U.S. DEPARTMENT OF
ENERGY

Water-Energy Nexus: Challenges and Opportunities

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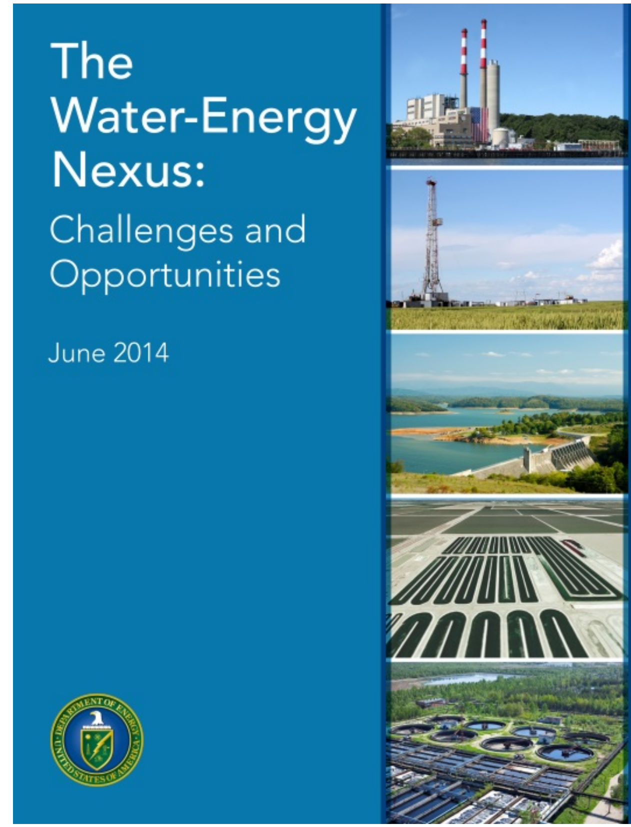
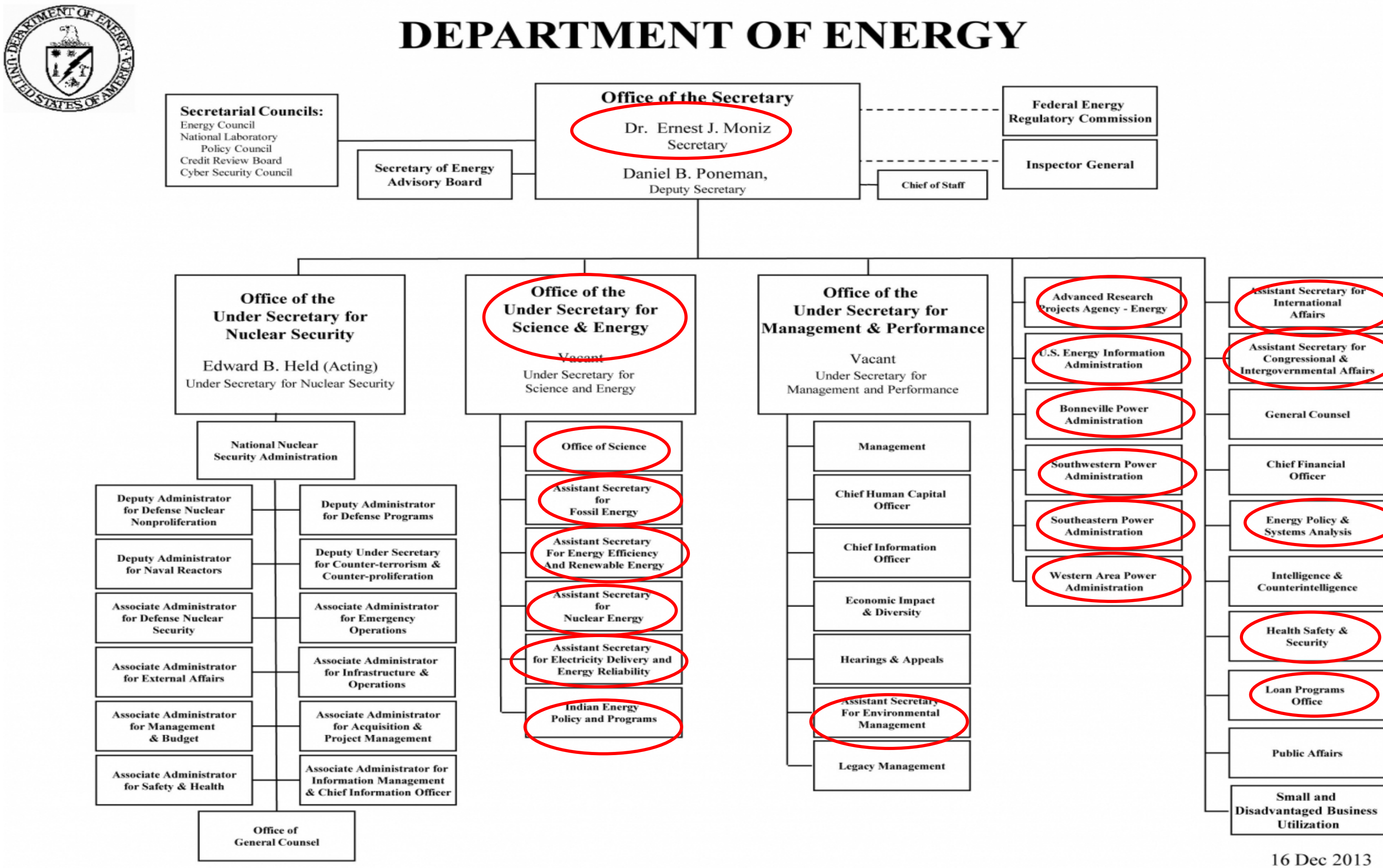
Water-Energy Nexus: Why Now? Why DOE?

- Energy and water are interdependent.
- Water scarcity, variability, and uncertainty are becoming more prominent.
    - This is leading to vulnerabilities of the U.S. energy system.
- We cannot assume the future is like the past in terms of climate, technology, and the evolving decision landscape.
- Aging infrastructure brings an opportunity to make some changes.
- DOE has strong expertise in technology, modeling, analysis, and data and can contribute to understanding the issues and pursuing solutions across the entire nexus.



Download the full report at energy.gov

DOE Offices in Water Energy Tech Team (WETT)



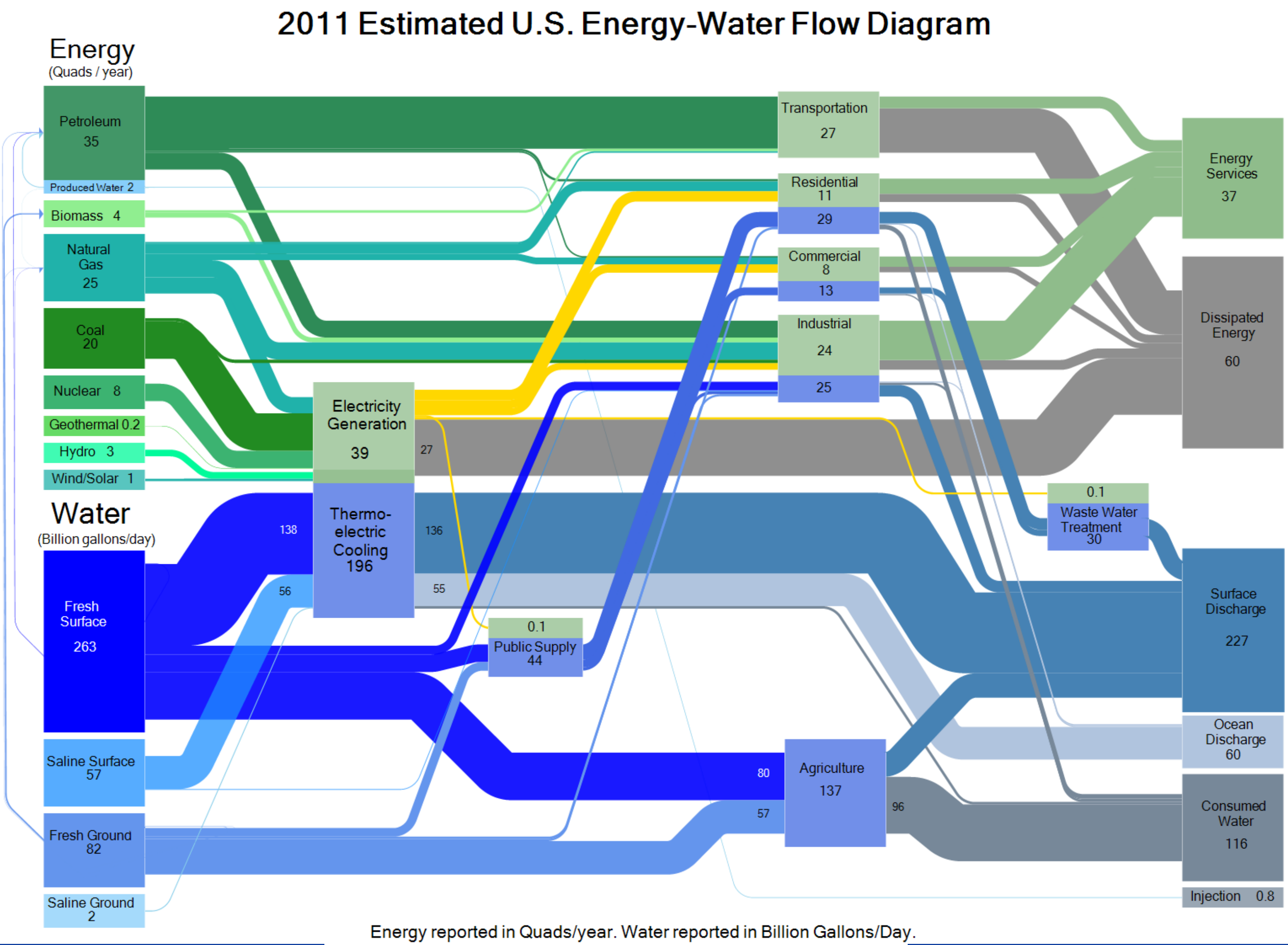
Report Overview

- **Executive Summary**
- **Chapter 1:** Introduction
- **Chapter 2:** Interconnected Energy and Water Systems
- **Chapter 3:** Implications of Climate Change and Other Trends
- **Chapter 4:** Decision-Making Landscape
- **Chapter 5:** Technology RDD&D
- **Chapter 6:** Data, Modeling, and Analysis
- **Chapter 7:** Future Opportunities
- **Appendices**

Strategic Pillars

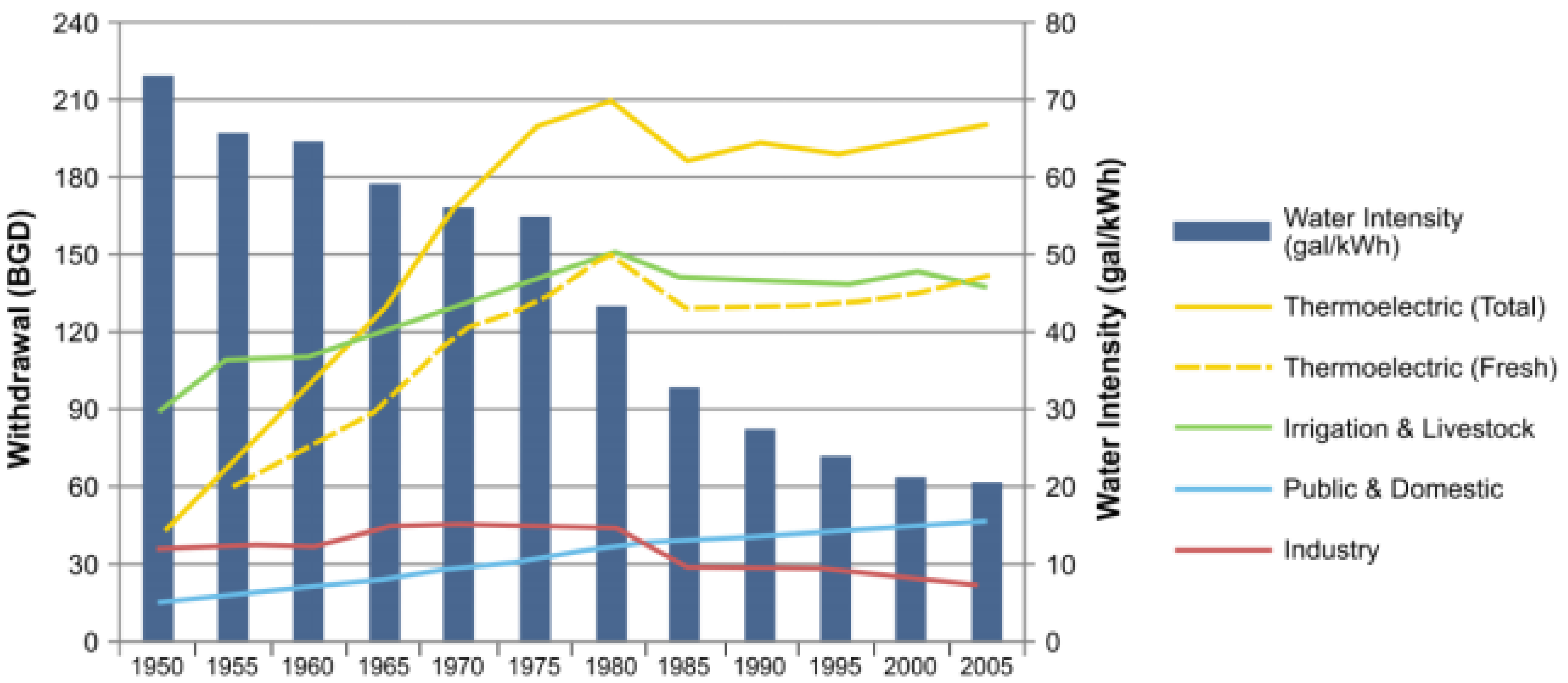
- Optimize the freshwater efficiency of energy production, electricity generation, and end use systems
- Optimize the energy efficiency of water management, treatment, distribution, and end use systems
- Enhance the reliability and resilience of energy and water systems
- Increase safe and productive use of nontraditional water sources
- Promote responsible energy operations with respect to water quality, ecosystem, and seismic impacts
- Exploit productive synergies among water and energy systems

Interconnected Energy and Water Systems



Water Withdrawals and Thermoelectric Generation

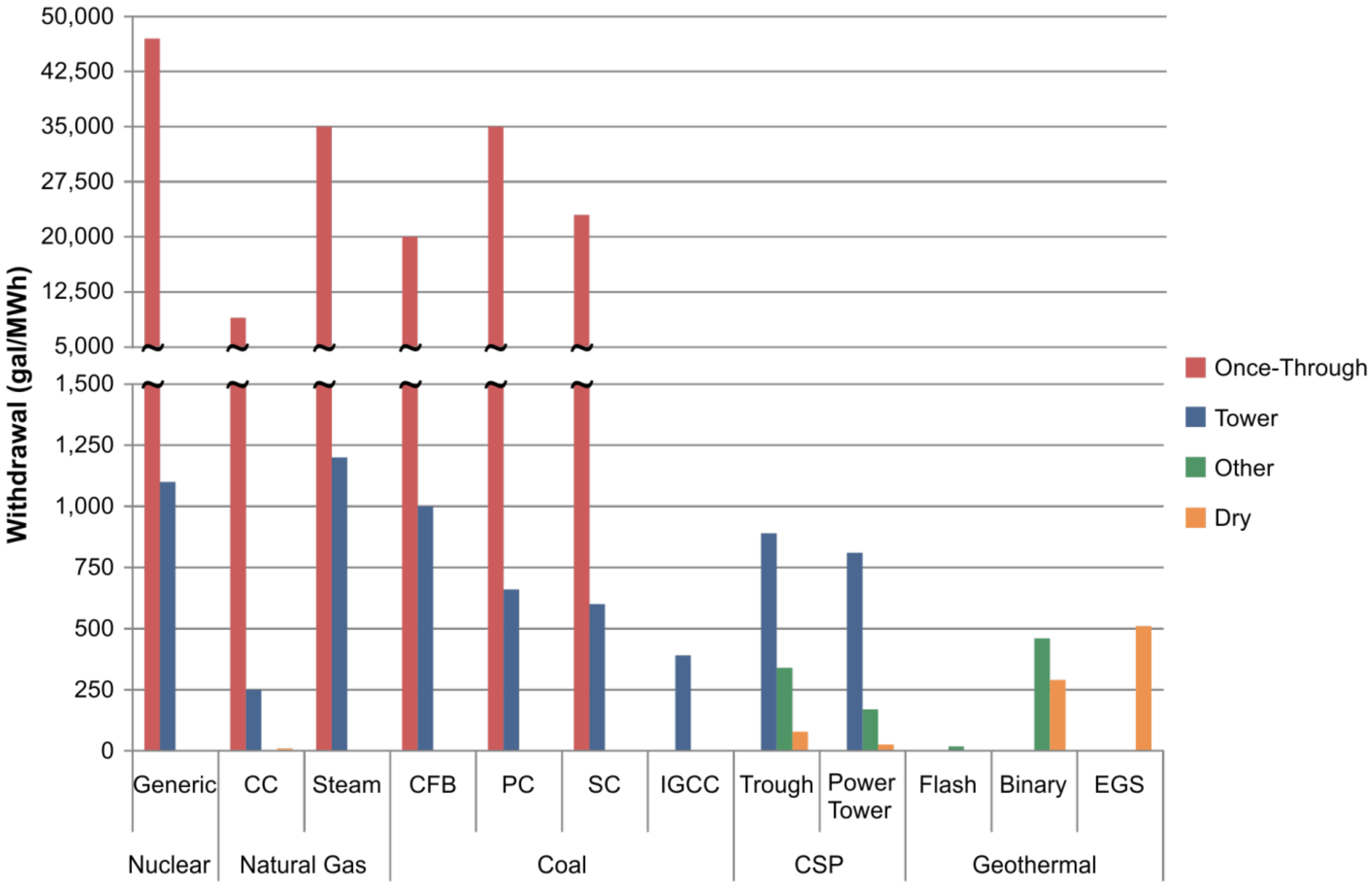
Water withdrawals for thermoelectric power generation have been relatively flat since 1980, and intensity of water use in the sector has decreased.



Data source: Kenny et al. (2009); EIA Monthly Energy Review (2014)

Water Withdrawals and Thermoelectric Generation

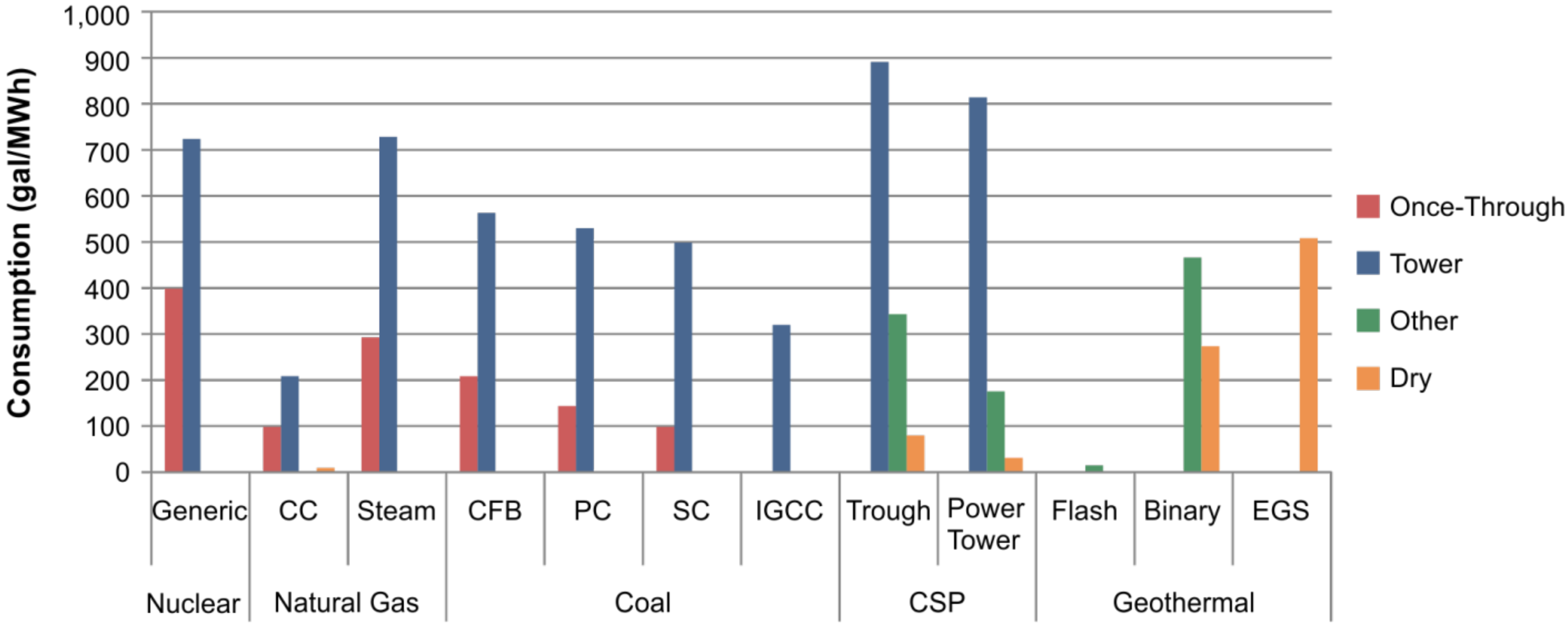
Water withdrawal intensity is highest for plants using once-through cooling technologies



Data source: Meldrum et al. (2013)

Water Consumption in Thermoelectric Power Generation

Thermoelectric power plants withdraw large volumes of water for cooling and other processes, but a transition to recirculating cooling technologies could increase water consumption.



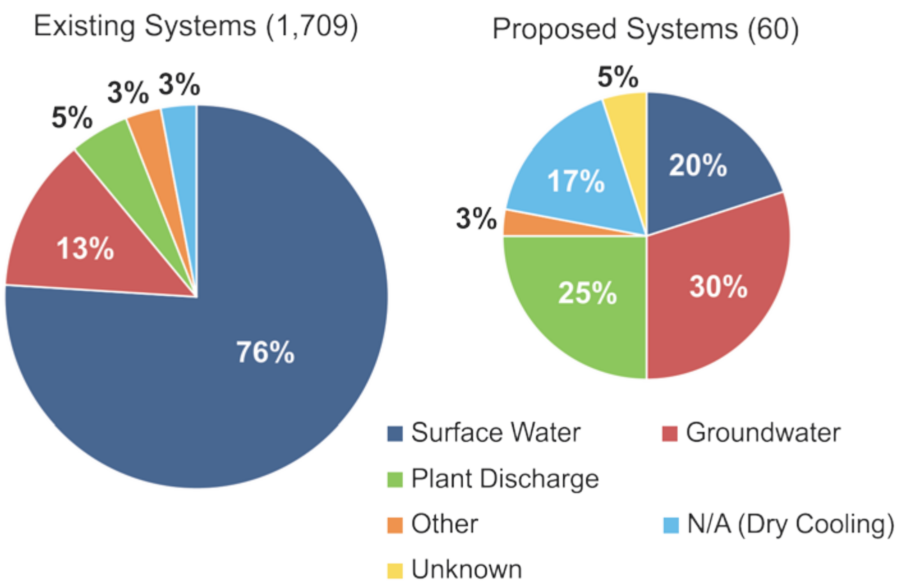
Abbreviations: Nuc: Nuclear; Nat Gas: Natural Gas; CC: Combined Cycle; CFB: Circulating Fluidized Bed; PC: Pulverized Coal; SC: Supercritical Pulverized Coal; IGCC: Integrated Gasification Combined Cycle; CSP: Concentrated Solar Power; EGS: Enhanced Geothermal System.

Data source: Meldrum et al. (2013)

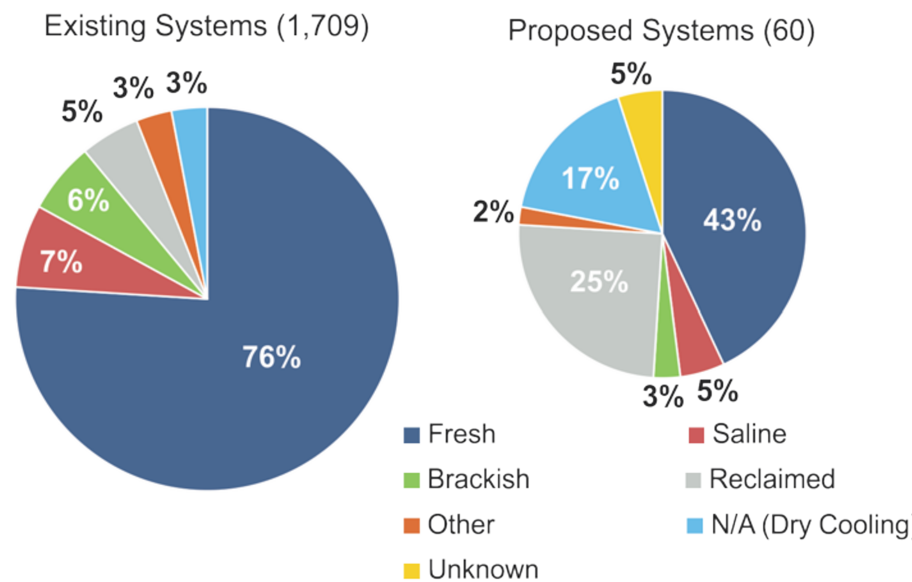
Diversification of Cooling Water Sources

The power sector is moving towards reclaimed municipal wastewater, groundwater, and dry cooling. Brackish and saline sources may be an opportunity.

Source Type



Water Type

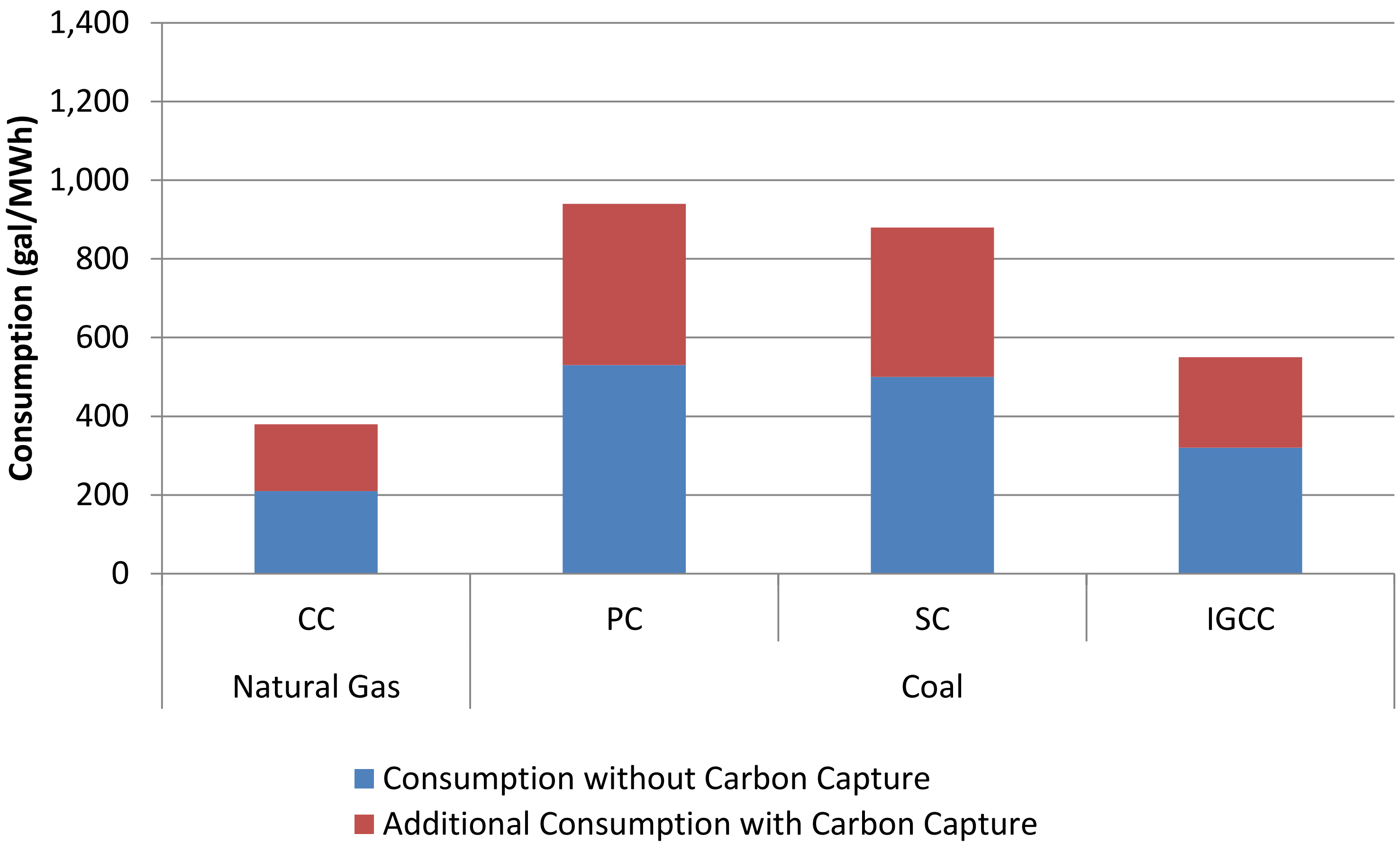


Proposed systems are scheduled to come online between 2013 and 2022

Data source: EIA Form 860 (2013)

Implications of Carbon Capture Technology

Depending on the technology, carbon capture can dramatically increase water requirements for thermoelectric cooling.



Data source: Meldrum et al. (2013)

Capture technology: monoethanolamine

Water Intensity of Fuels Production

Various fuels require a range of water withdrawal and consumption over their life cycle, including extraction or growing and refining.

	Consumption (gal/mile)		Withdrawal (gal/mile)	
	Extraction/ Growing	Processing/ Refining	Extraction/ Growing	Processing/ Refining
Gasoline from Liquid Petroleum	0–0.25	0.05–.1	0–0.25	0.6
Diesel from Liquid Petroleum	0–0.18	0.04–0.09	0–0.18	0.4
E85 from Irrigated Corn Grain	3.0–84	0.1–0.3	6.7–110	0.3–0.4
E85 from Non-Irrigated Corn Grain	0.004–0.006	0.1–0.3	0.08–0.1	0.3–0.4
E85 from Irrigated Corn Stover	2.4–45	0.2–0.3	5.2–64	0.35
E85 from Non-Irrigated Corn Stover	0.003	0.24–0.25	0.7	0.35
Biodiesel from Irrigated Soy	0.6–24	0.002–0.01	1.1–26.2	0.007–0.03
Biodiesel from Non-Irrigated Soy	0.002–0.01	0.002–0.01	0.01	0.007–0.03

Data source: King and Webber (2008); Wu and Chiu (2011)

Oil and Gas Resources

Some resources are located in relatively water-scarce regions, which could put additional stress on the water system as exploration and production expands.

Shale plays in the lower 48 states

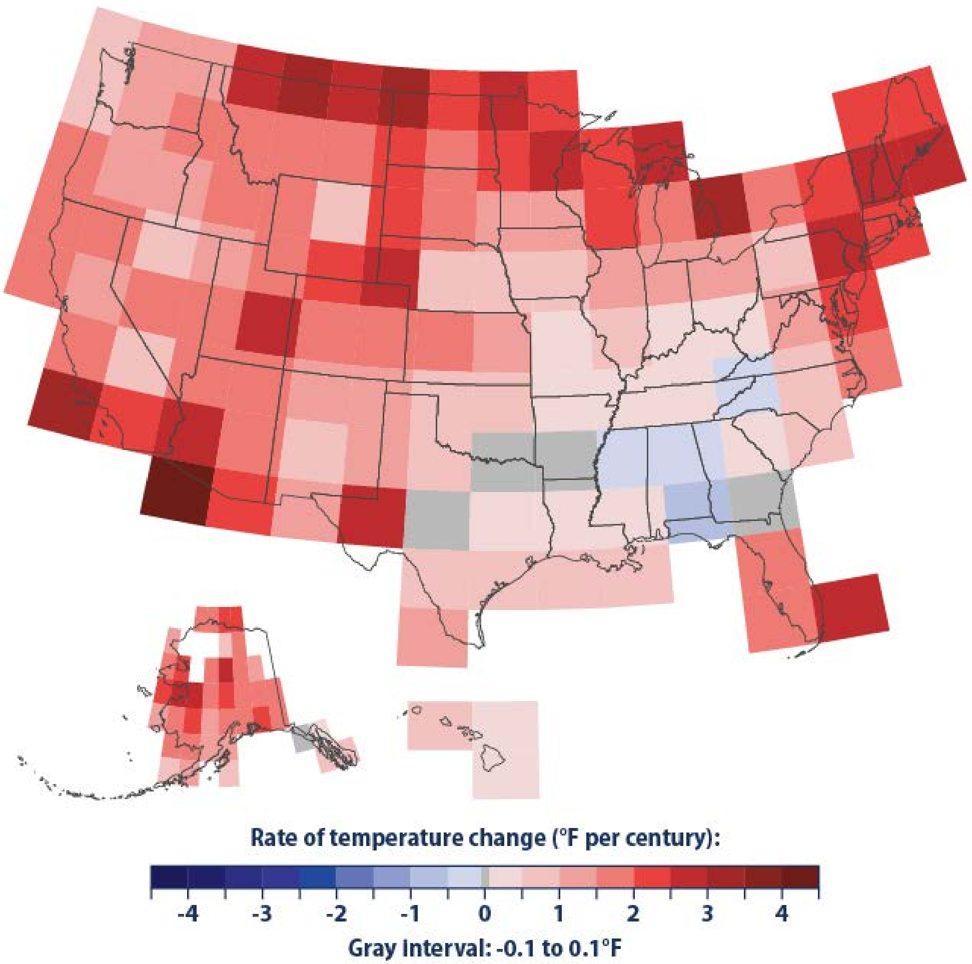
Source: EIA (2011)

Energy Intensity of Water Treatment and Pumping

Treatment of water that is either high in salinity or contains large amounts of organic material has relatively high energy requirements. Pumping and conveyance across basins is energy-intensive.

Energy Intensity for California	Low (kWh/MG)	High (kWh/MG)	Notes	Reference
Treatment				
Drinking Water Treatment	100	16000	High: Desalination	(CEC 2005)
Wastewater Treatment and Distribution	1100	4600		(CEC 2005)
Pumping				
Water Supply/Conveyance	0	14000	High: Interbasin transfer (State Water Project); Low: Gravity fed	(CEC 2005)
Primary Drinking Water Distribution	700	1200		(CEC 2005)
Recycled Water Distribution	400	1200		(CEC 2005)
Groundwater for Agriculture	500	1500	High: CO River Basin Low: North CA Coast	(CPUC 2011)

Implications of Climate Change



Temperature Change in the U.S. (1901-2012)

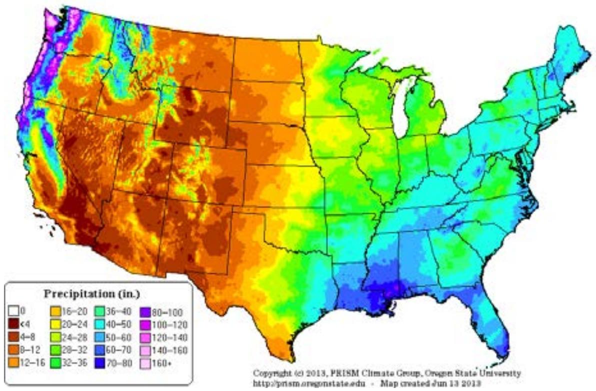
Source: EPA (2013)

The future of the water-energy nexus will bring changes and variation in the availability of water resources due to:

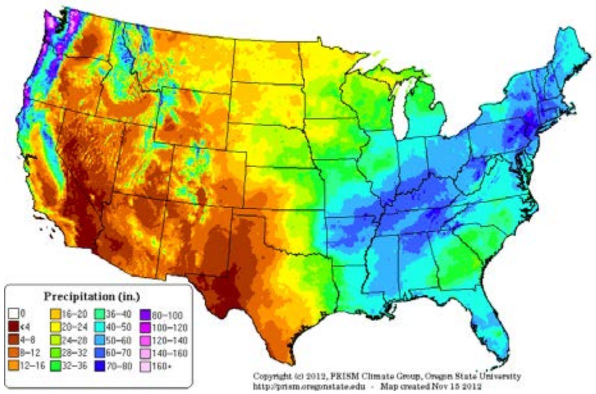
- increasing temperatures
- changes in precipitation patterns
- increasing climate variability
- more frequent extreme weather events (e.g. floods and droughts)

Variability in Water Resources

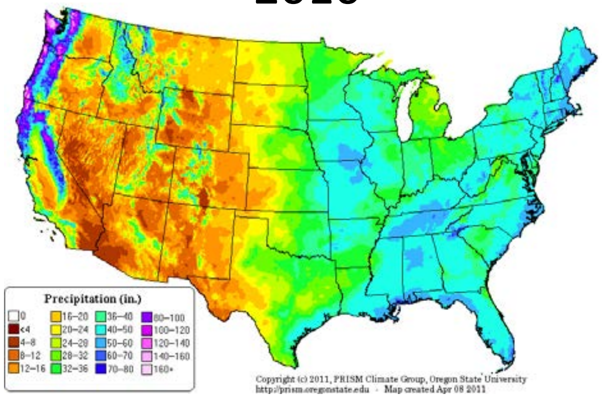
2012



2011



2010



Annual Average Precipitation (2010 -2012)

Variability in available water resources will pose challenges for:

- Optimizing operations (especially for hydroelectric plants)
- Developing effective water management strategies
- Choosing sites for energy production activities

Source: PRISM Climate Group, OSU

Complex Decision-Making Landscape

The water-energy decision-making landscape is characterized by market and institutional factors varying by region and sector.

Market Drivers

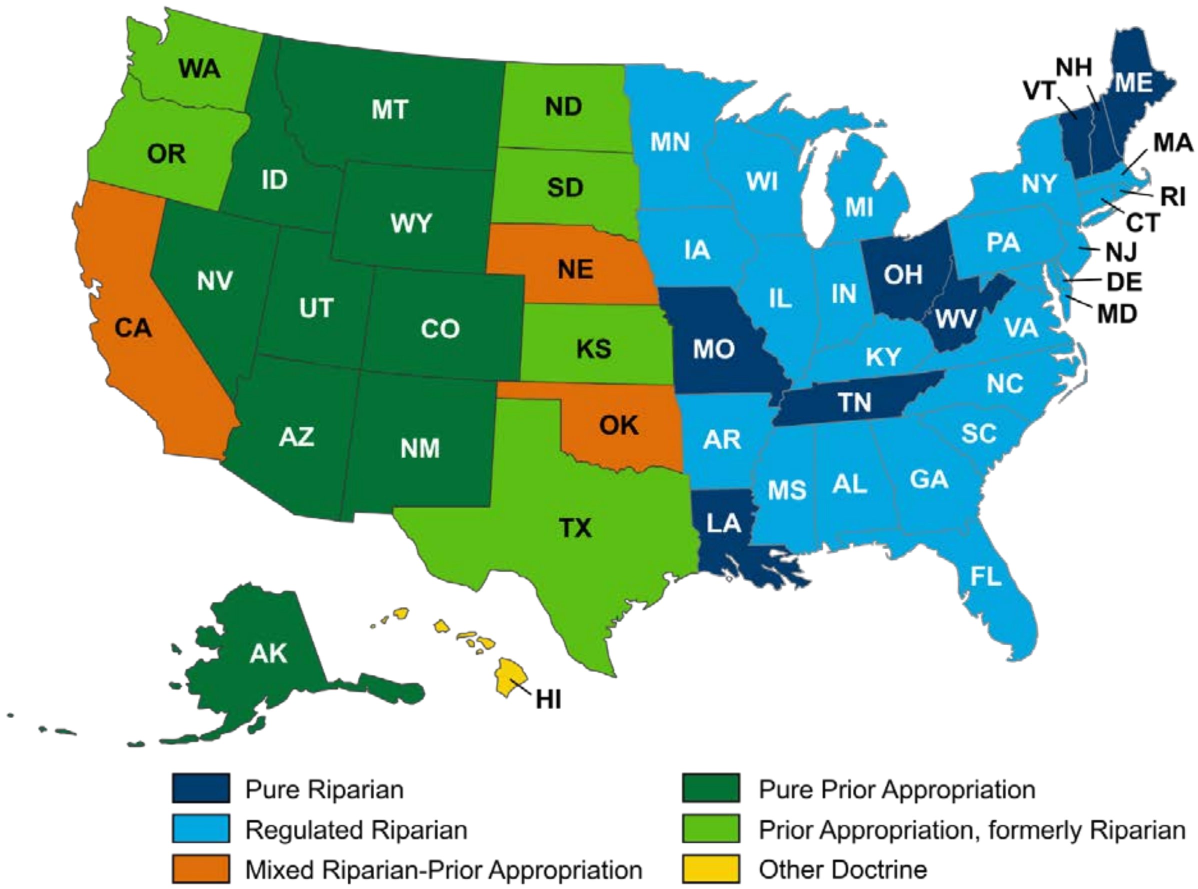
- Water prices and costs
- Relative fuel prices and costs
- Financial incentives

Institutional Factors

- Water rights and permitting
- Aging infrastructure
- O&G: regulatory response to rapid growth
- Power & Transportation: renewable energy mandates

Regional Variation in Water Policy Regimes

Eastern states tend to operate under riparian water policies, while the western states typically uses prior appropriation

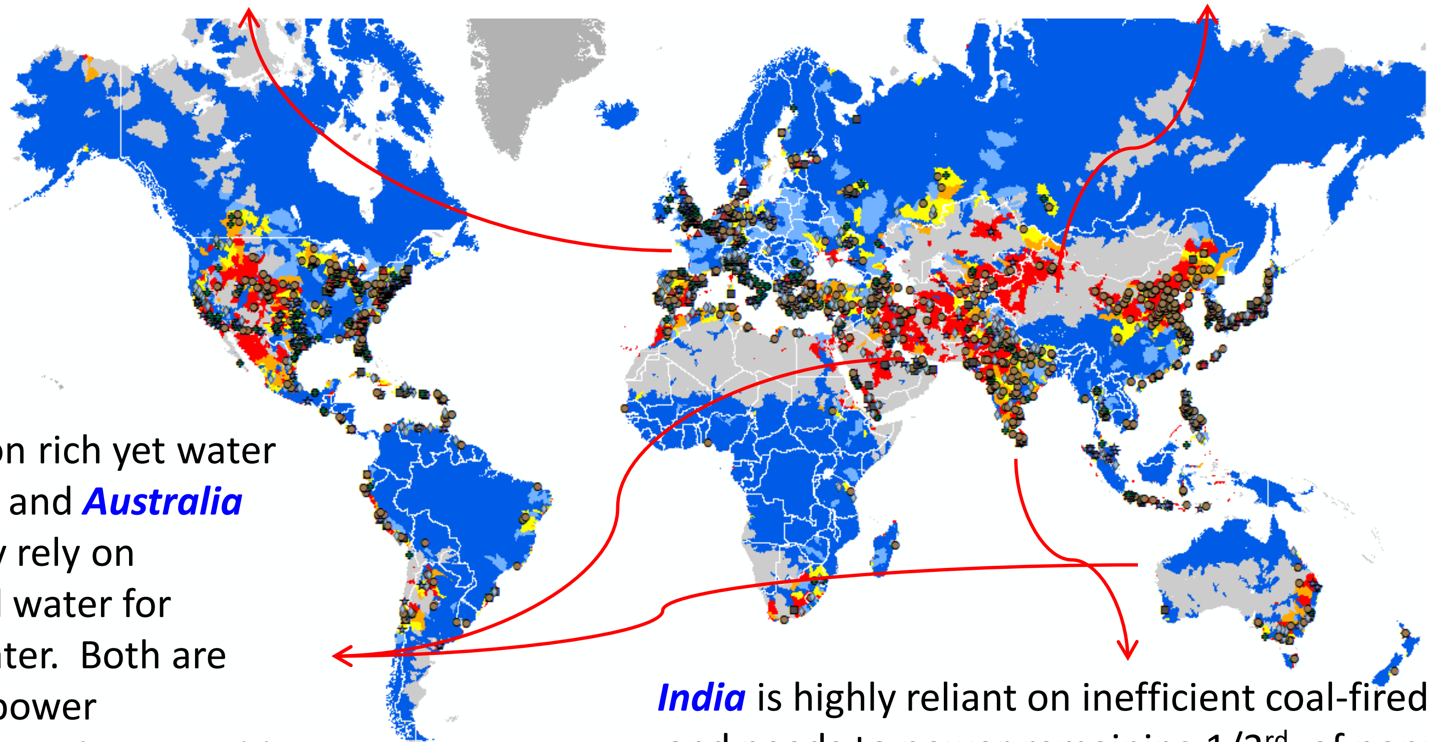


Data source: Gleick and Christian-Smith (2012)

Global Interest in the Water-Energy Nexus

France is particularly vulnerable due to high power sector water dependency from nuclear generation and recurring heat waves.

Coal-rich but water poor, ***China*** is adopting direct and indirect measures to reduce water intensity in coal-fired power generation.



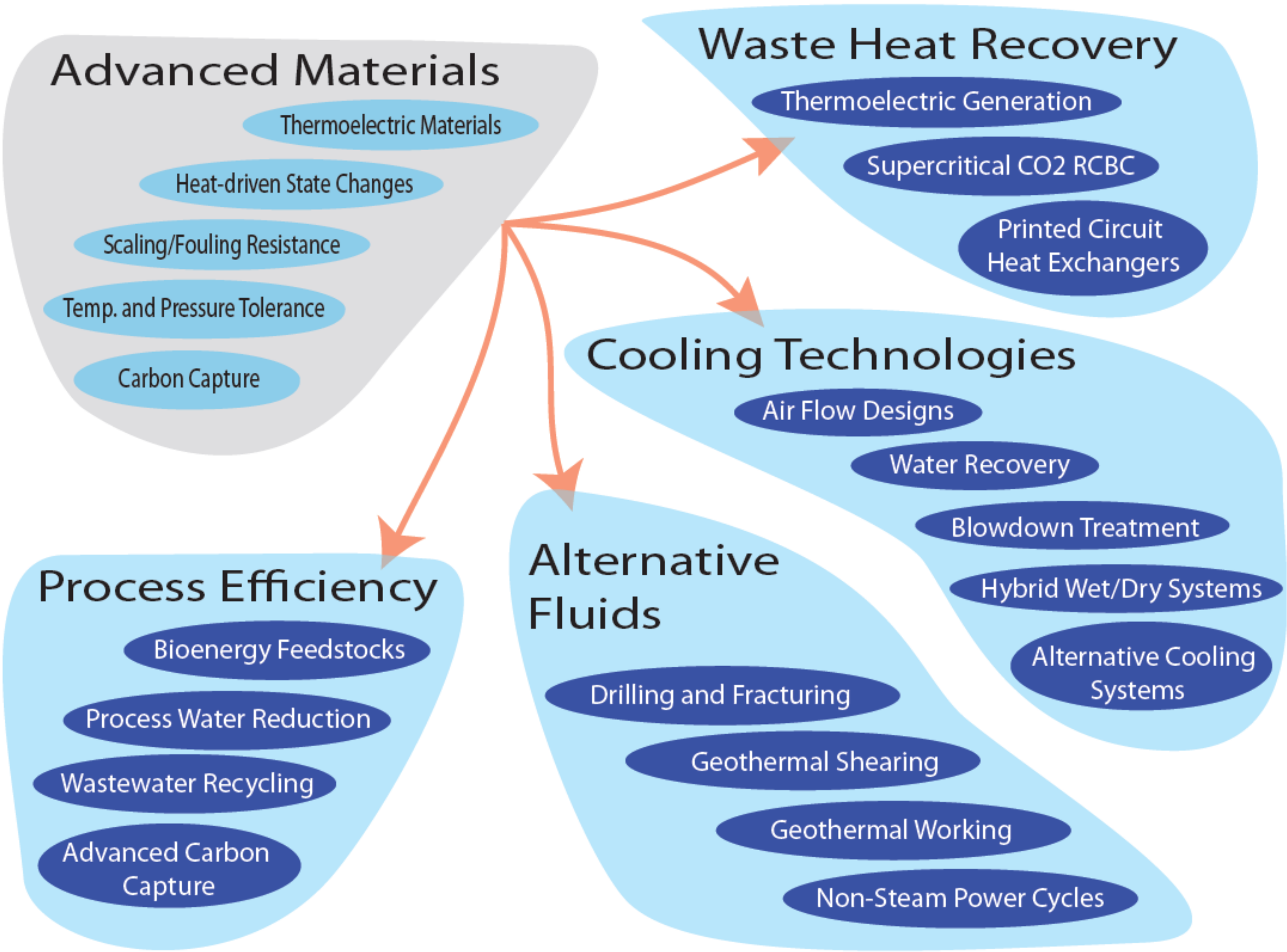
Hydrocarbon rich yet water poor ***Qatar*** and ***Australia*** increasingly rely on desalinated water for drinking water. Both are moving to power desalination with renewable power and waste heat.

India is highly reliant on inefficient coal-fired generation, and needs to power remaining 1/3rd of population. The country is improving coal-fired power generation efficiency and reclaiming waste water.

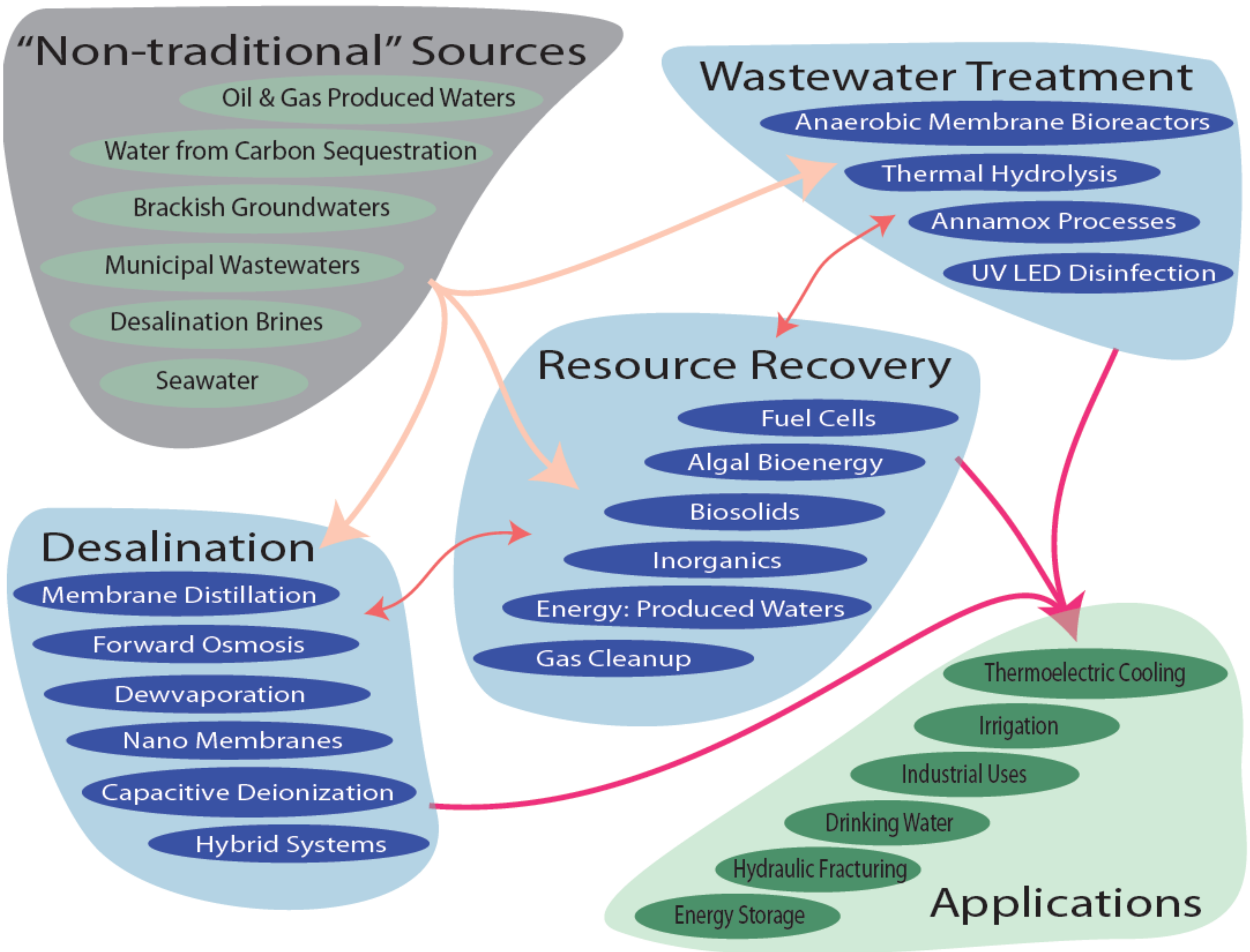
Global Generation Units with Water Stress

- yellow, orange, and red correspond with medium, high, to extremely high stress levels

Technology RDD&D: Water for Energy



Technology RDD&D: Energy for and from Water



Needs and Priorities in Data, Modeling, and Analysis

User/Societal Needs

- National and regional-scale assessments
- Sustainable development planning
- Investment and siting decisions
- Adaption strategies
- Technology analysis and R&D insights

Current Capabilities

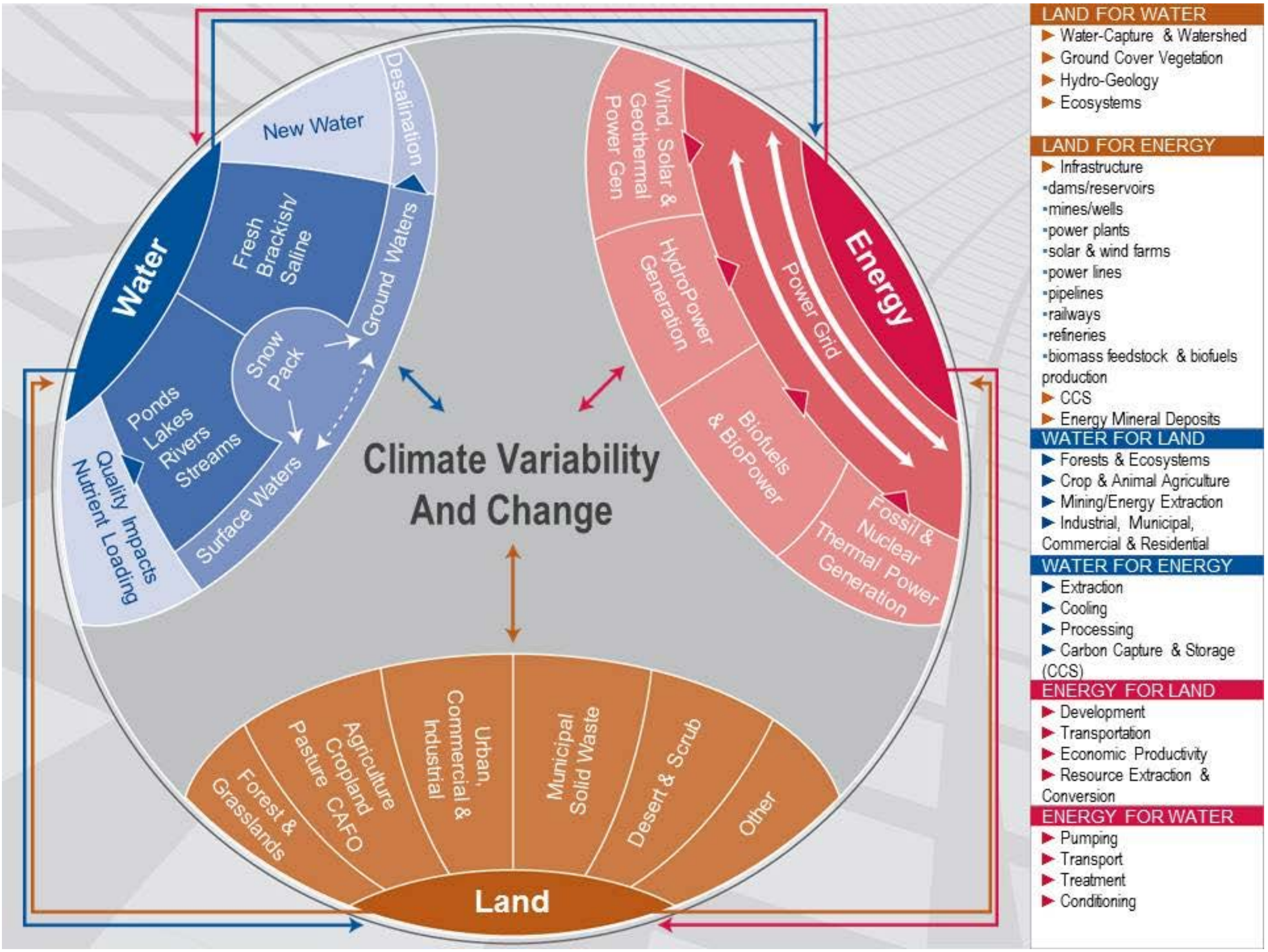
- Integrated modeling of human and Earth systems
- Modeling and analysis of human systems
- Modeling and analysis of Earth systems
- Crosscutting modeling & analysis methodologies
- Data, computation, software, observations and the user interface

Priorities for Data, Modeling, and Analysis

- Robust projections, analyses, and scenarios at decision-relevant scales
- Characterization of uncertainty and risks
- Modeling and analysis of extreme events
- Interoperable modeling, data, and analysis platforms
- Confronting models with observations and using observations to improve projections

Interconnections for Data, Modeling, and Analysis

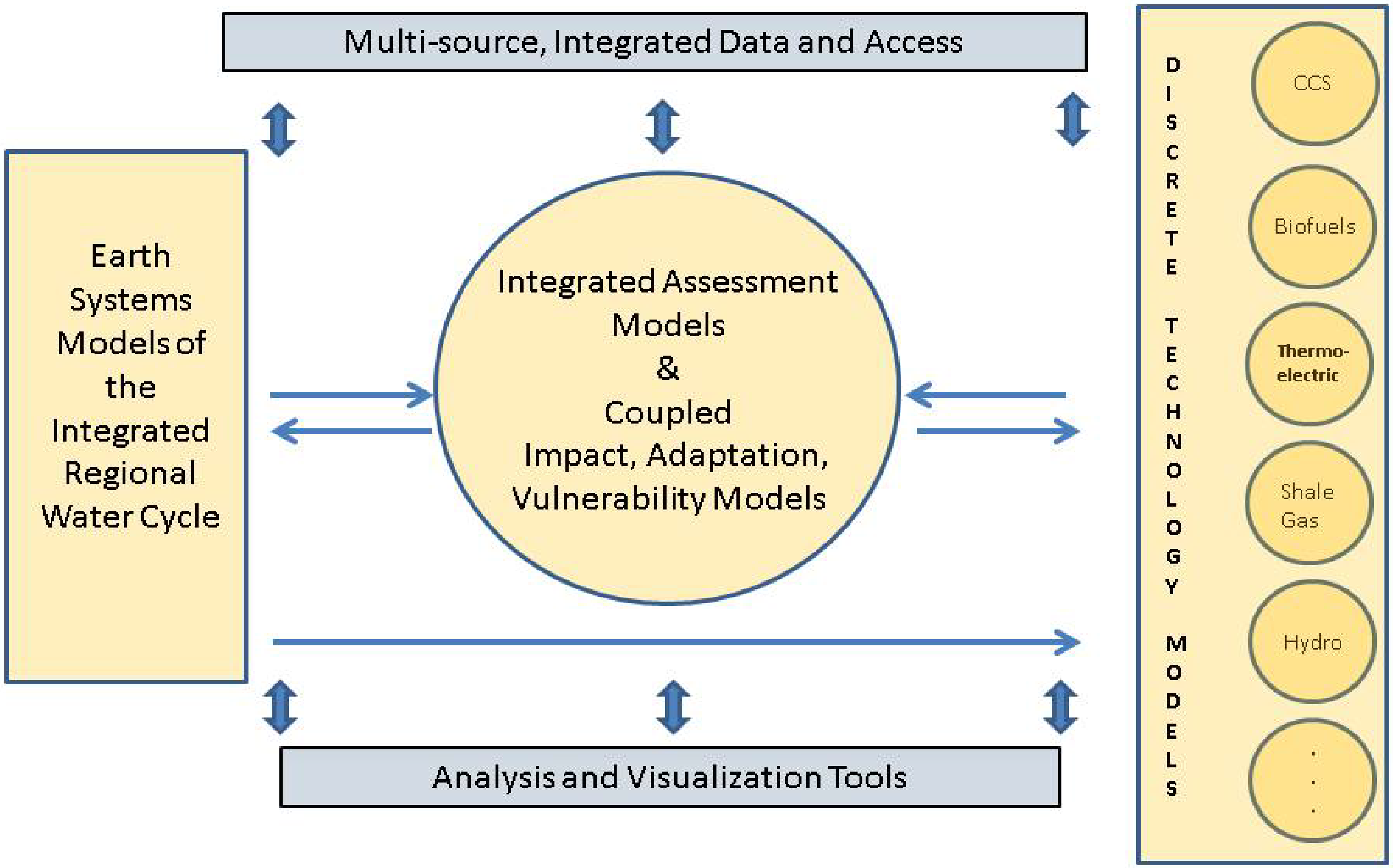
Land is an important consideration for integrative modeling and analysis



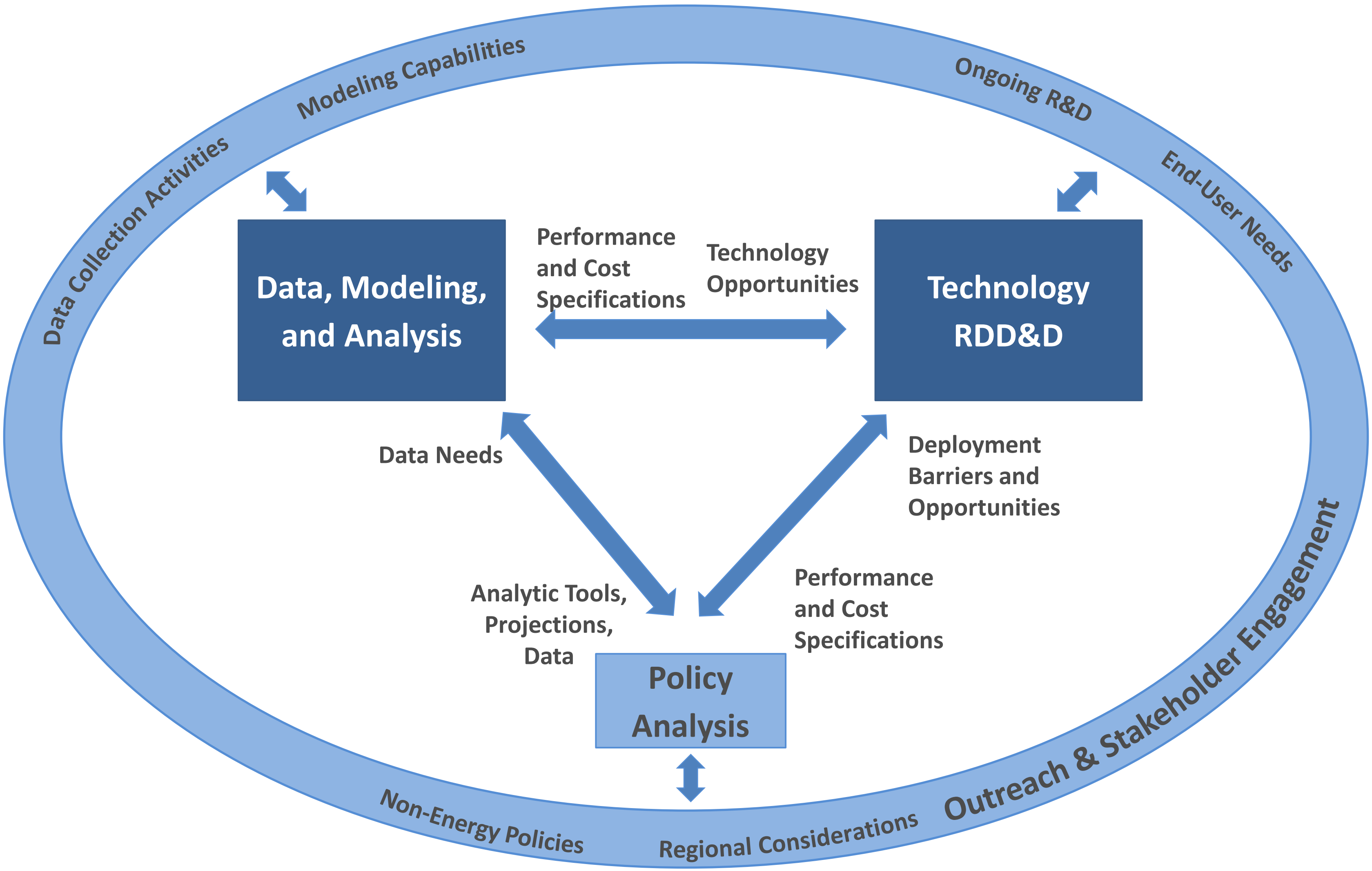
Source:
Skaggs et al. (2012)

Data, Modeling, and Analysis: An Integrated Model

A unifying framework can integrate and synthesize across model, data, and analytic components



An Integrated Approach to Energy-Water Systems of the Future



Challenges in the Energy-Water System

Energy Technology Pathways

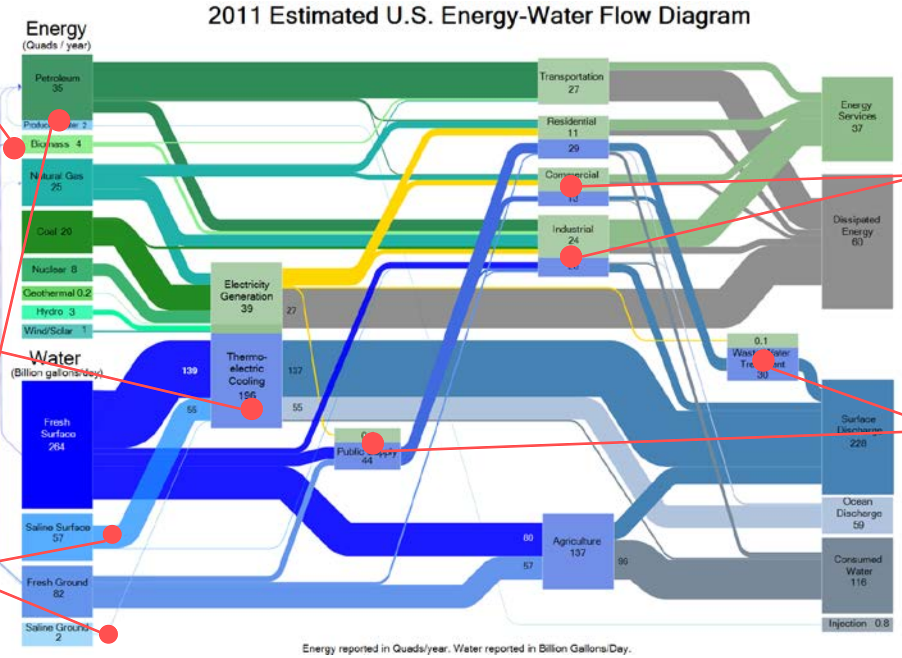
Climate Change
Mitigation
Adaptation

Regional Economic Development

Improved Water Efficiency in Bioenergy Systems

Water-Efficient Cooling

Treatment, Management, and Beneficial Use of Nontraditional Waters



Optimized Water and Energy in Commercial and Industrial Systems

Sustainable Utilities

Policy and institutional Changes

Land Use & Land Cover Change

Stakeholder and Consumer Preferences

Population/Migration

Urbanization & Infrastructure Dynamics

Next Steps

- Pursue R&D priorities in technology and modeling
- Develop in-depth roadmaps and/or technical specifications
  - Sustainable utilities,
  - Treatment, management, and beneficial use of nontraditional waters
  - Water-efficient cooling
  - Layered data and information
- Fill data gaps
- Develop systems analyses that bridge between policy and technology opportunity
- Incorporate regionality into identification of needs and delivery of tools and resources
- Pursue productive collaborative relationships across the federal government, states, local entities, tribes, the private sector, etc.
- Pursue international collaborations that promote shared learning and exchange