Water-Energy Nexus: Challenges and Opportunities

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SWRR Sustainable Water Resources Roundtable
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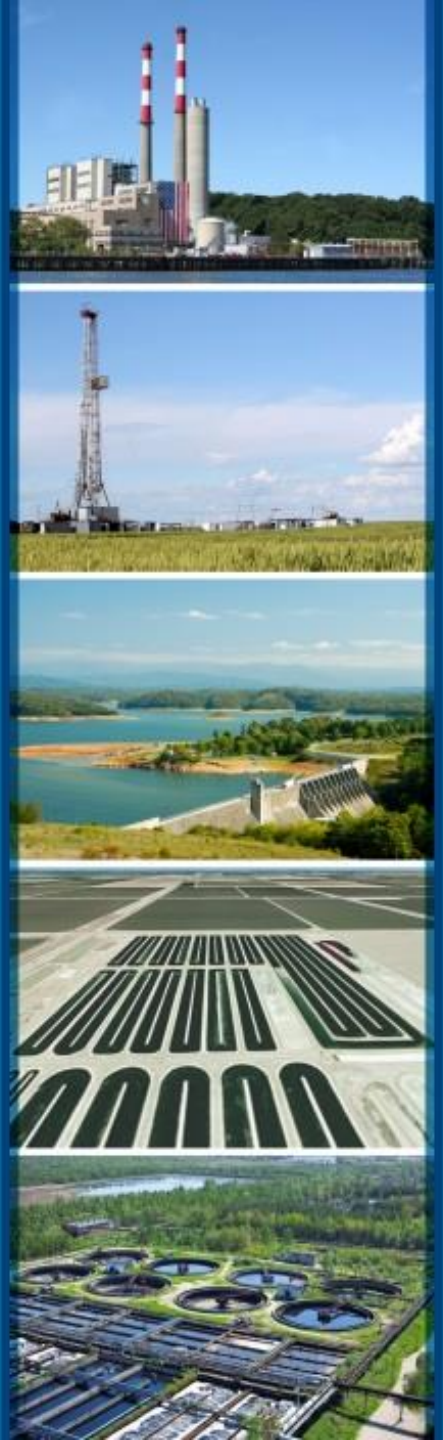


Energy-Water Nexus: Critical National Needs

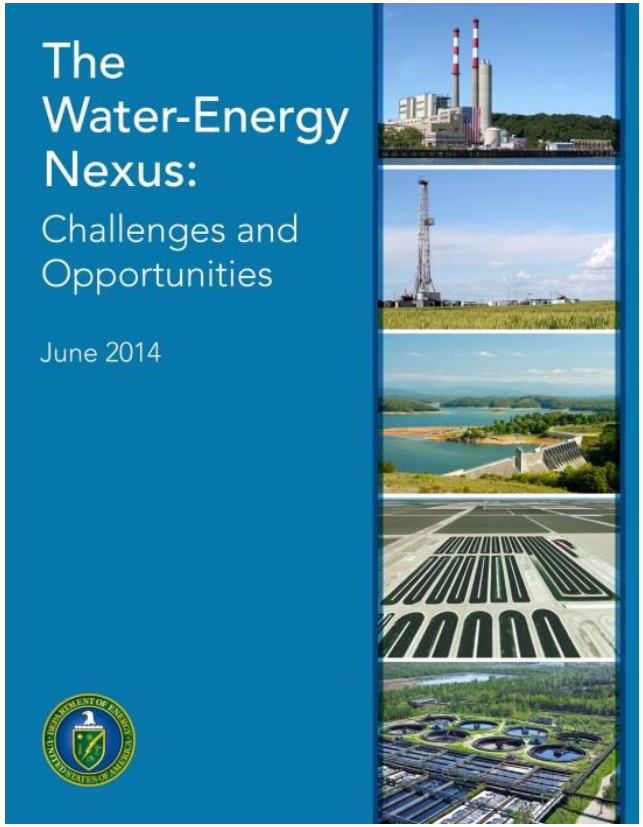
- Energy and water are interdependent.
- Water scarcity, variability, and uncertainty are becoming more prominent.
  - This is leading to vulnerabilities in the U.S. energy system.
- We cannot assume the future is like the past in terms of climate, technology, and the evolving decision landscape.
- Replacing aging infrastructure brings an opportunity to make some changes.
- Energy and water issues are gaining international prominence.

Energy-Water Nexus: DOE's Role

- DOE has strong expertise in technology, modeling, analysis, and data and can contribute to understanding the issues and pursuing solutions across the entire nexus.

- Our work has broad and deep implications
  - User-driven analytic tools for national decision-making supporting energy resilience with initial focus on the water-energy nexus
  - Solutions through technology RDD&D, policy analysis, and stakeholder engagement

- We can approach the diffuse water area strongly from the energy side
  - Focus on our technical strengths and mission
  - Leverage strategic interagency connections



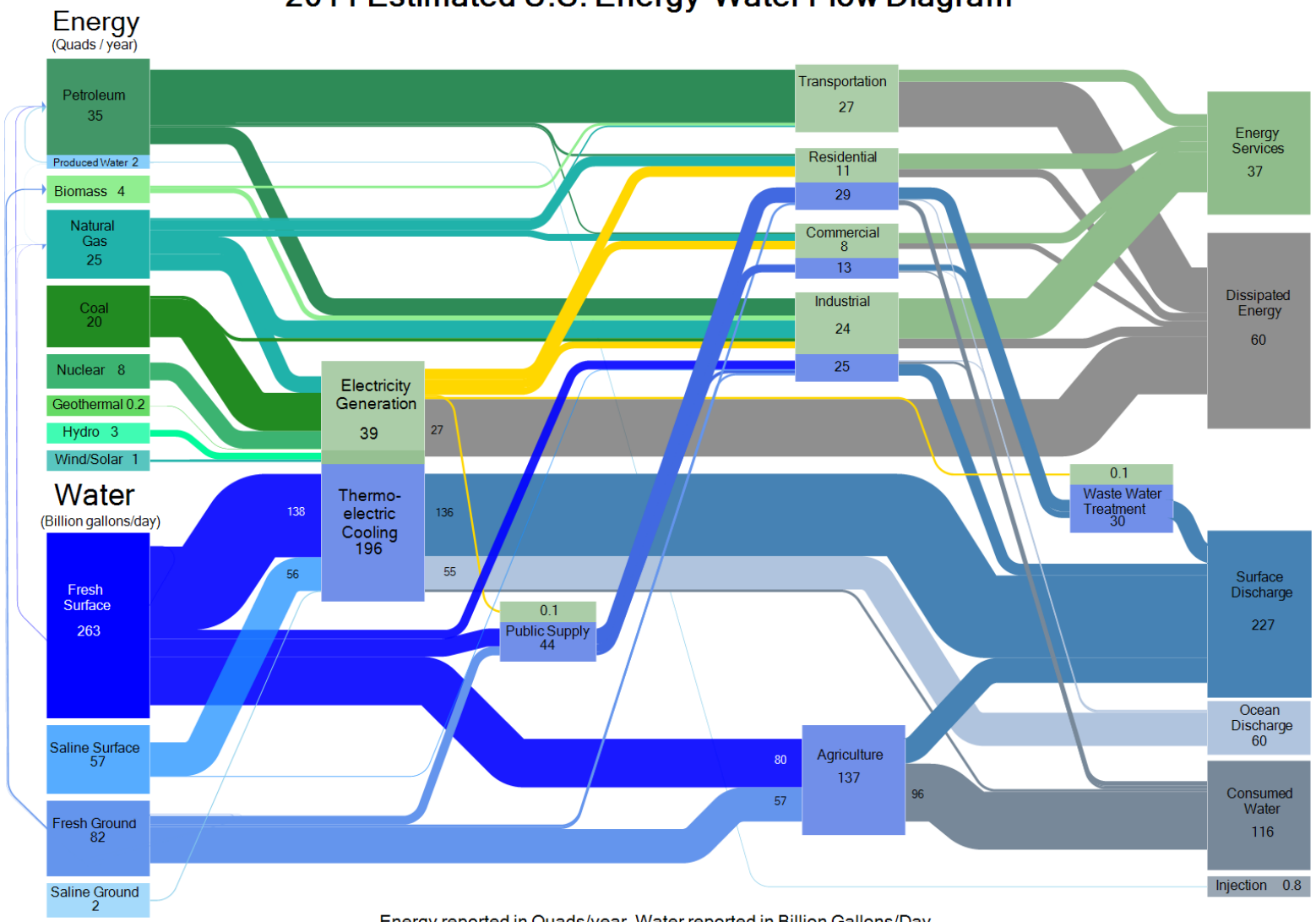
Download the full report at energy.gov

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

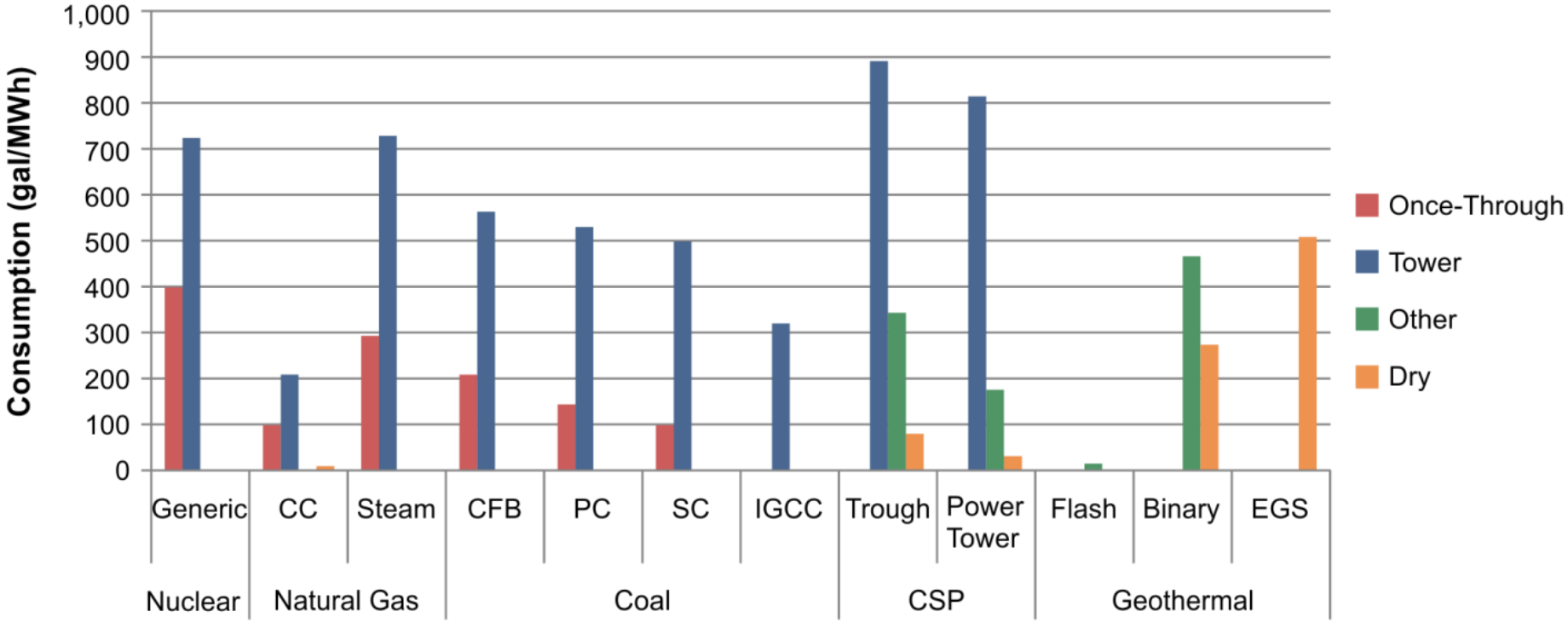
2011 Estimated U.S. Energy-Water Flow Diagram



Energy reported in Quads/year. Water reported in Billion Gallons/Day.

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.

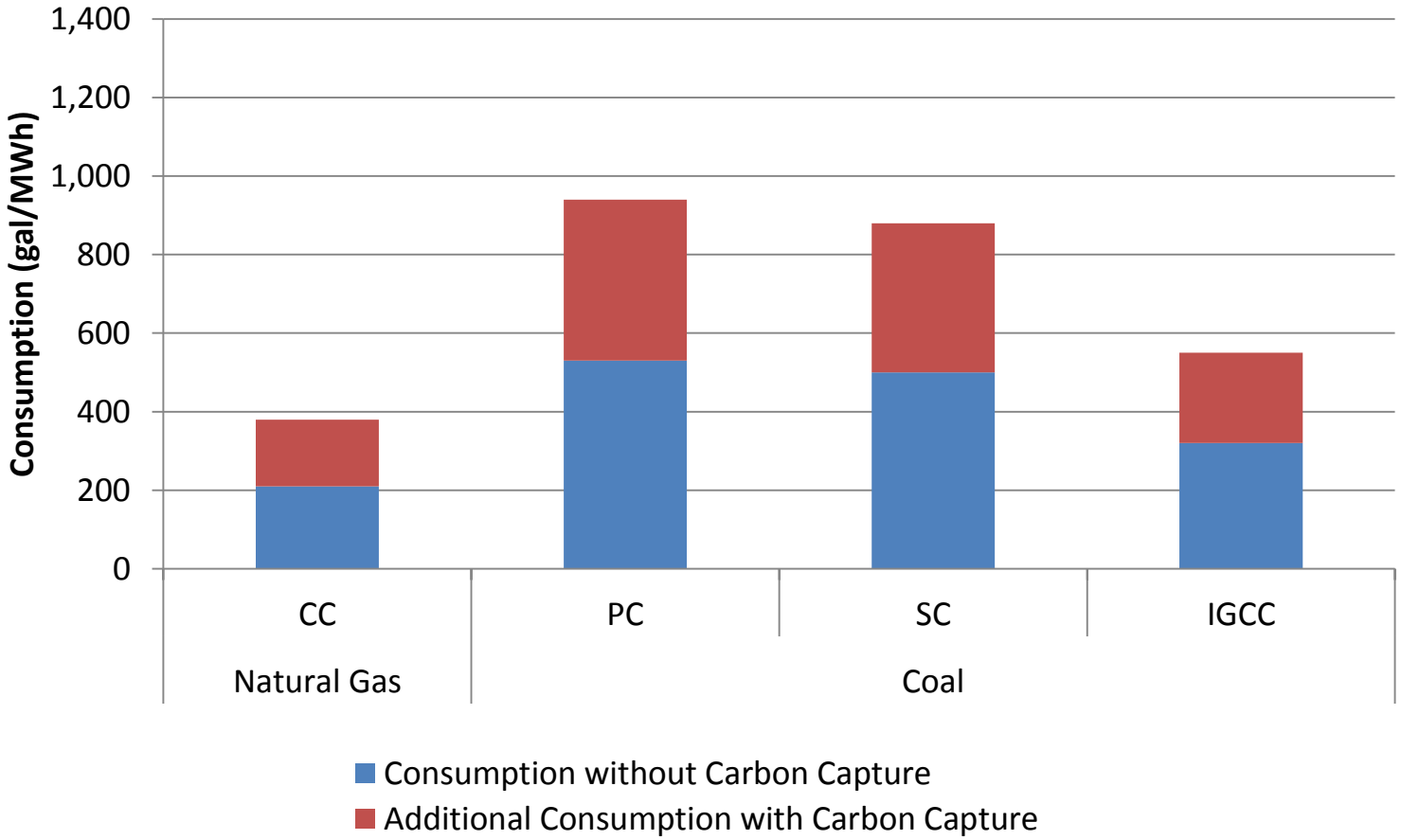


Abbreviations: Nuc: Nuclear; Nat Gas: Natural Gas; CC: Combined Cycle; CFB: Circulating Fluidized Bed; PC: Pulverized Coal; SC: Supercritical Pulverized Coal; IGCC: Integrated Gasification Combined Cycle; CSP: Concentrated Solar Power; EGS: Enhanced Geothermal System.

Data source: Meldrum et al. (2013)

Implications of Carbon Capture Technology

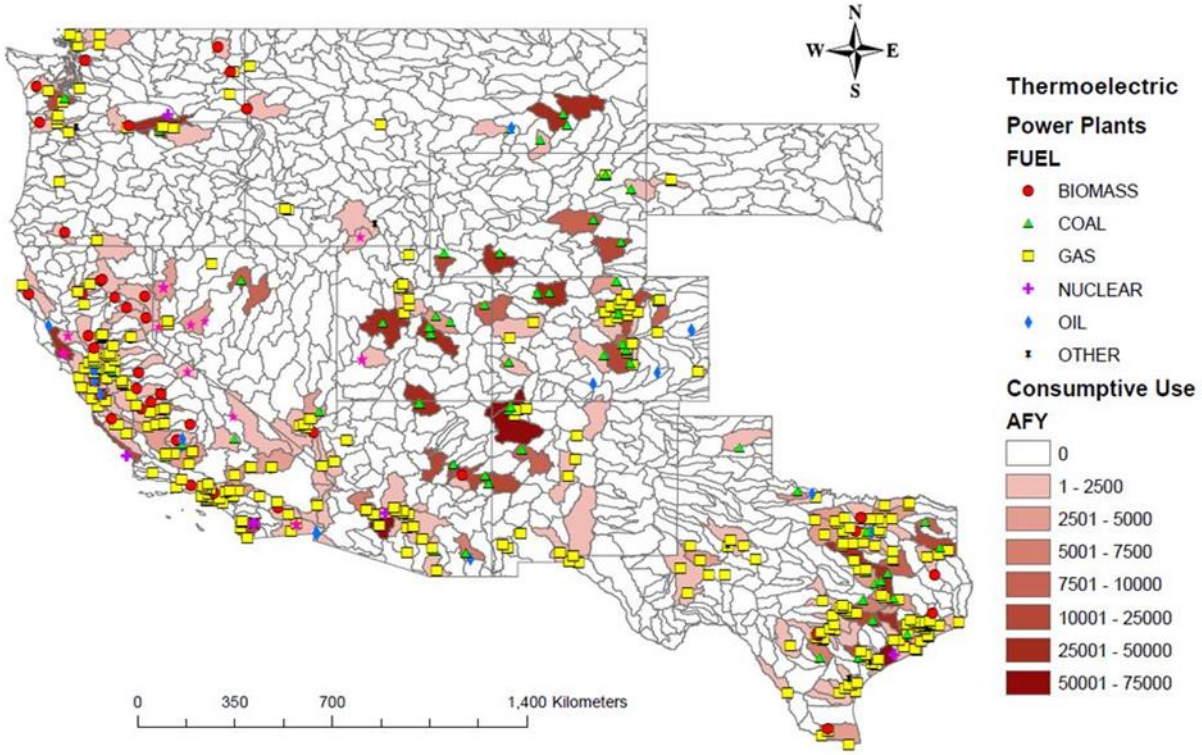
Depending on the technology, carbon capture can dramatically increase water requirements for thermoelectric cooling.



Data source: Meldrum et al. (2013)

Capture technology: monoethanolamine

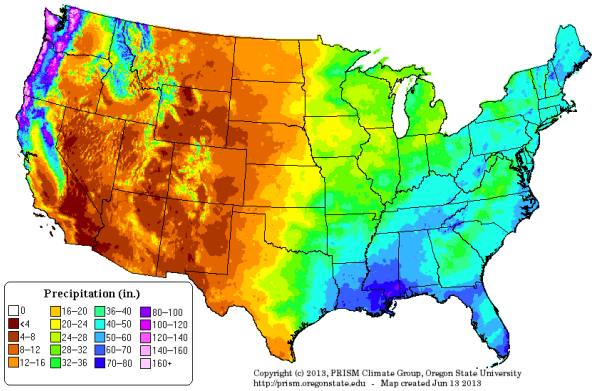
Local Variations in Water Requirements



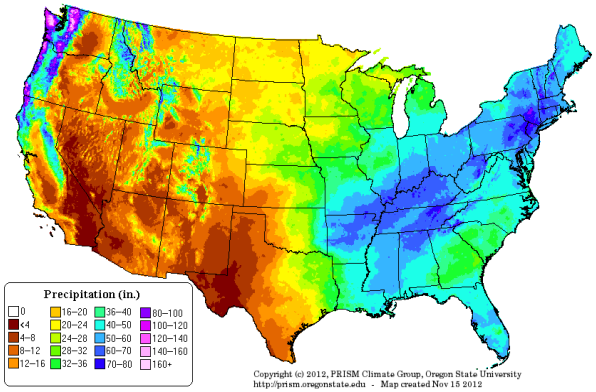
Source: Sandia National Laboratory

Variability in Water Resources

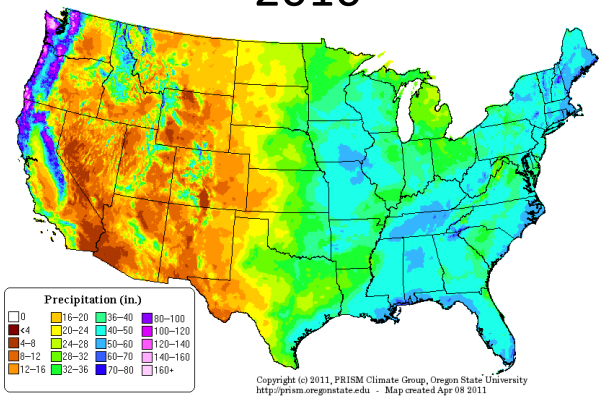
2012



2011



2010



Annual Average Precipitation (2010 -2012)

Variability in available water resources will pose challenges for:

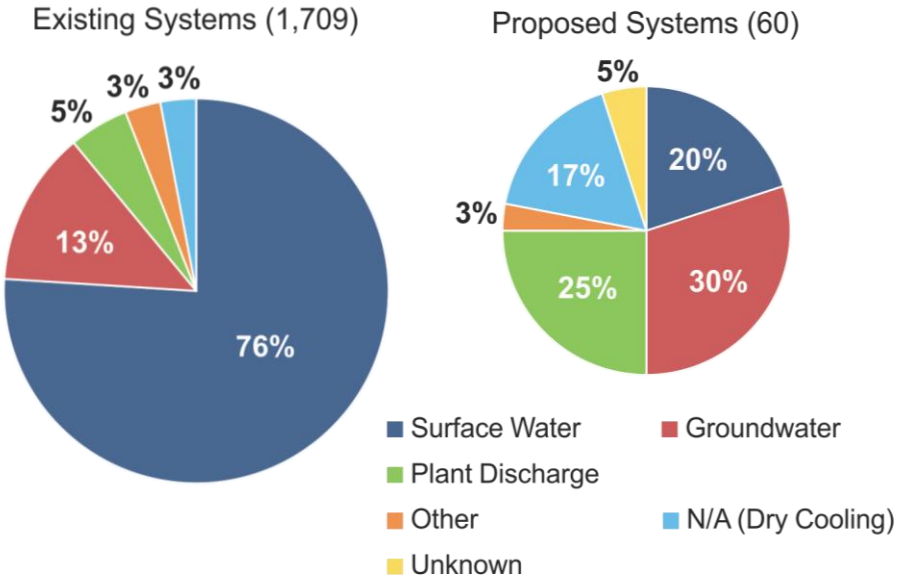
- Optimizing operations (especially for hydroelectric plants)
- Developing effective water management strategies
- Choosing sites for energy production activities

Source: PRISM Climate Group, OSU

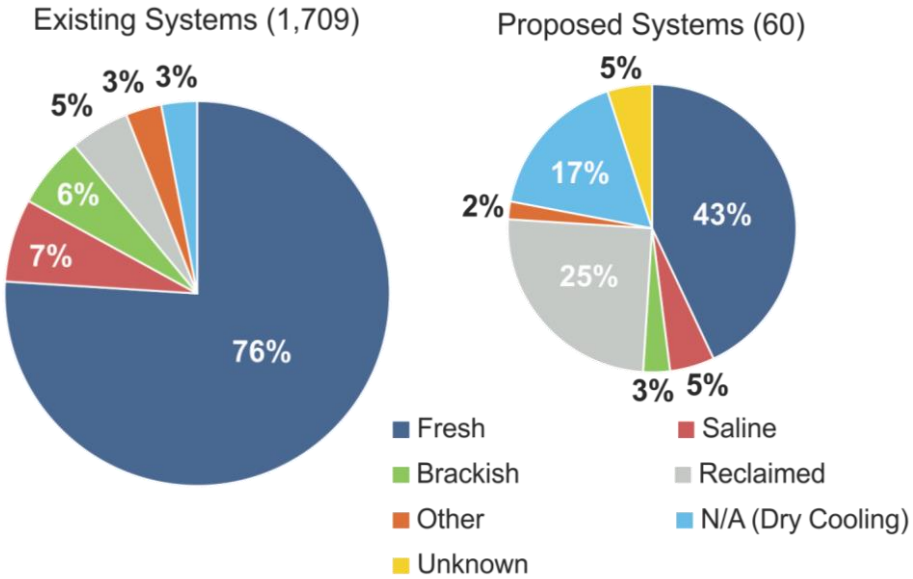
Diversification of Cooling Water Sources

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

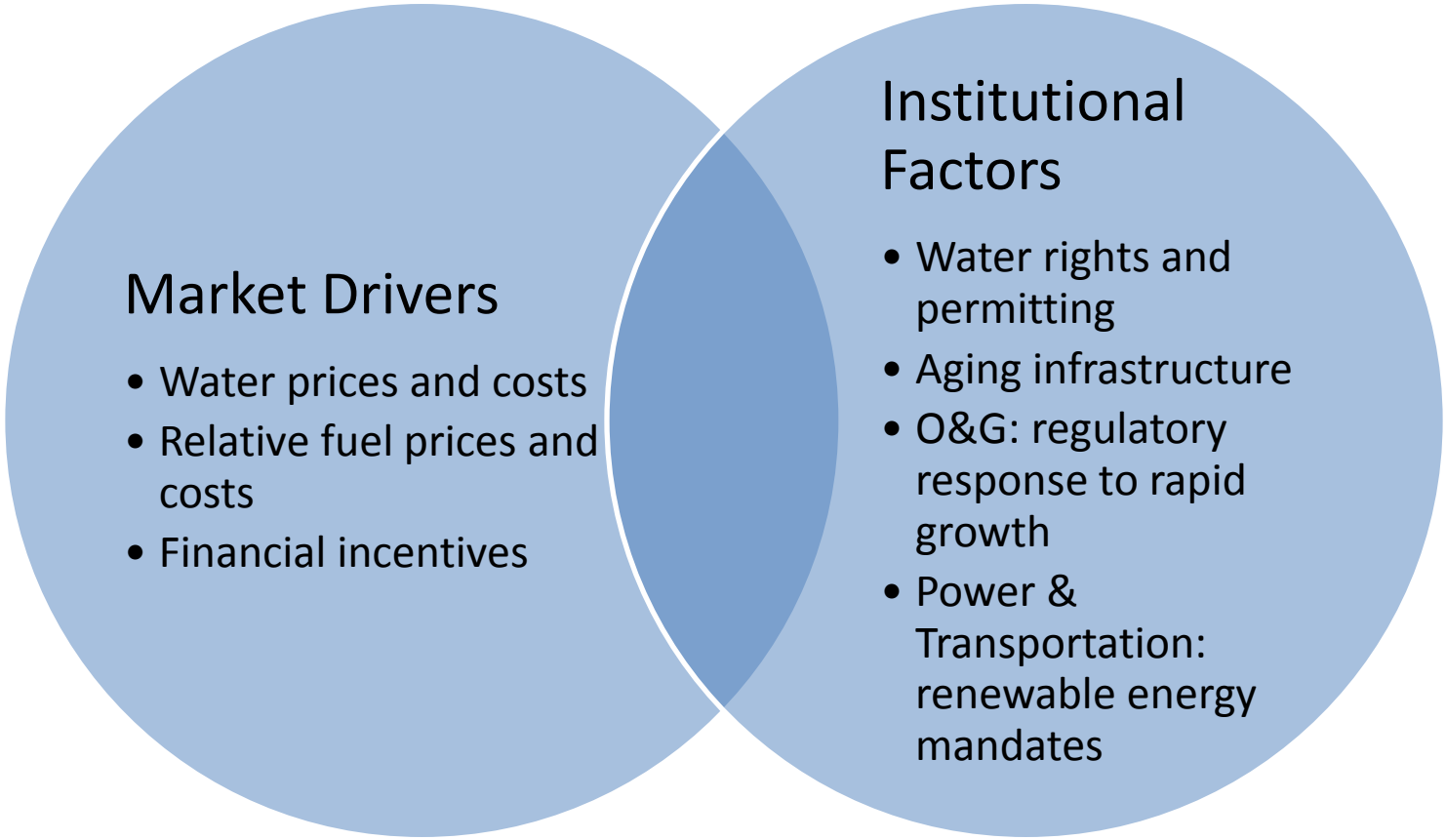


Proposed systems are scheduled to come online between 2013 and 2022

Data source: EIA Form 860 (2013)

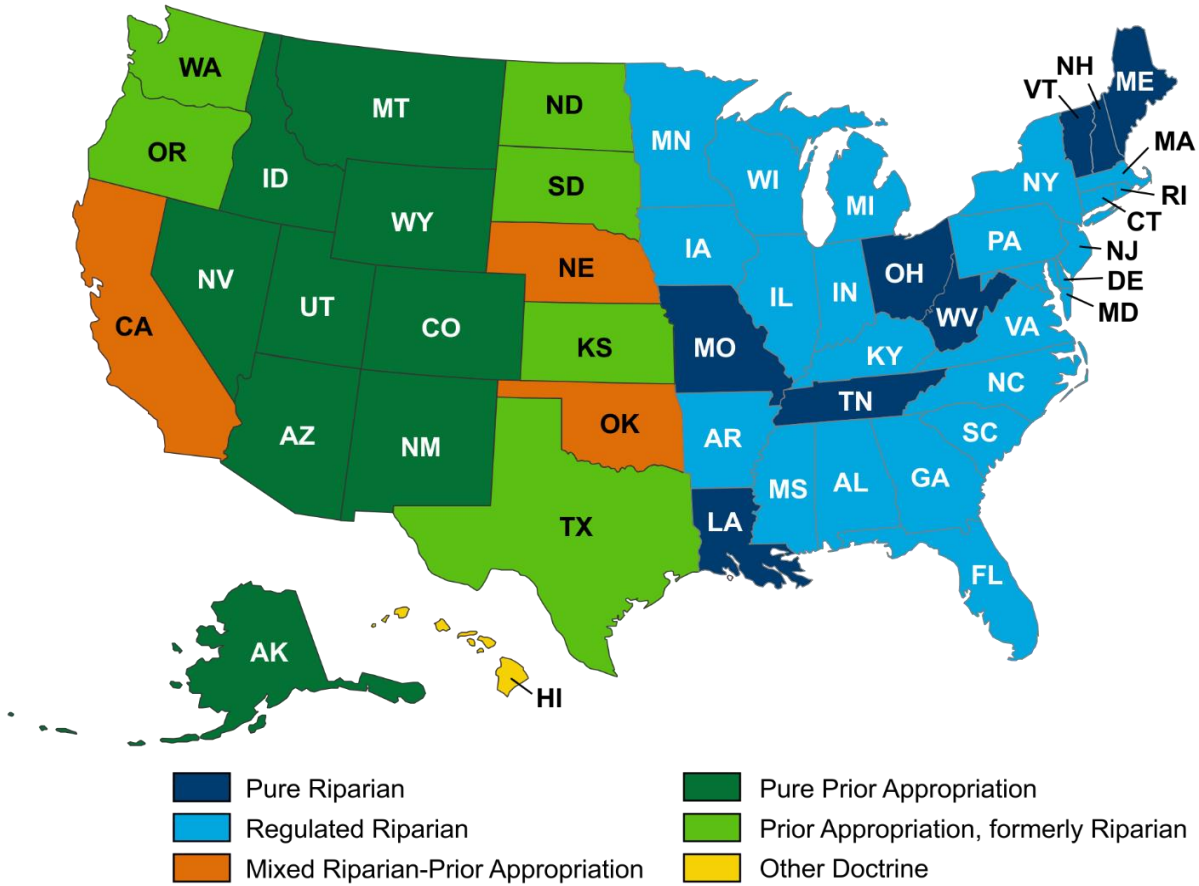
Complex Decision-Making Landscape

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



Regional Variation in Water Policy Regimes

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

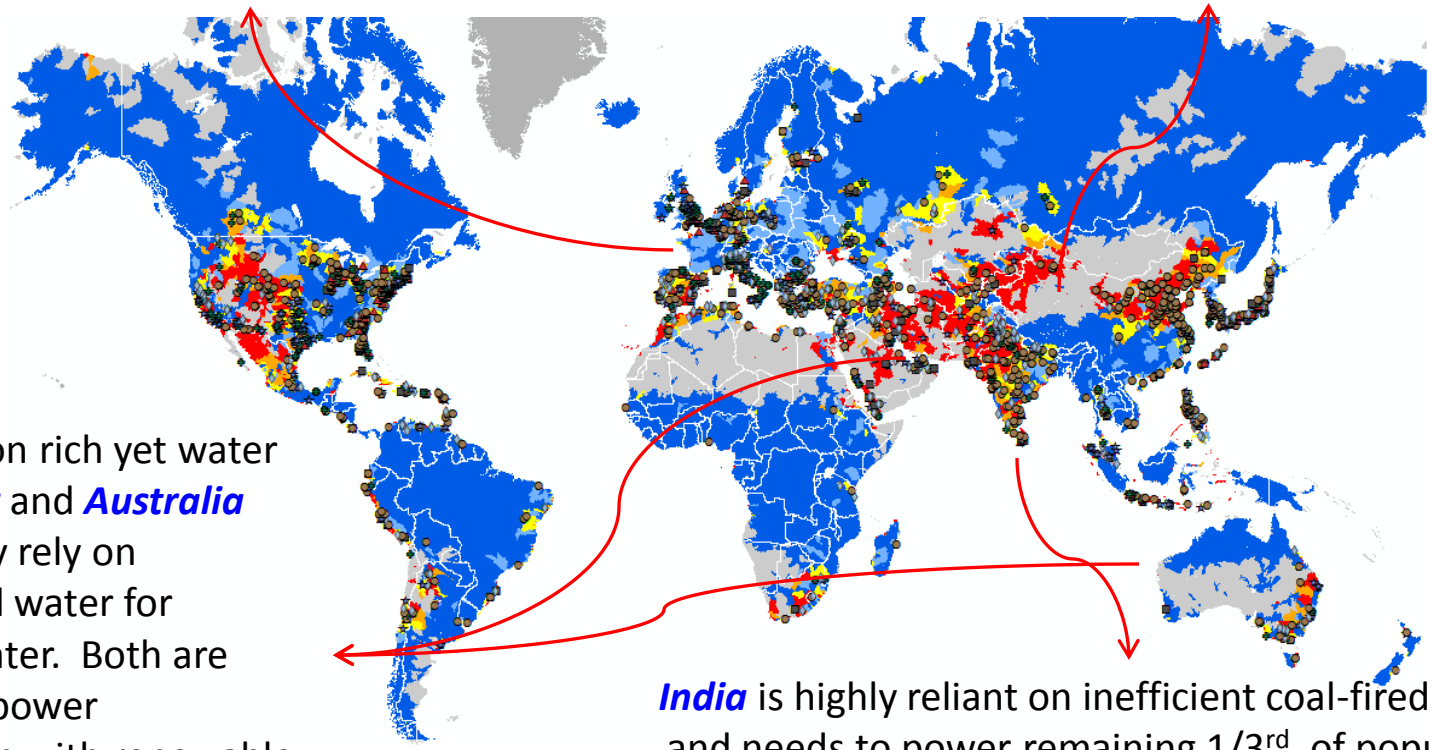


Data source: Gleick and Christian-Smith (2012)

Global Interest in the Energy-Water 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

Responding to Challenges in the Energy-Water System

Energy Technology Pathways

Forces on System

Climate Change (Mitigation and Adaptation)

Technology Solutions

Improved Water Efficiency in Bioenergy Systems

Water-Efficient Cooling for Electricity Generation

Treatment, Management, and Beneficial Use of Nontraditional Waters

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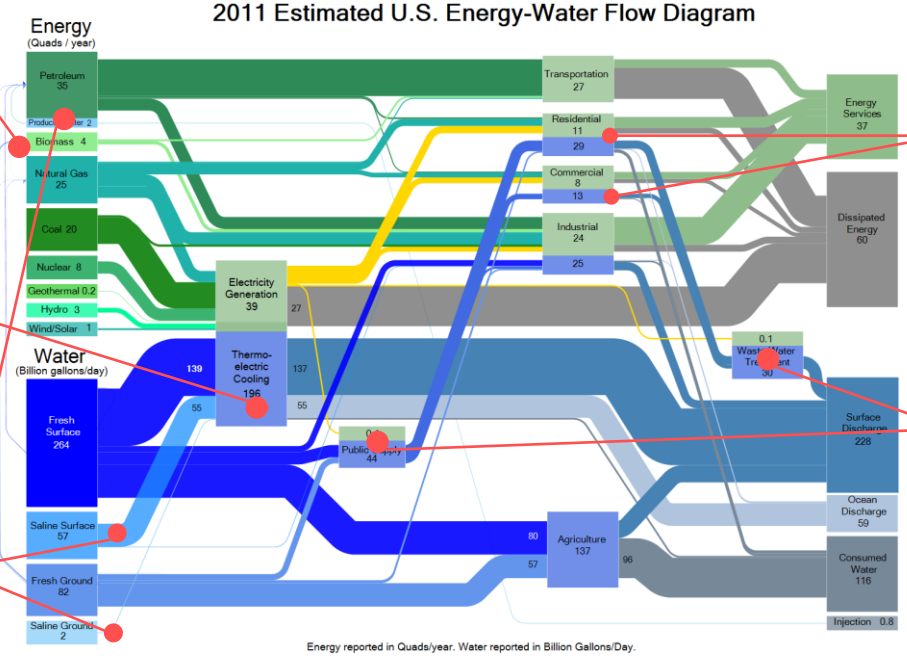


Coupled Water and Energy Efficiency

Sustainable Water Utilities

Policy and Institutional Changes

Land Use & Land Cover Change

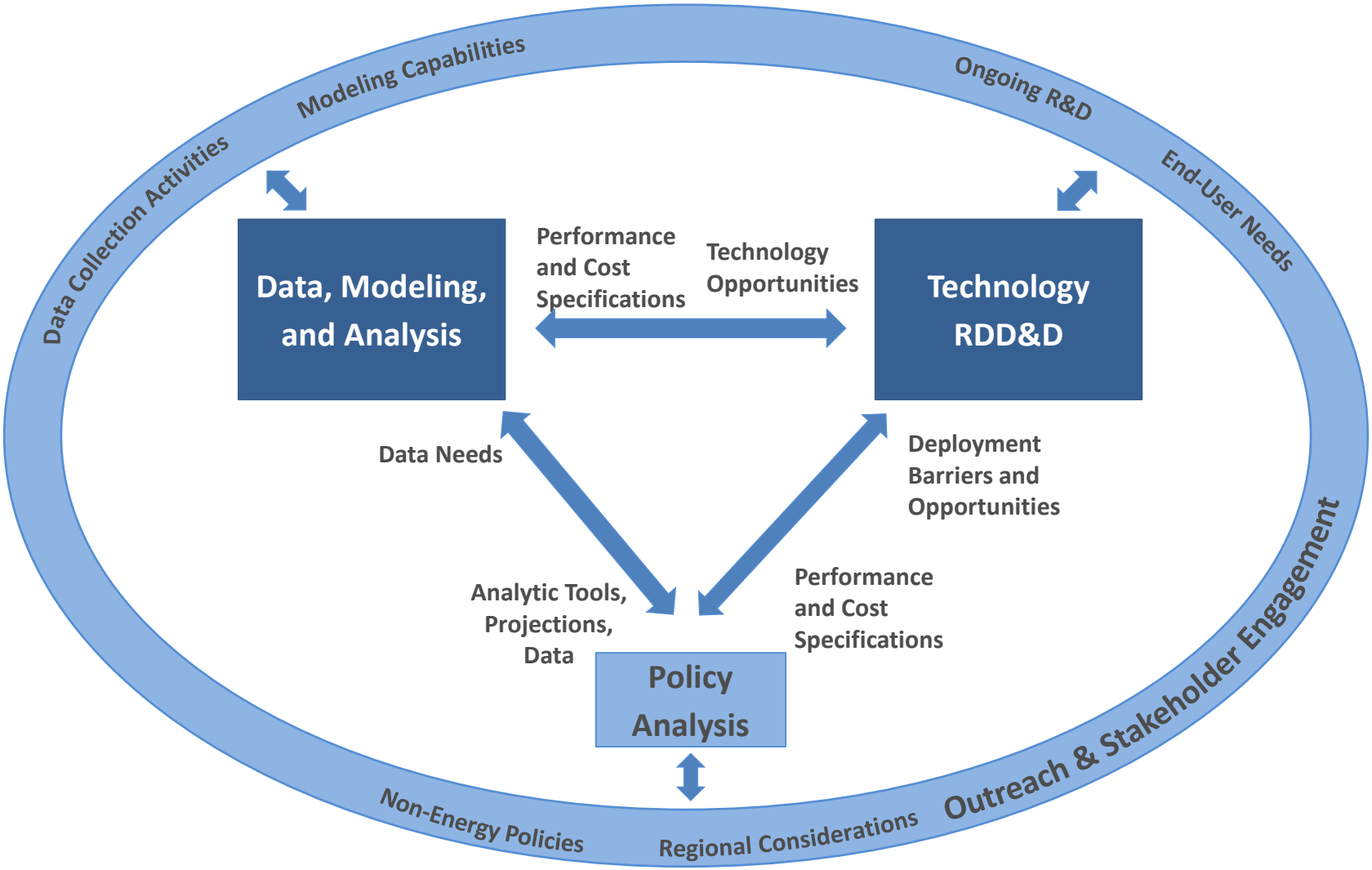
Stakeholder and Consumer Preferences

Population/ Migration

Urbanization & Infrastructure Dynamics

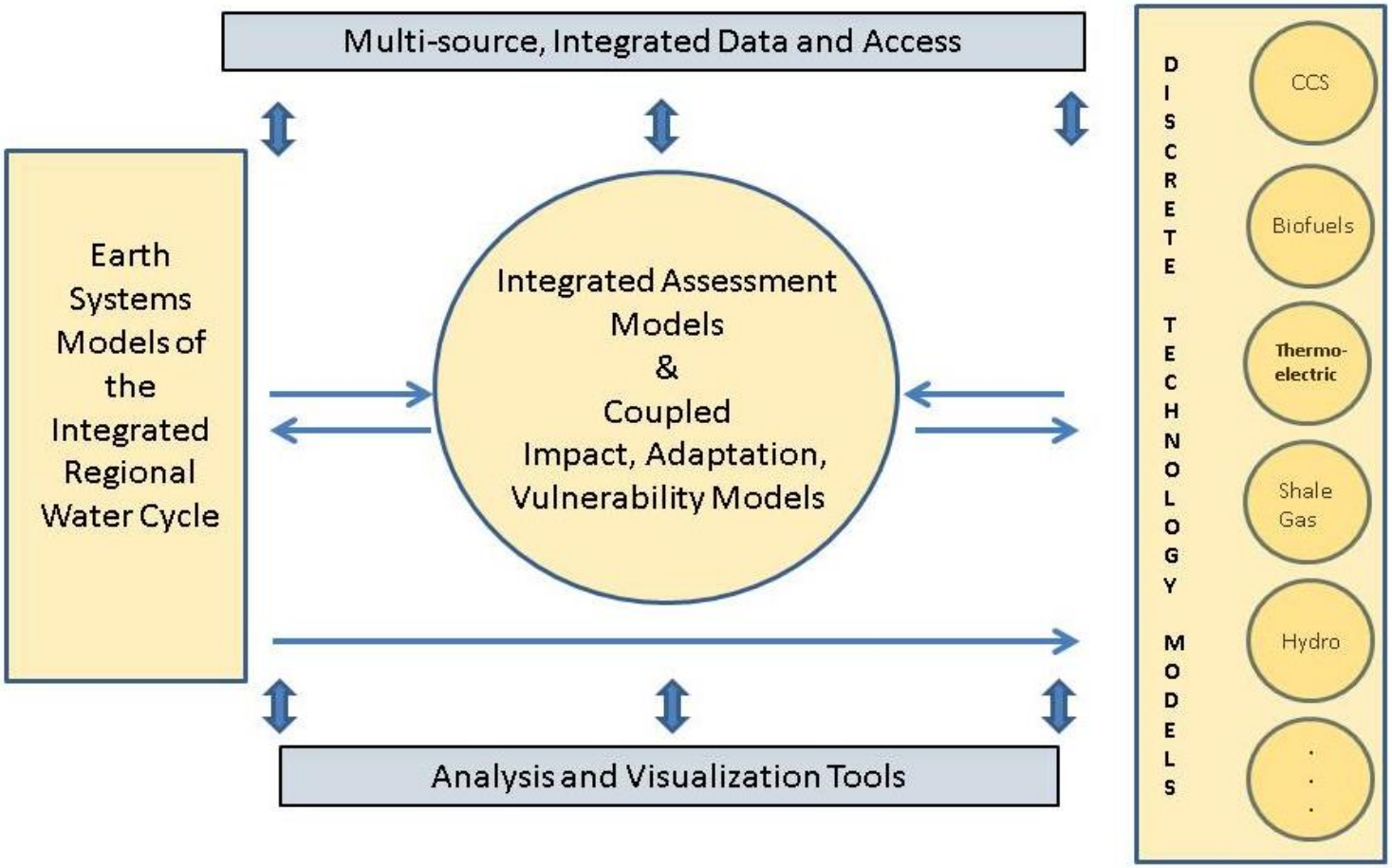
Regional Economic Development

An Integrated Approach to Energy-Water Systems of the Future



Data, Modeling, and Analysis: An Integrated Model

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



Next Steps for DOE

- Pursue technology R&D; provide technical assistance; develop in-depth technology roadmaps
  - Water-efficient cooling
  - Treatment, management, and beneficial use of nontraditional waters
  - Net positive energy water utilities
  - Improved water efficiency in bioenergy systems
  - Coupled water and energy efficiency in buildings
- Fill data gaps and improve data accessibility
- Analyze connections between policy developments and technology opportunity
- Pursue fundamental advances to enable models to inform regional decision-making
- Collaborate domestically and internationally