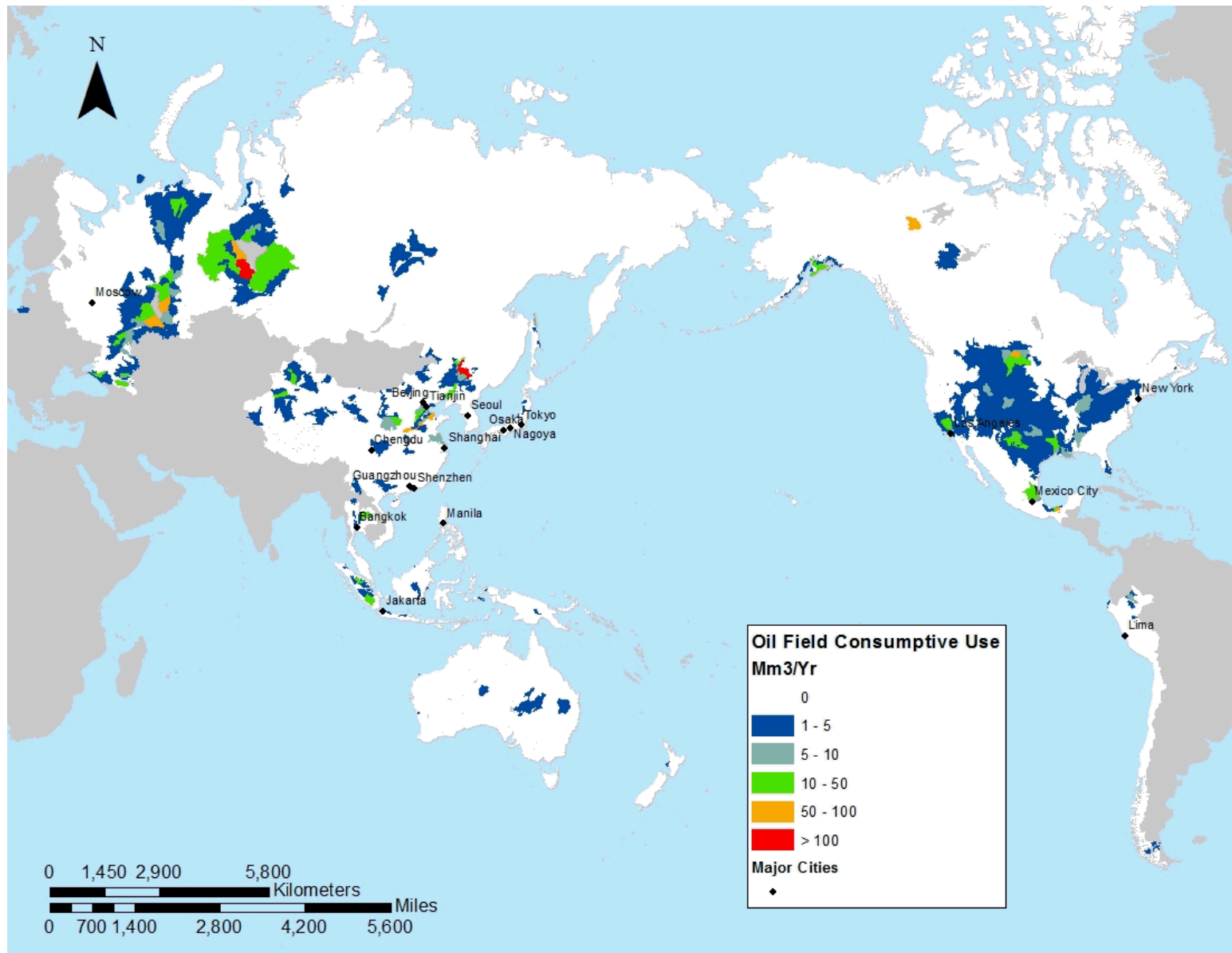


# Water for Coal Extraction

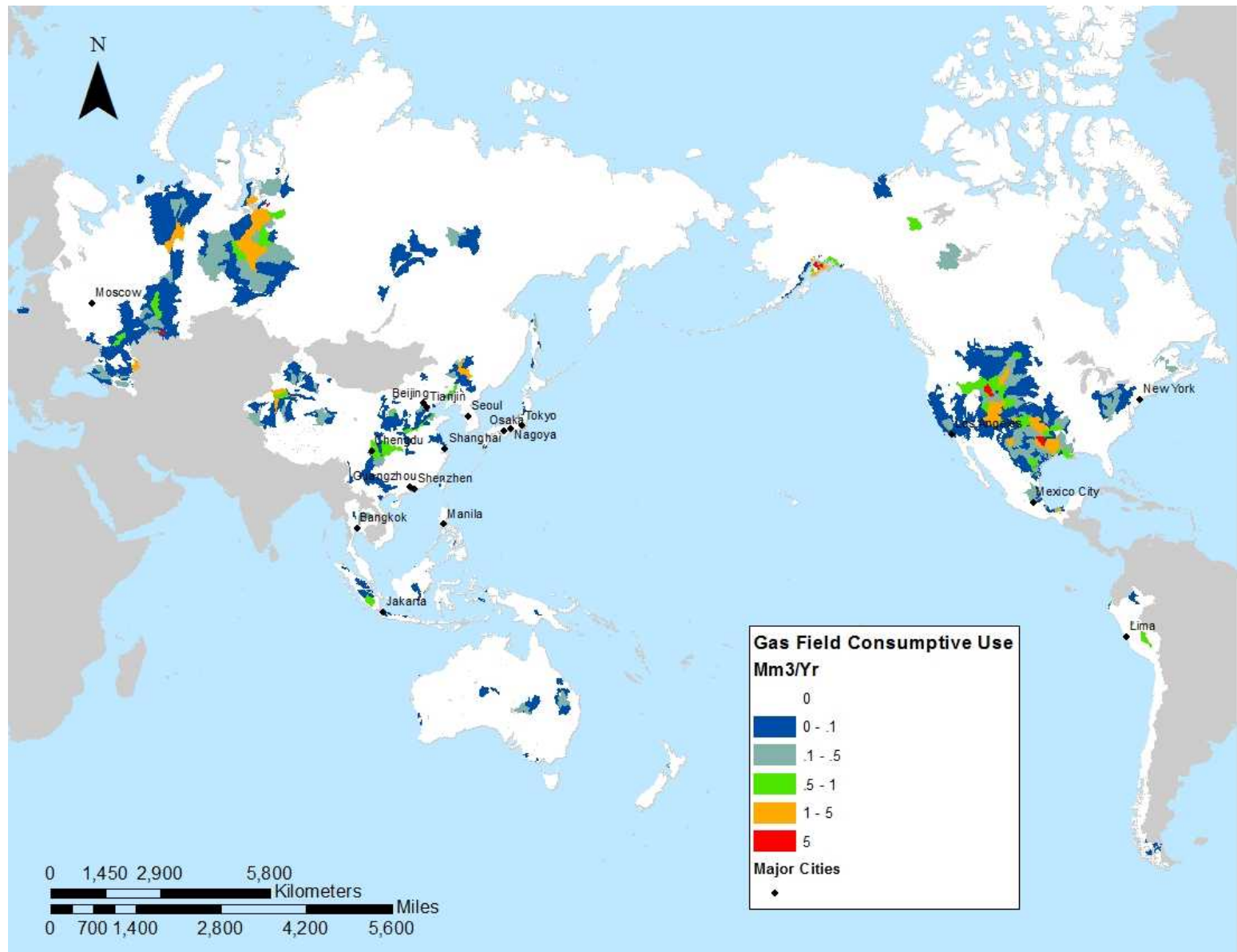




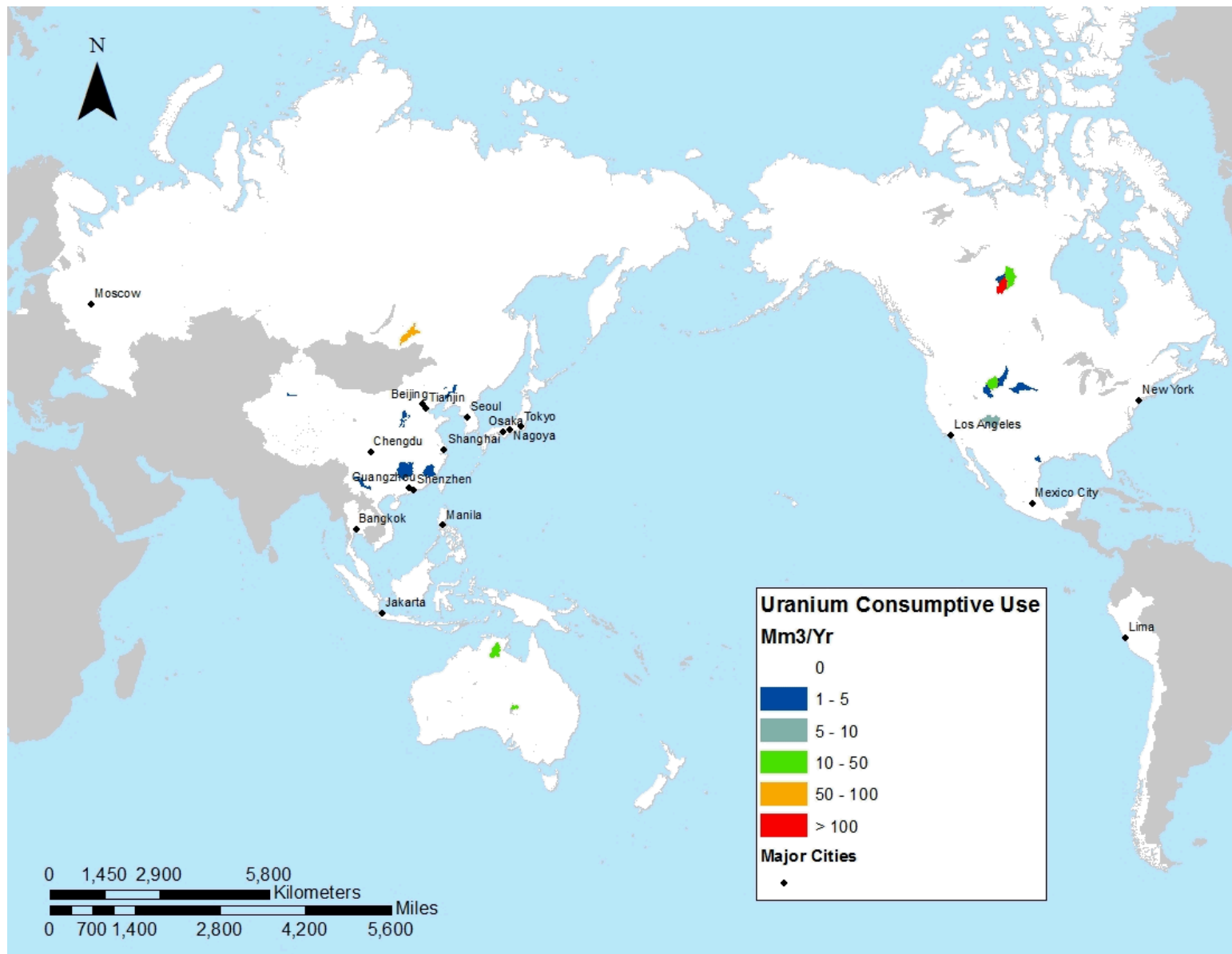
# Water for Oil Extraction



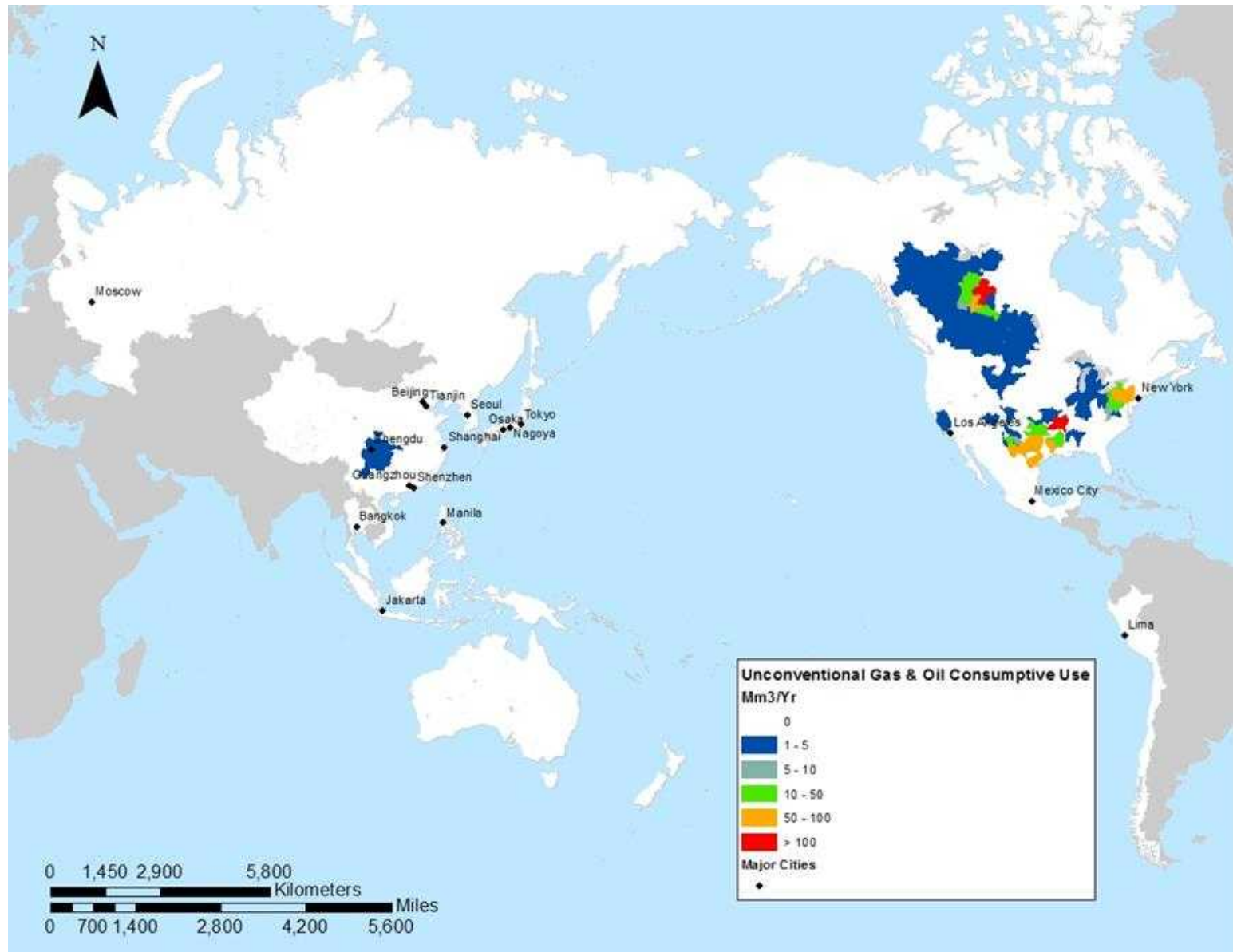
# Water for Natural Gas Extraction



# Water for Uranium Extraction

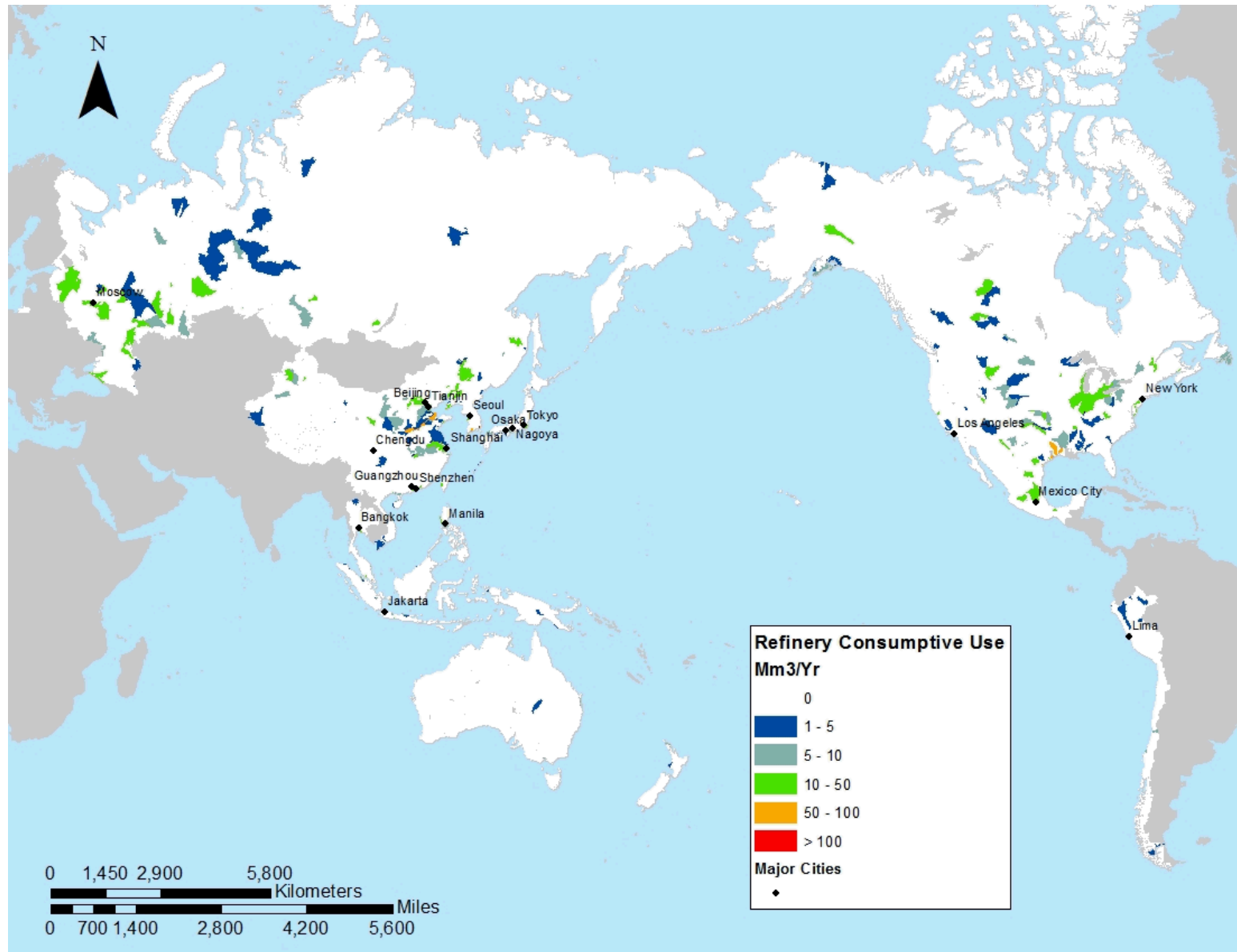


# Water for Unconventional Oil and Gas

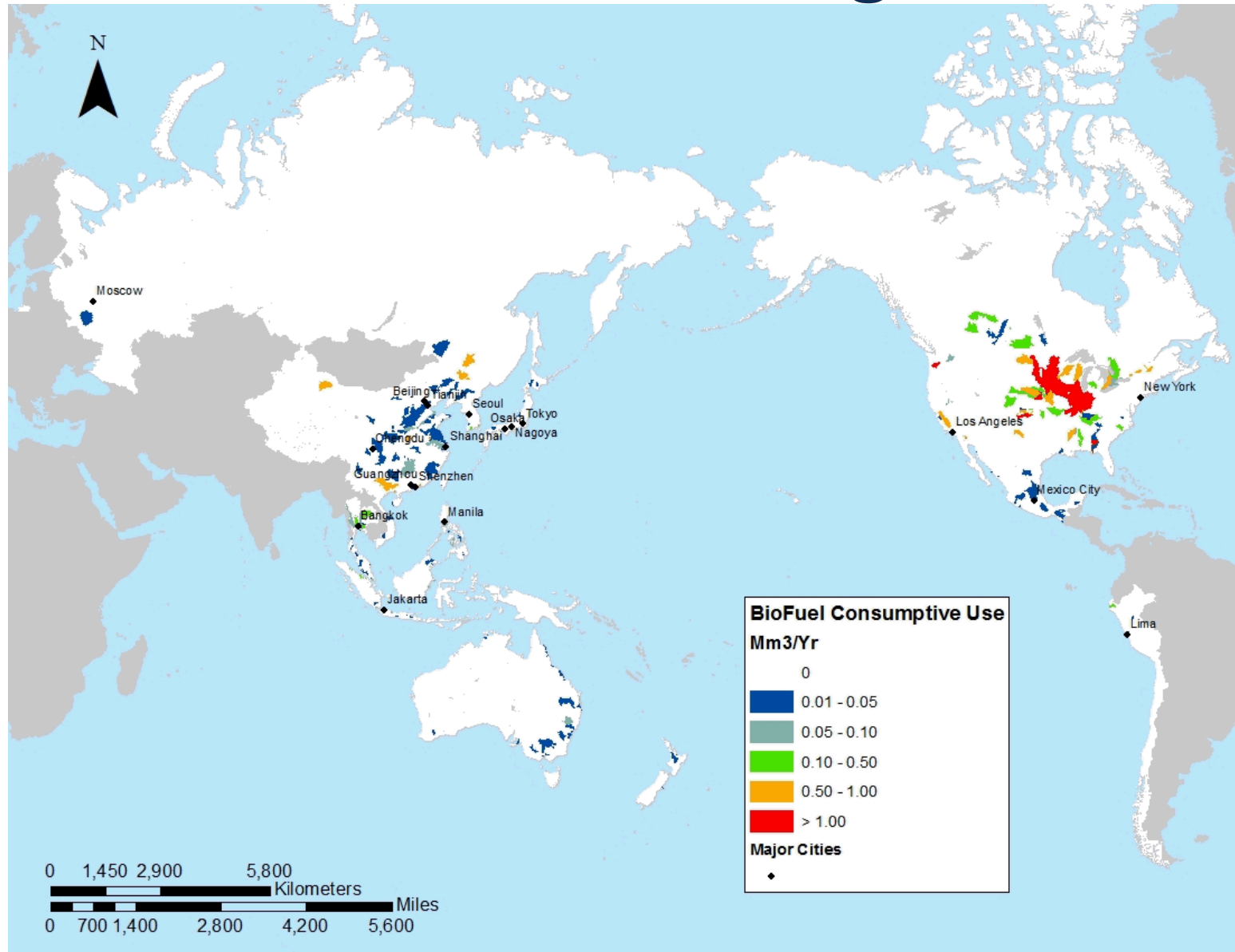




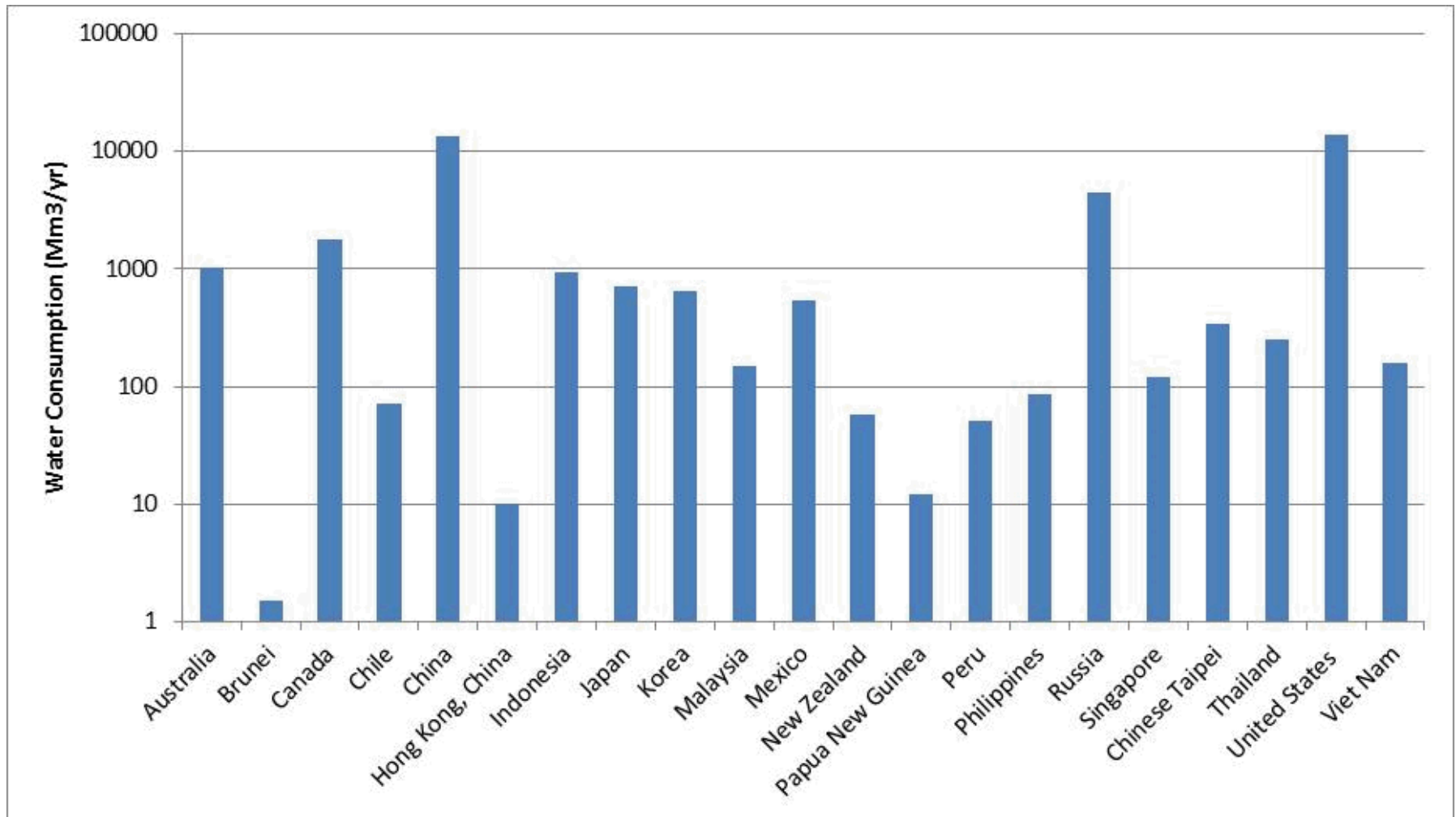
# Water for Oil Refining



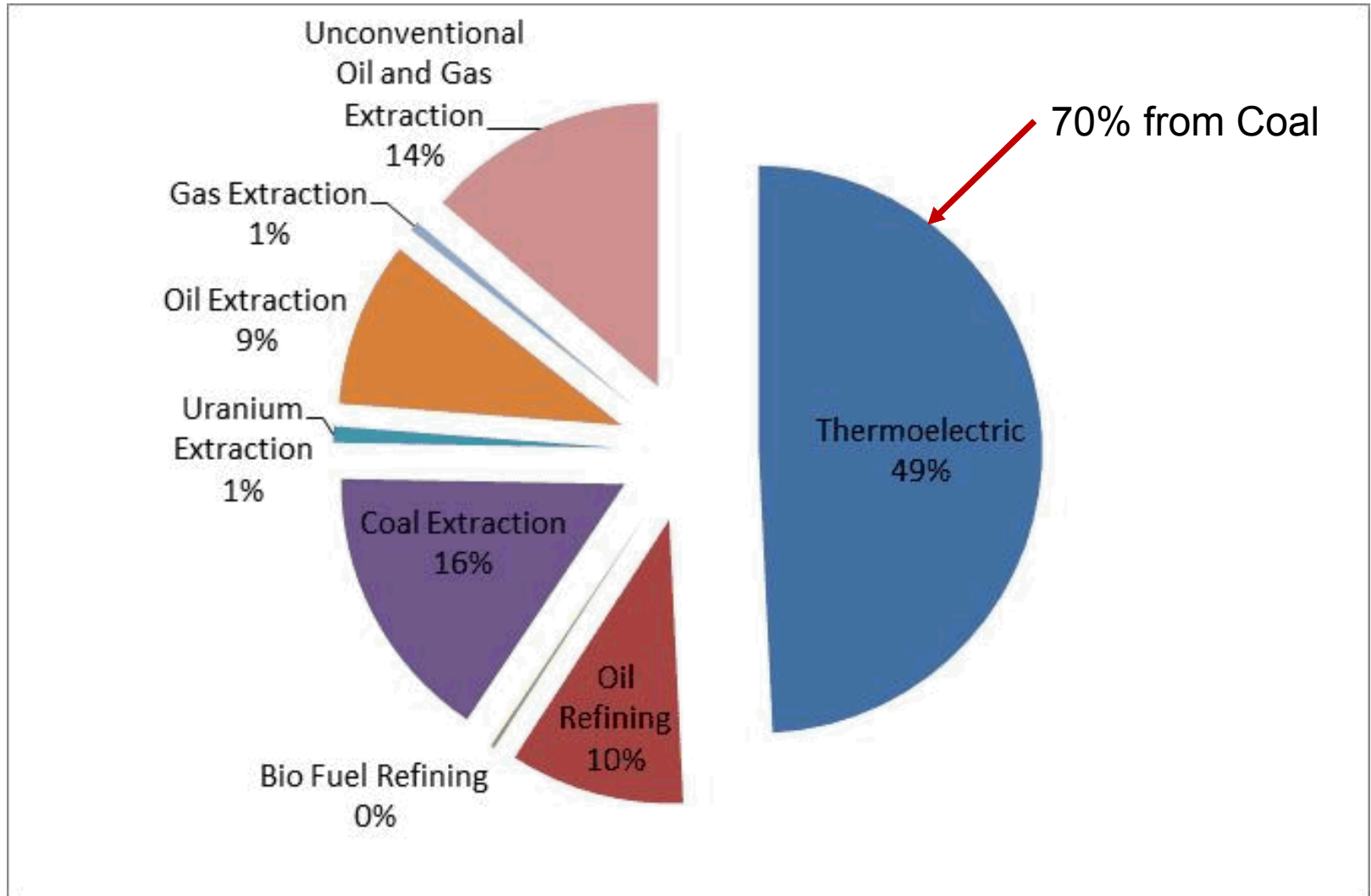
# Water for Biofuel Refining



# Water for Energy by Economy

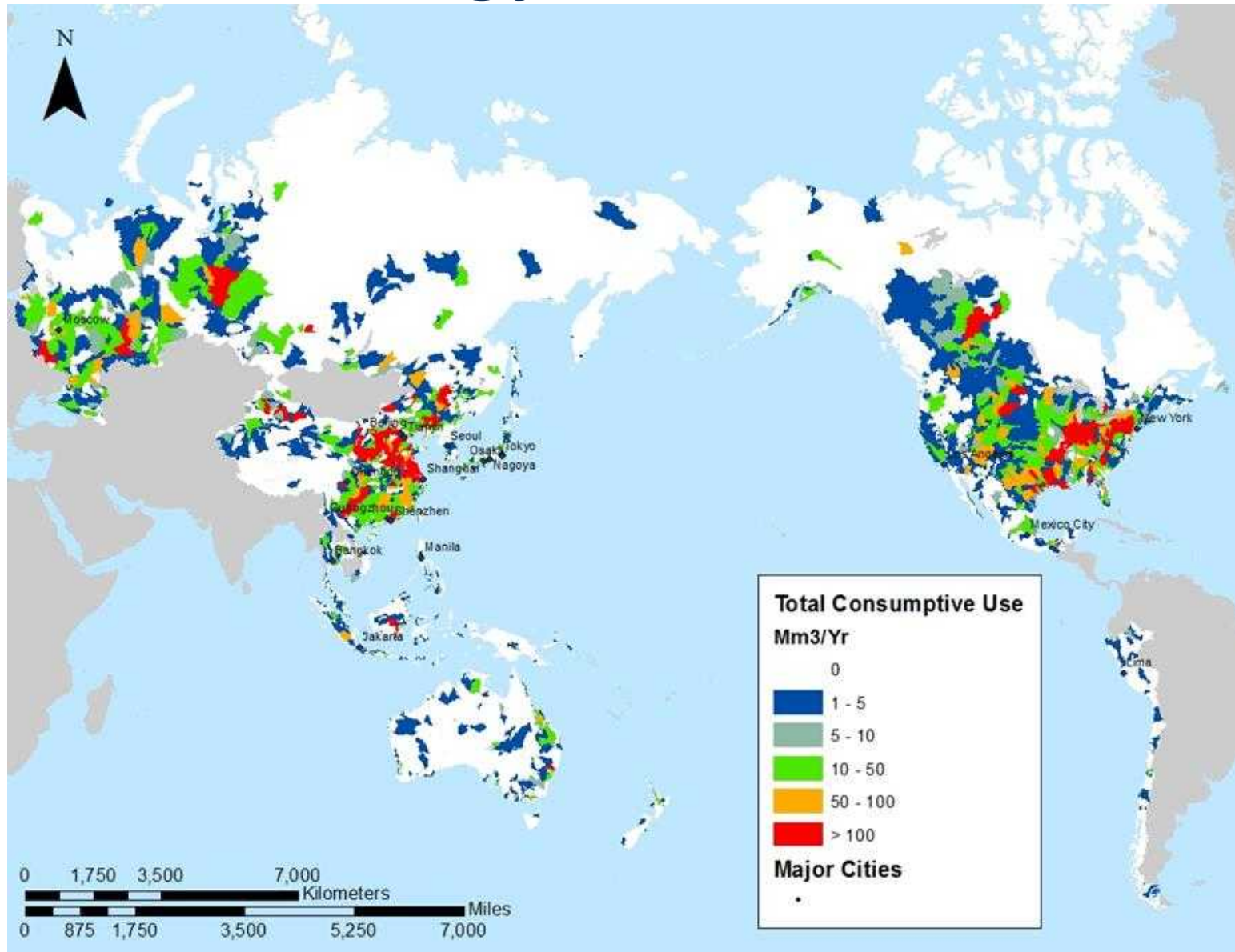


# Water for Energy by Sector

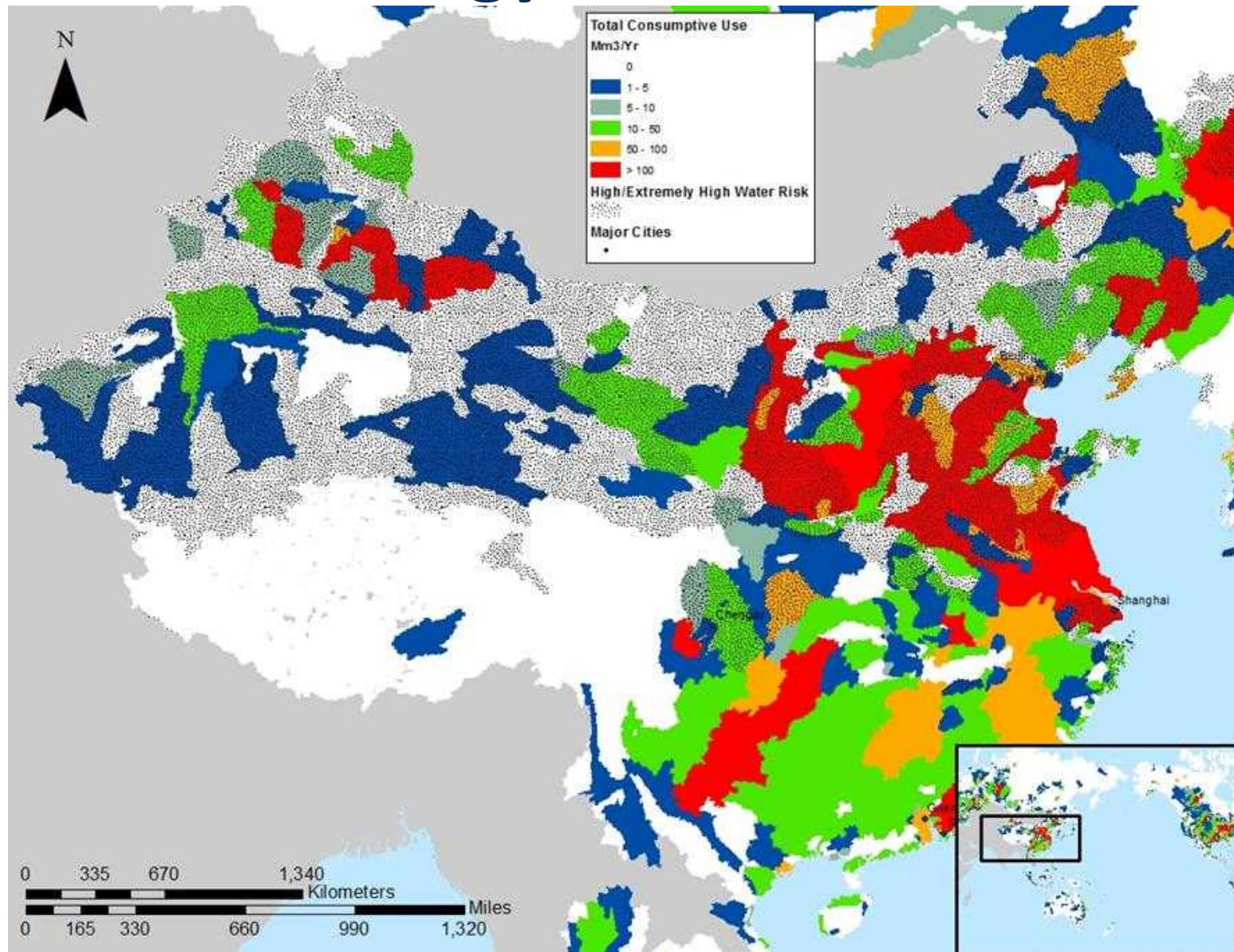




# Water for Energy with Water Stress

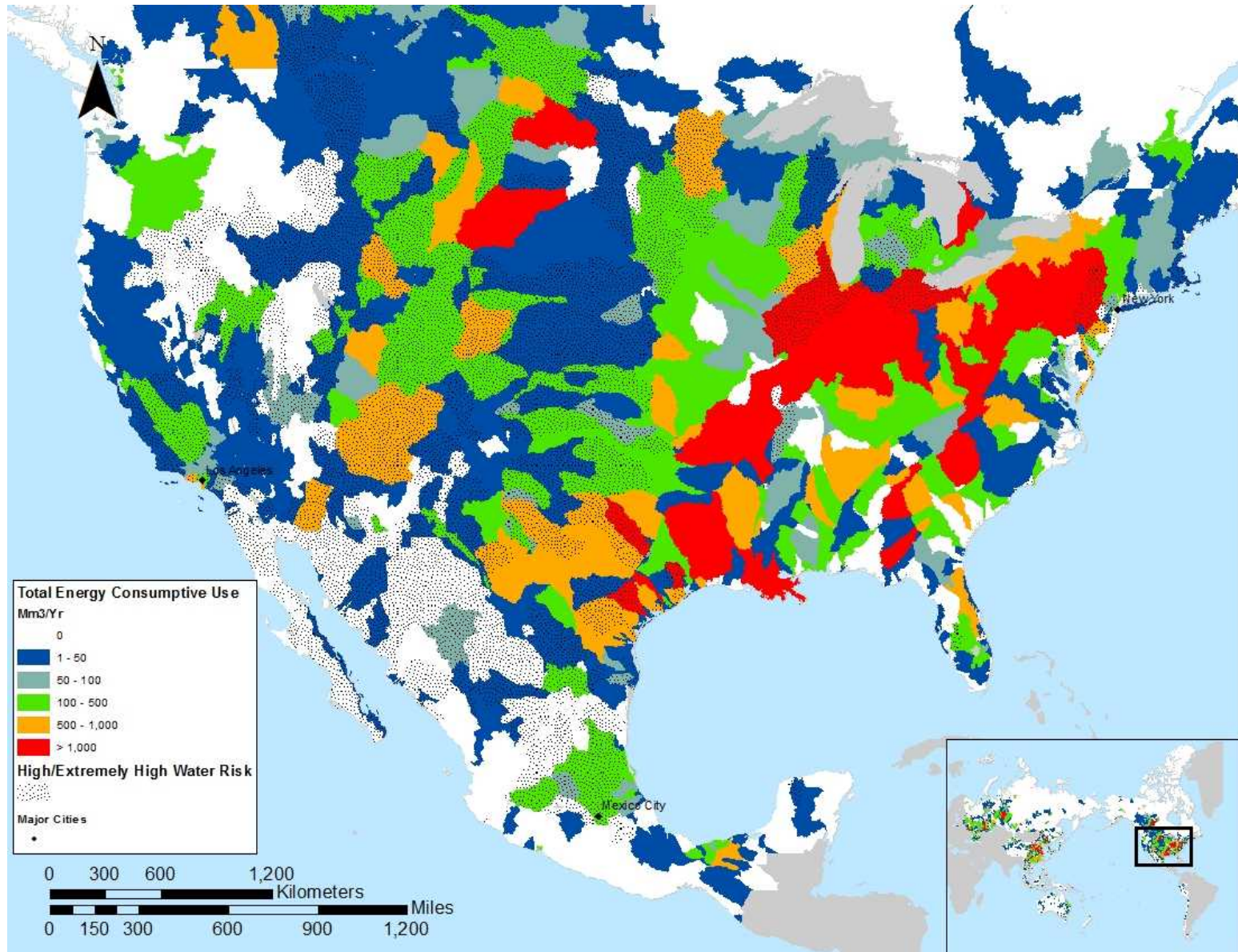


# Water for Energy: Detail China

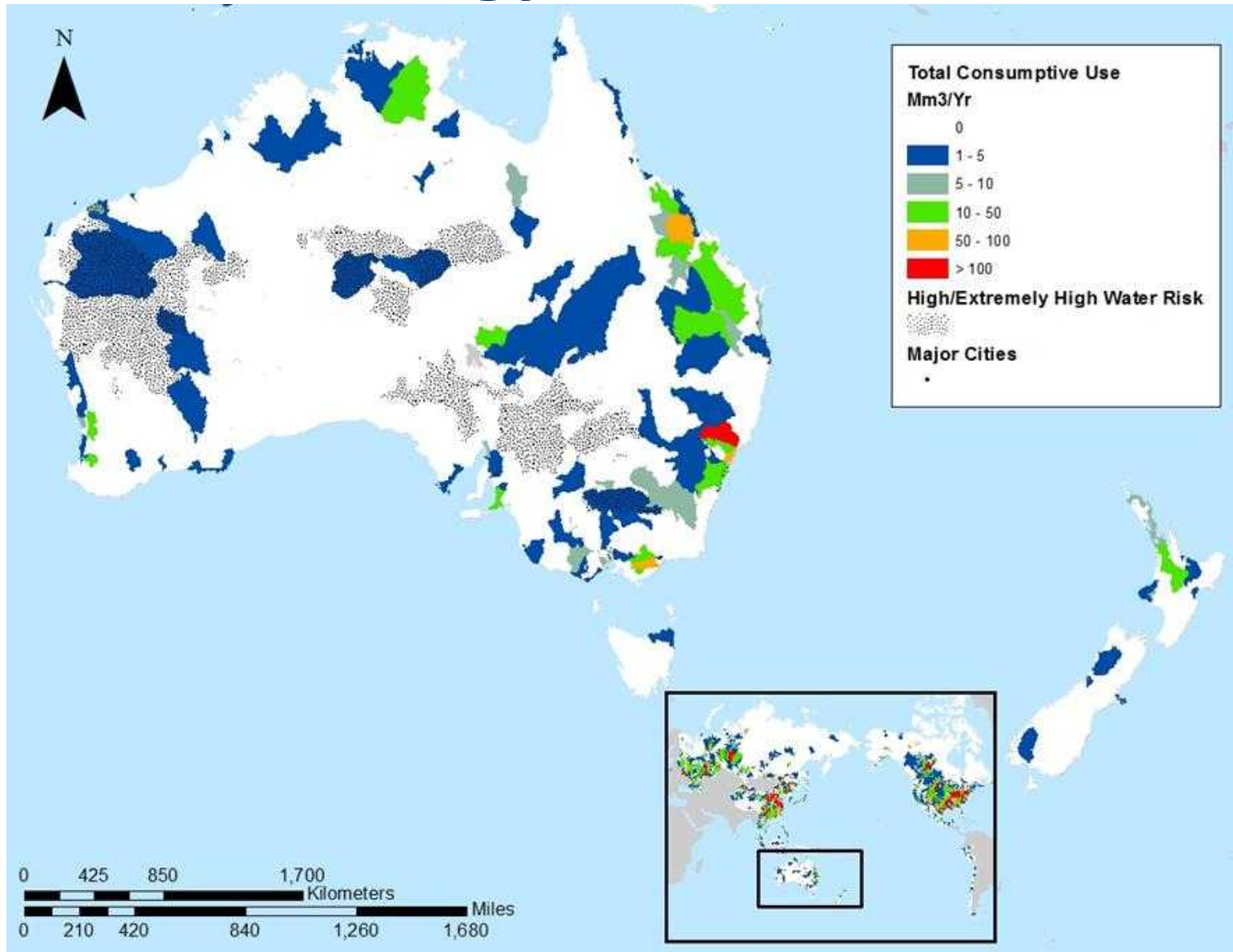




# Water for Energy: Detail United States

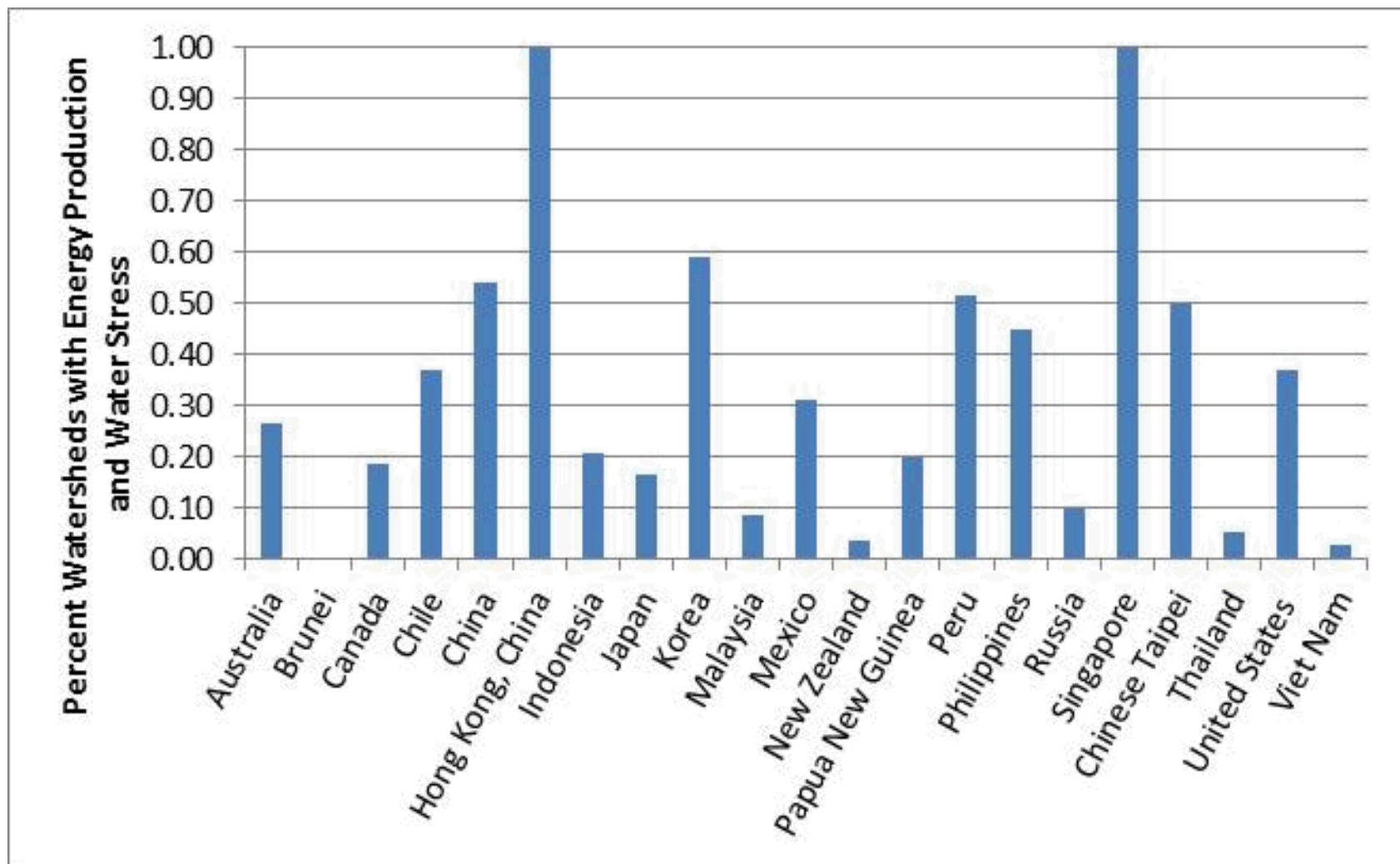


# Water for Energy: Detail Australia



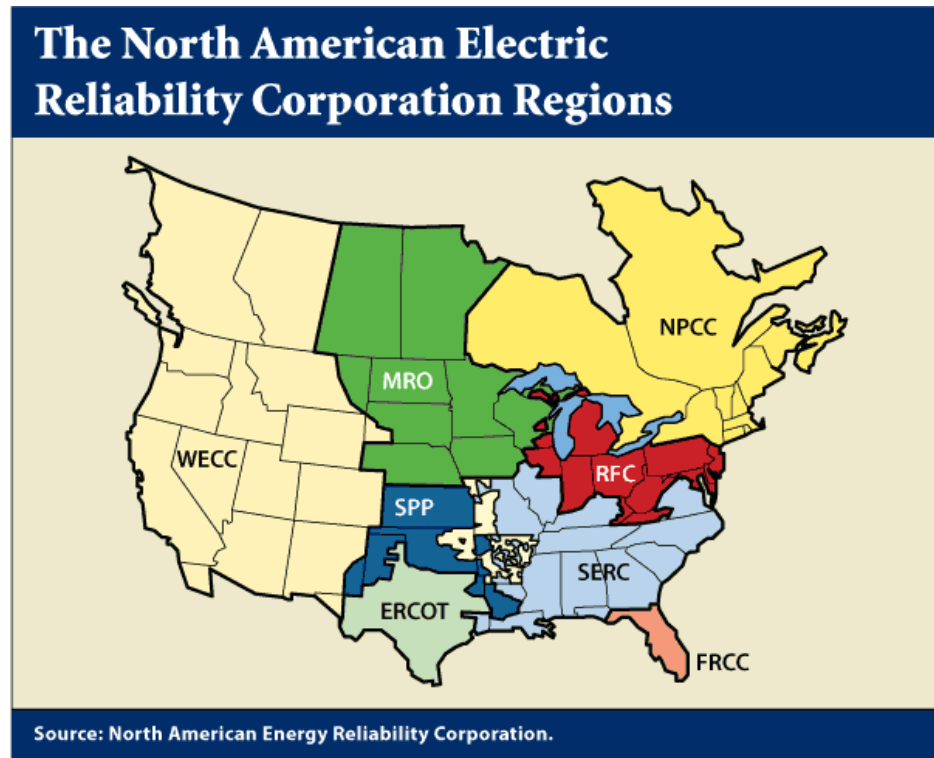


# Energy-Water Risk



# 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



**WESTERN  
GOVERNORS'  
ASSOCIATION**

*Serving the Governors of 19 States and 3 US-Flag Pacific Islands*



**WECC**



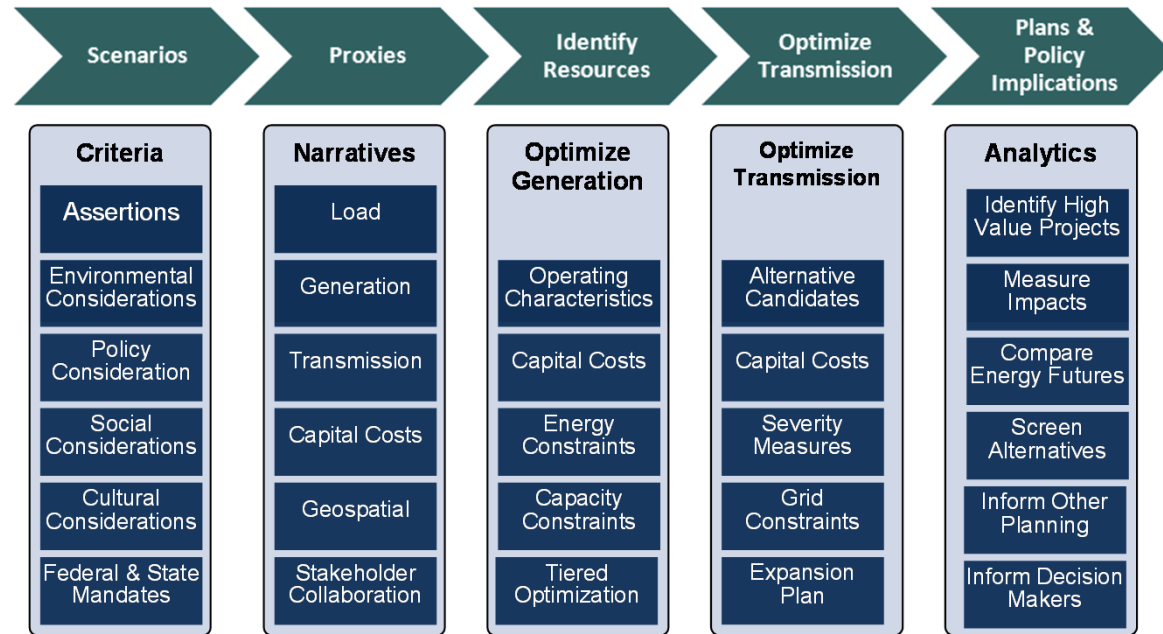
**WSWC**

**Western States Water Council**

# Methods: Capital Expansion

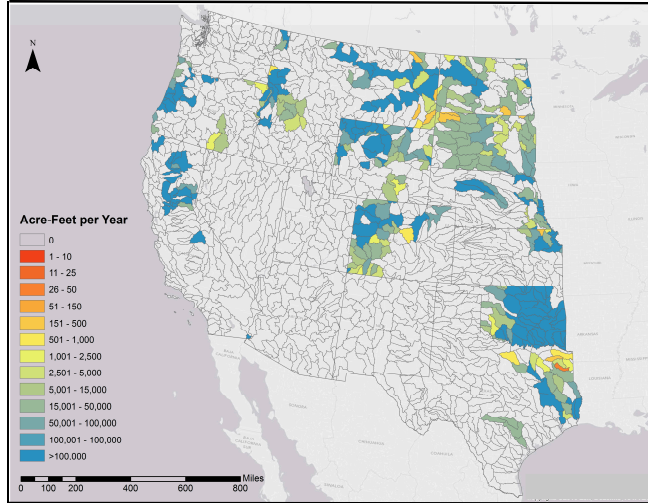
Source: WECC 2013

- 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.

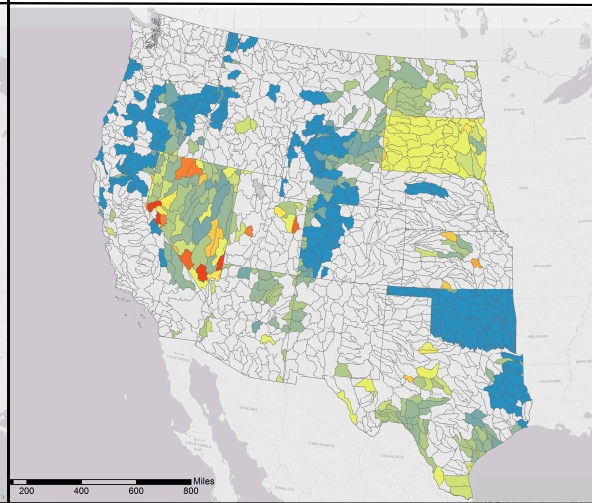


# Results: Water Supply Availability

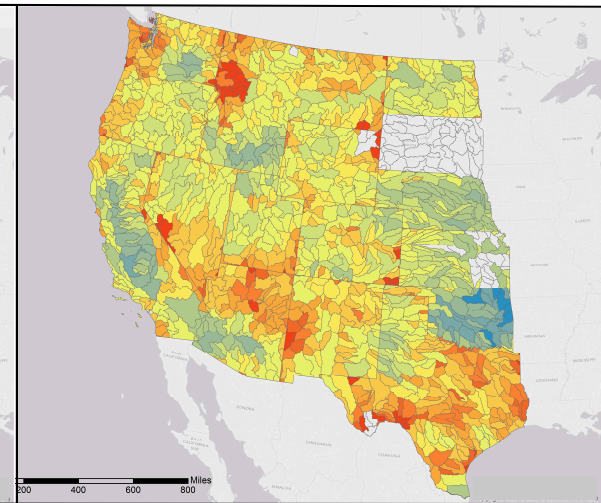
## Unappropriated Surface Water



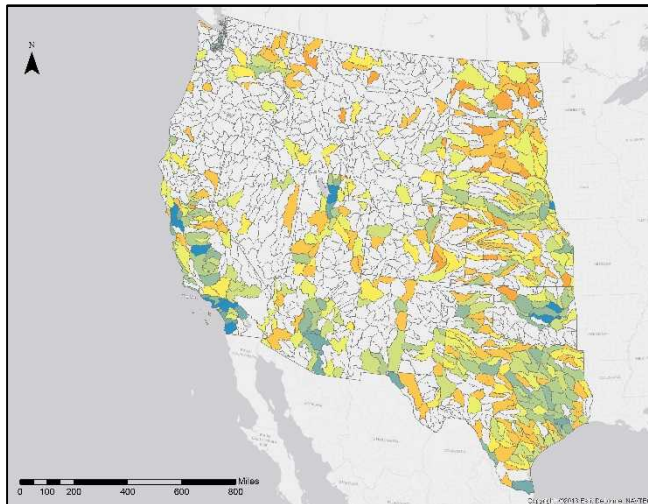
## Unappropriated Groundwater



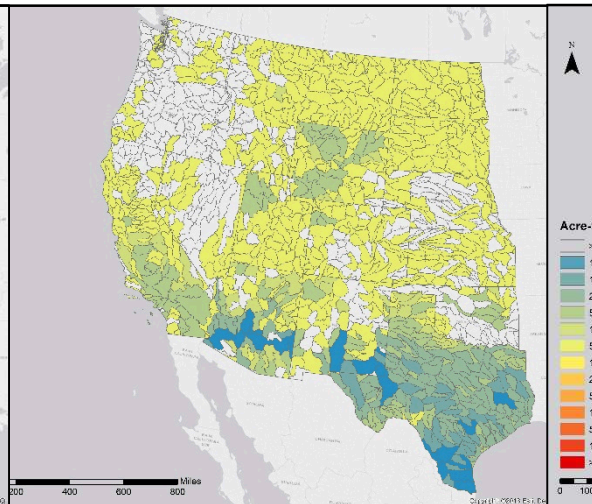
## Appropriated Water



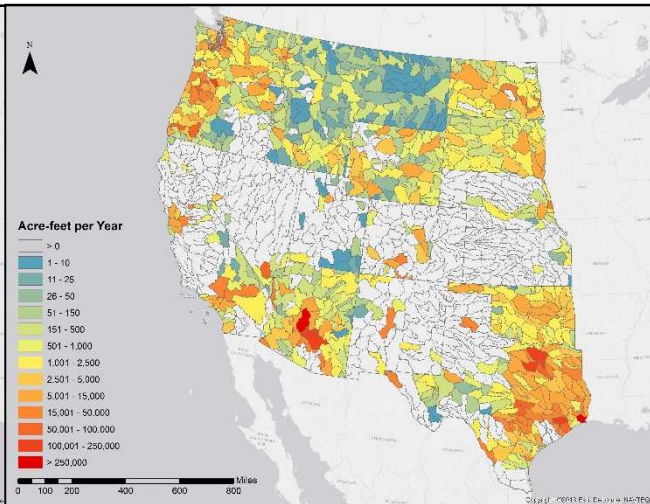
## Municipal Wastewater



## Brackish Groundwater

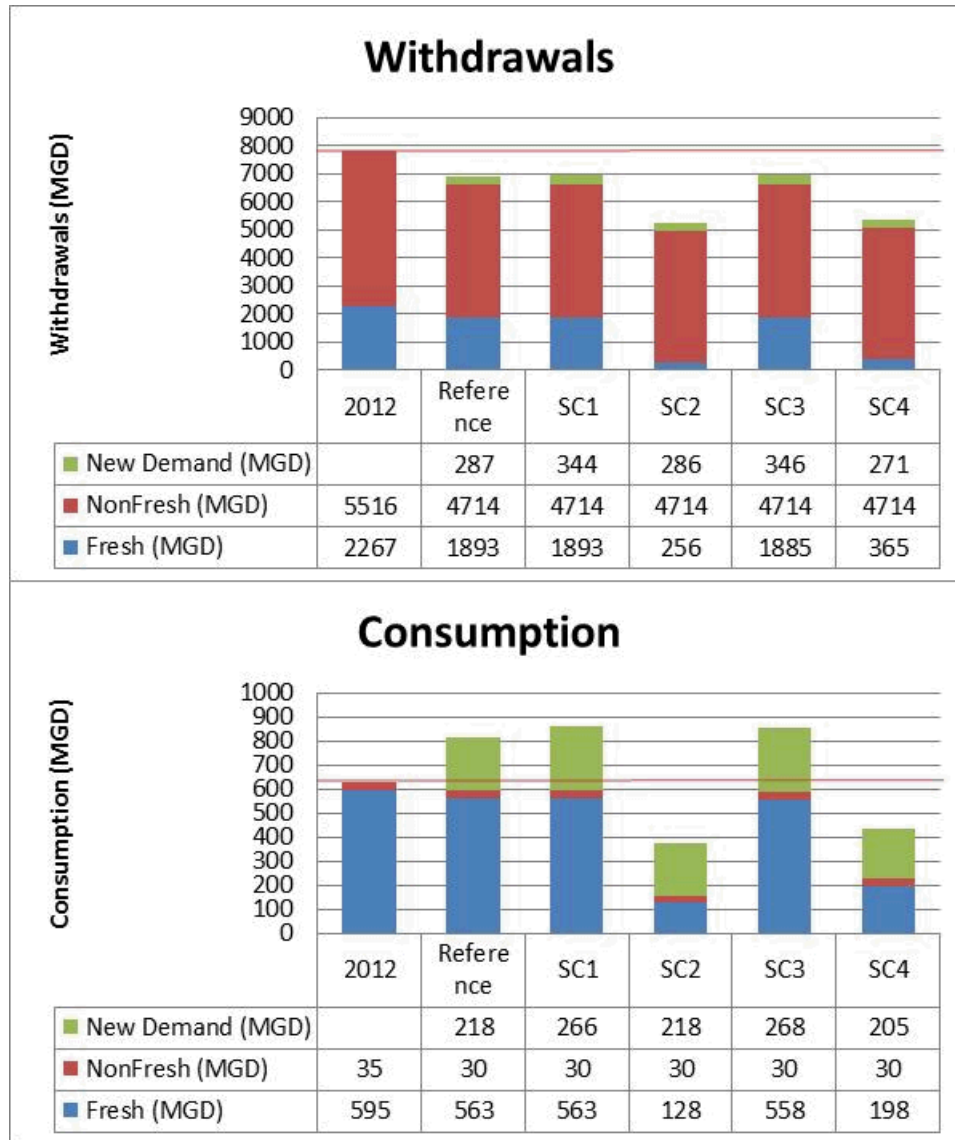


## Consumptive Demand 2010-2030





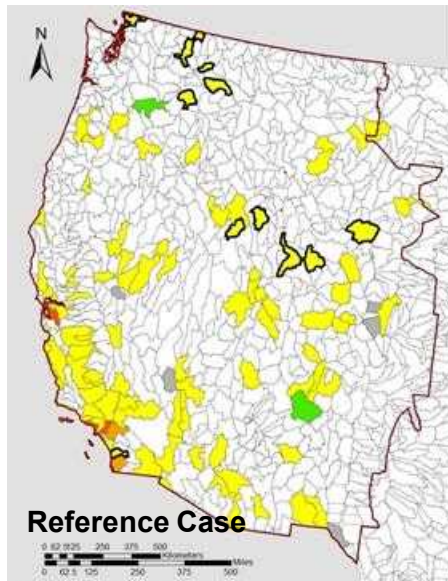
# Results: Water Use



- 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



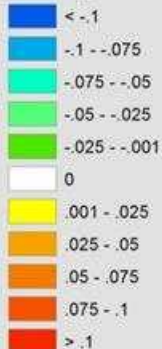
# Results: Watershed Impacts



**Reference Case**

## Total Change

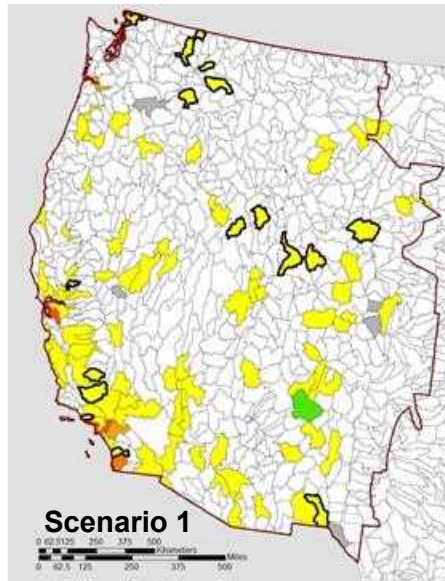
Mm3/day



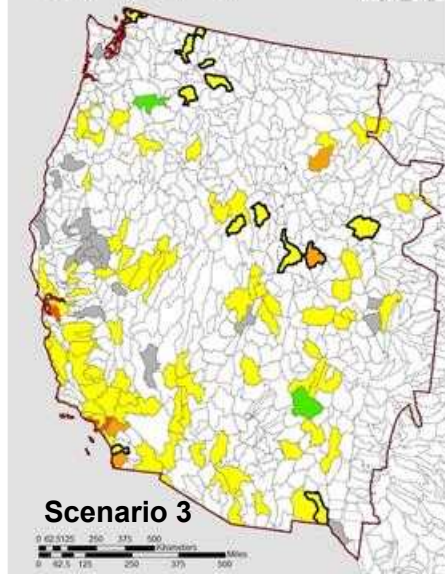
■ New Demand = Displaced

■ WECC

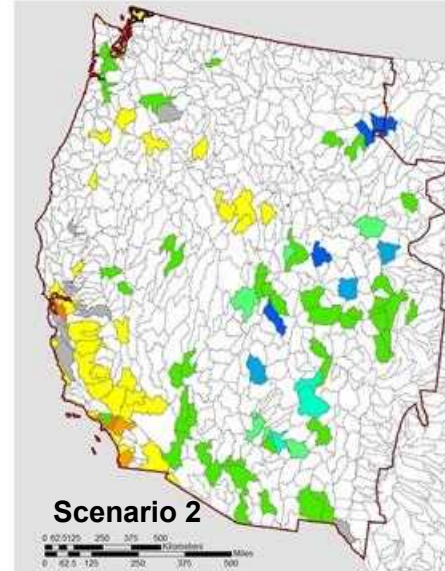
■ Used > 10% Available Water



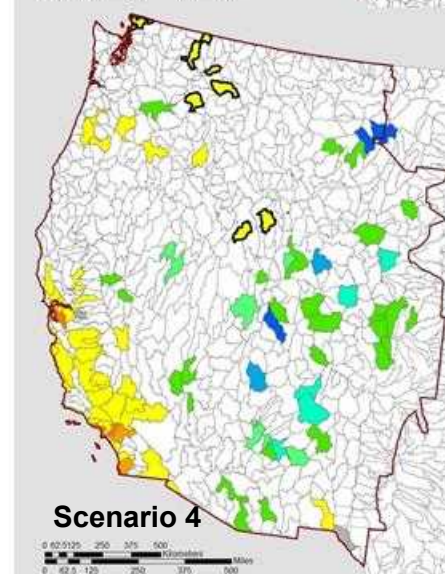
**Scenario 1**



**Scenario 3**



**Scenario 2**

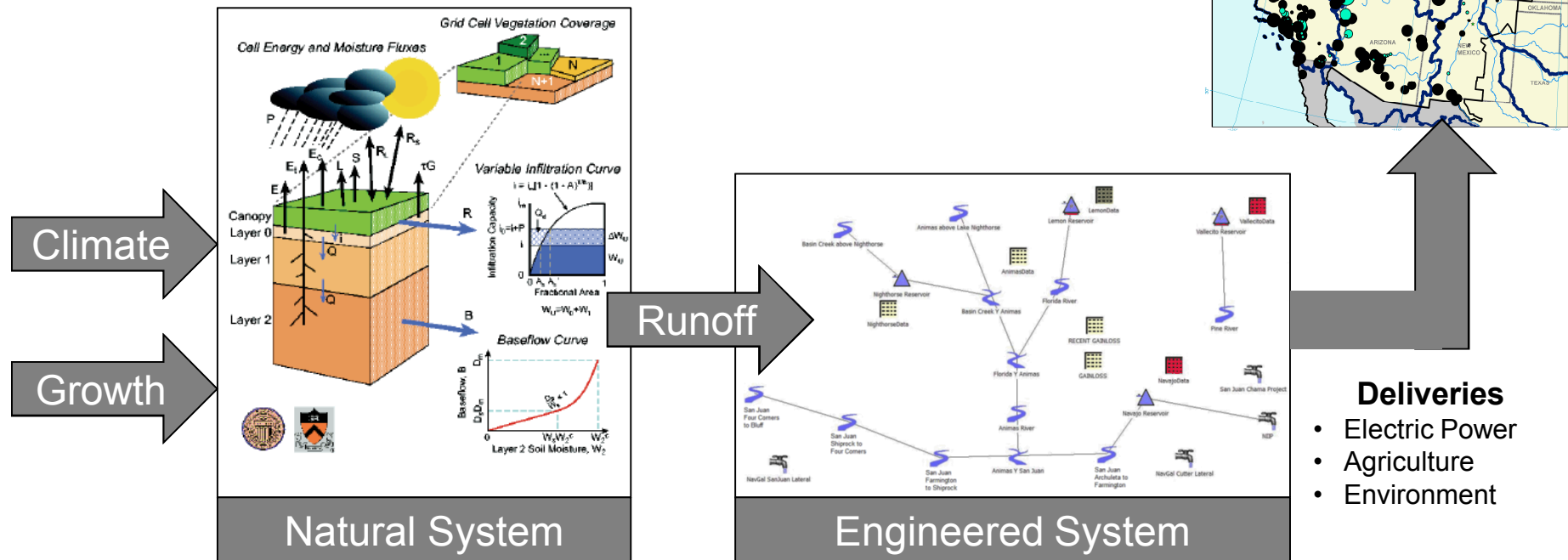


**Scenario 4**

- 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.



# San Juan Basin



## Four Corners Region



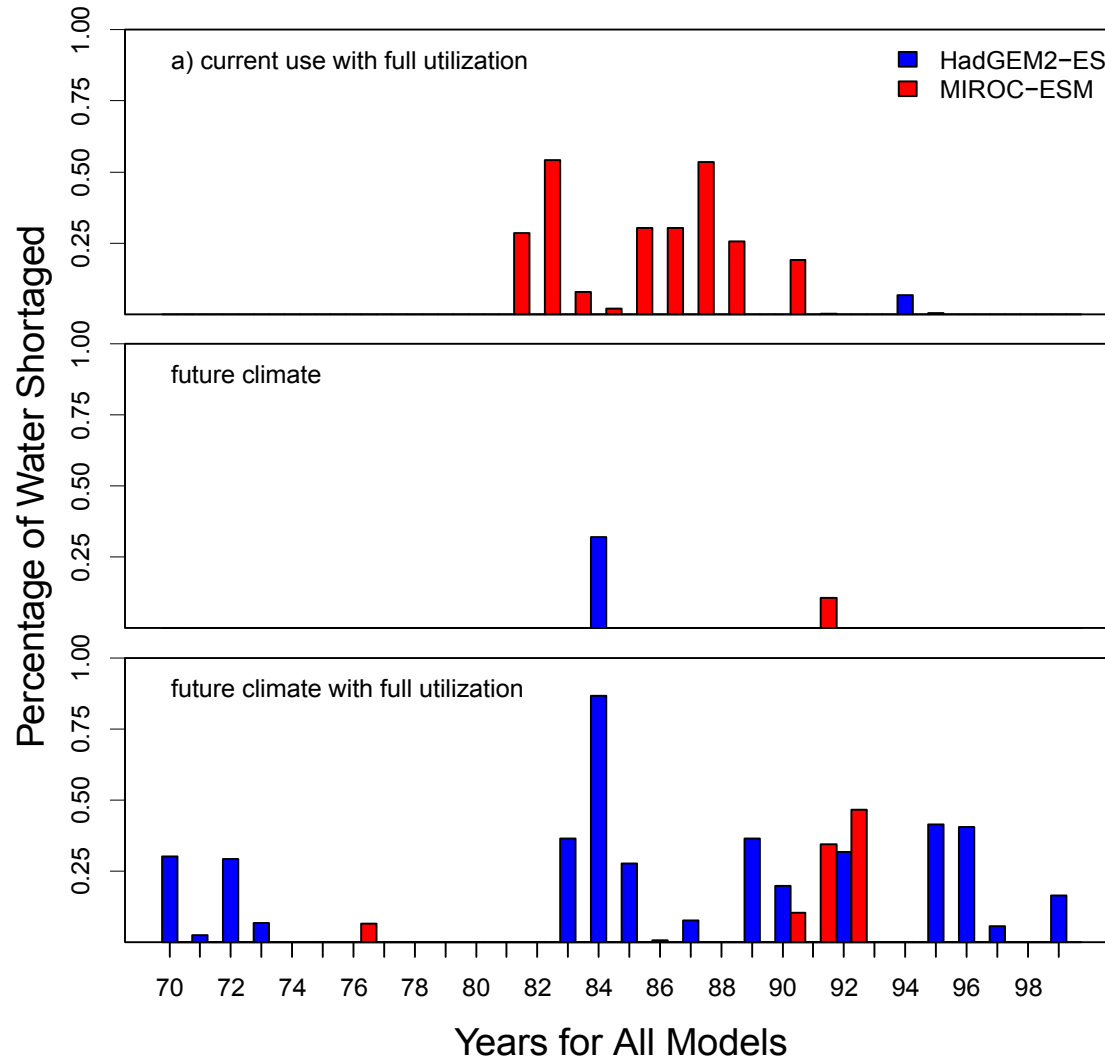
- Colorado River basin
- Snow melt dominated system

## Water Users

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

# Water Delivery Shortages

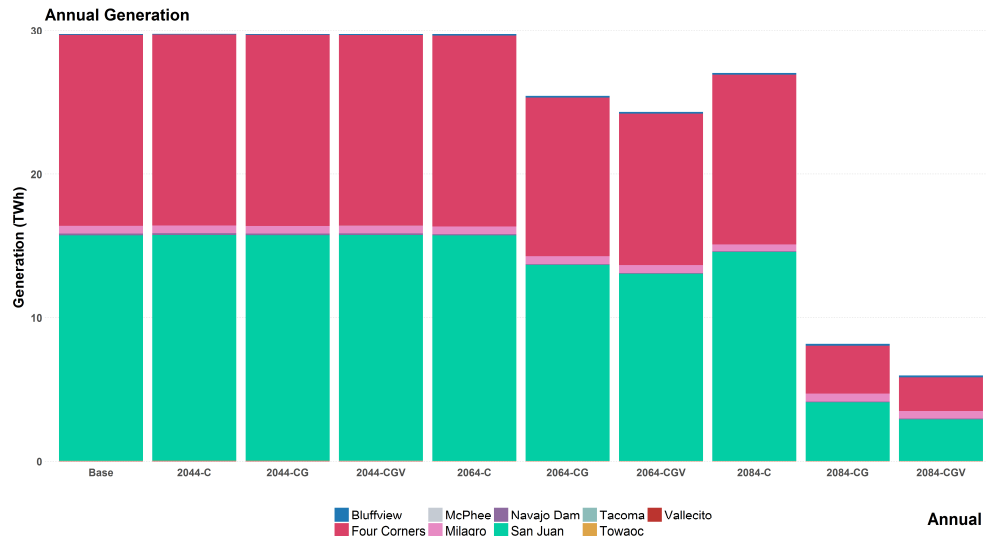
Shortages: 2080-2099



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

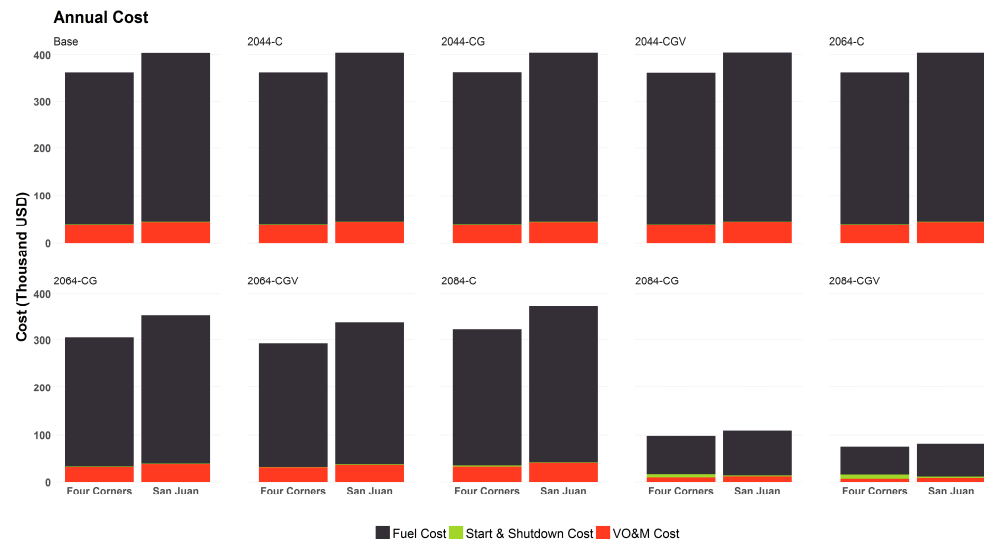
# Generation Vulnerability

## 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,
  - 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.

■ Project data available at:  
[http://energy.sandia.gov/?page\\_id=1741](http://energy.sandia.gov/?page_id=1741)

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The screenshot shows the Sandia National Laboratories website. The main navigation bar includes 'Energy and Climate' and sub-sections like 'RENEWABLE SYSTEMS', 'CLIMATE/ENVIRONMENT', 'ENERGY INFRASTRUCTURE', 'ENERGY RESEARCH', and 'ABOUT EC'. The page title is 'Energy and Water in the Western and Texas Interconnects'. Below the title, there's a 'Background' section with a list of bullet points: 'Hydroelectric power generation', 'Thermoelectric power plant cooling and air emissions control', and 'Energy-resource extraction, refining, and processing'. To the right, there's a 'WATER SECURITY PROGRAM' sidebar with links to 'Water Infrastructure Security', 'Water, Energy, and Natural Resource Systems', and 'Energy and Water in the Western and Texas Interconnects'. Below this is an 'ENERGY-WATER DATA PORTAL' with a map of the Western United States. The page is tagged with various keywords like 'Air Emissions Control', 'ARRA', 'Climate', 'Climate Variability', etc. The last updated date is August 7, 2014.

The footer section contains several columns of links and information. The first column is 'EC' with links to 'About Energy and Climate (EC)', 'Energy Security', 'Climate Security', 'Infrastructure Security', 'Energy Research', 'Key Facilities', and 'Partnerships'. The second column is 'EC Highlights' with links to 'Sandia Report Presents Analysis of Glac Impacts of Yontub Solar Power Site', 'Sandia Wins Award for Best Paper at IEEE Photovoltaic Specialist Conference (PVSC)', 'Sandia Completes Hydrostructural Analysis of Coastal Renewable Power Company's TIGER™ Turbine', and 'The Influence of Solar Blade Design on Wake Development'. The third column is 'EC Top Publications' with links to 'Solar Energy Grid Integration Systems: Final Report of the Florida Solar Energy Center Team', 'Modeling System Losses in PVarray', 'Improved Test Method to Verify the Power Rating of a Photovoltaic (PV) Project', and 'Solar Energy Grid Integration Systems (SEGIS) Productive Intelligent Advances for Photovoltaic Systems'. The fourth column is 'Related Topics' with links to 'Concentrating Solar Power', 'CSP EPRC Energy', 'Energy Efficiency Energy', 'Security Infrastructure', 'Infrastructure Security National', 'Solar Thermal Test Facility', 'NSTTF photovoltaic', 'Photovoltaics PV', 'Renewable Energy solar Solar', 'Energy solar power Solar', 'Research Solid-State', and 'Lighting SSLs'. The fifth column is 'Connect' with links to 'Contact Us', 'RSS', 'Google+', 'Twitter', 'Facebook', 'LinkedIn', 'YouTube', and 'iStock'.