Water-Energy Nexus Dialogue Event
Energy & Climate Partnership for the America
Sankey Diagram and Data

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Overview

- DOE’s role in the Energy-Water Nexus
- The U.S. Energy-Water Sankey Diagram
- Data & calculations
- DOE’s next steps
- The Sankey Diagram’s value

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.

- DOE can:
  - Develop solutions through technology RDD&D, policy analysis, and stakeholder engagement
  - Provide user-driven analytic tools for national decision-making and supporting energy resiliency with an initial focus on the water-energy nexus

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

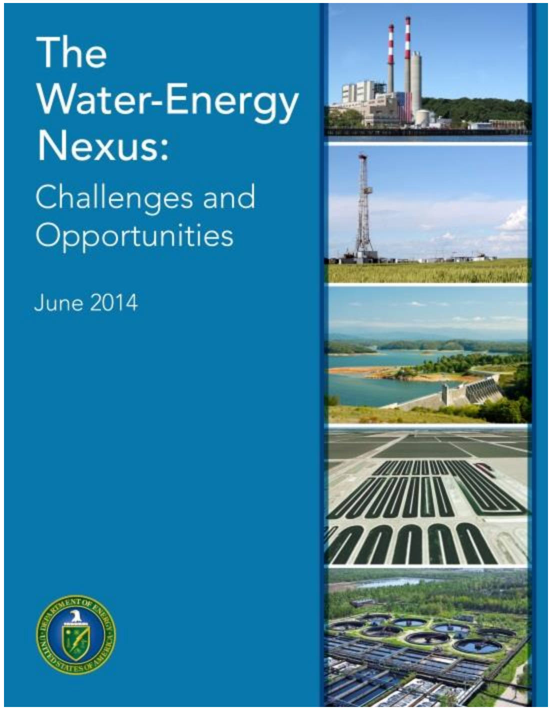
Water-Energy Nexus: Challenges and Opportunities

Strategic Pillars

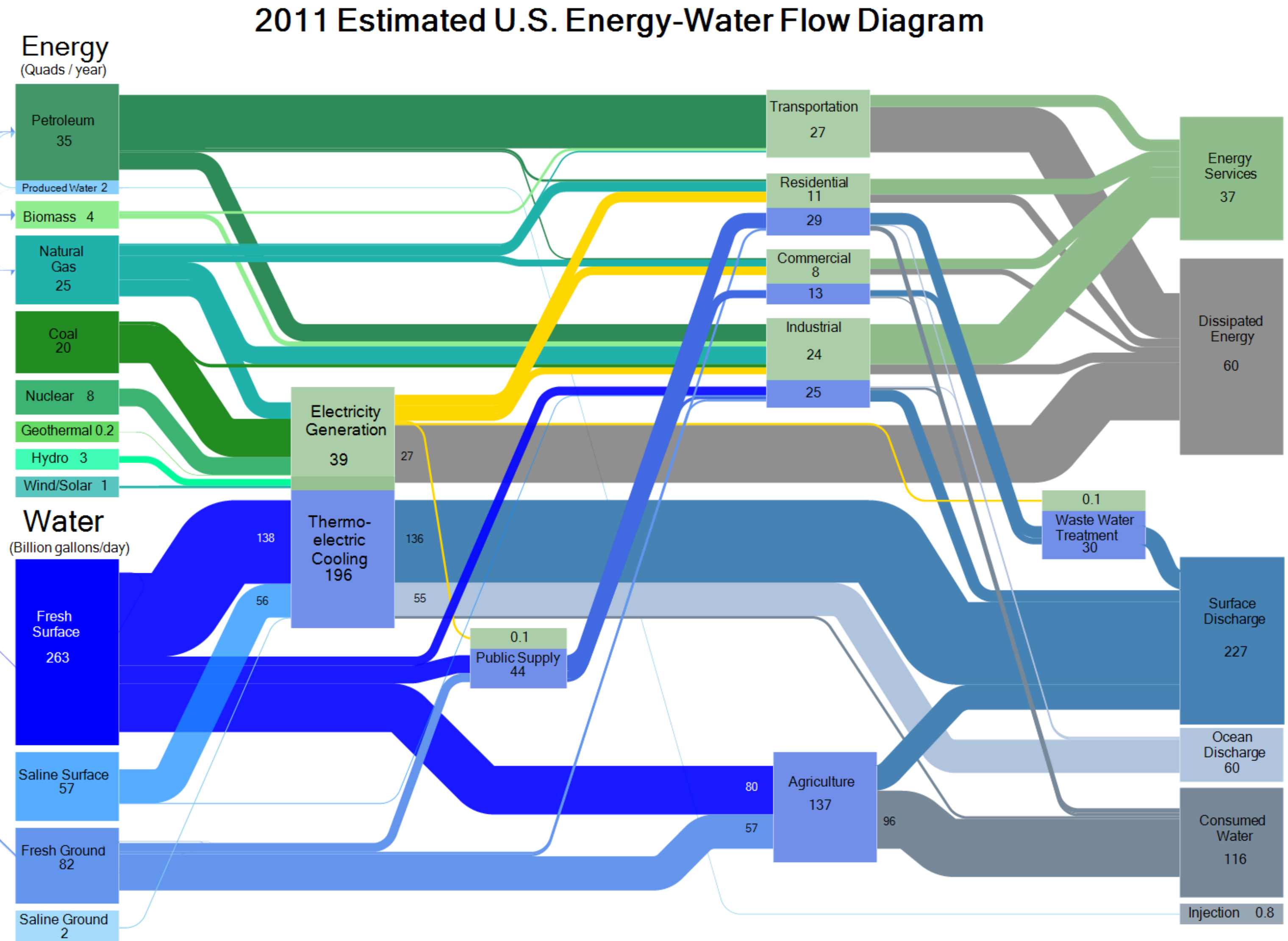
- Optimize the freshwater efficiency of energy production, electricity generation, and end use systems
- Optimize the energy efficiency of water management, treatment, distribution, and end use systems
- Enhance the reliability and resilience of energy and water systems
- Increase safe and productive 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

Water-Energy Nexus: Challenges and Opportunities

- DOE developed the Sankey Diagram to:
  - Form the basis for DOE analysis in the report
  - Conceptualize and communicate the energy-water problem space
  - Inform DOE technology and policy decisions
  - Identify available data/data gaps and start a conversation about how to improve data quality/data availability



U.S. Energy-Water Sankey Diagram



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

Responding to Challenges in the Energy-Water System

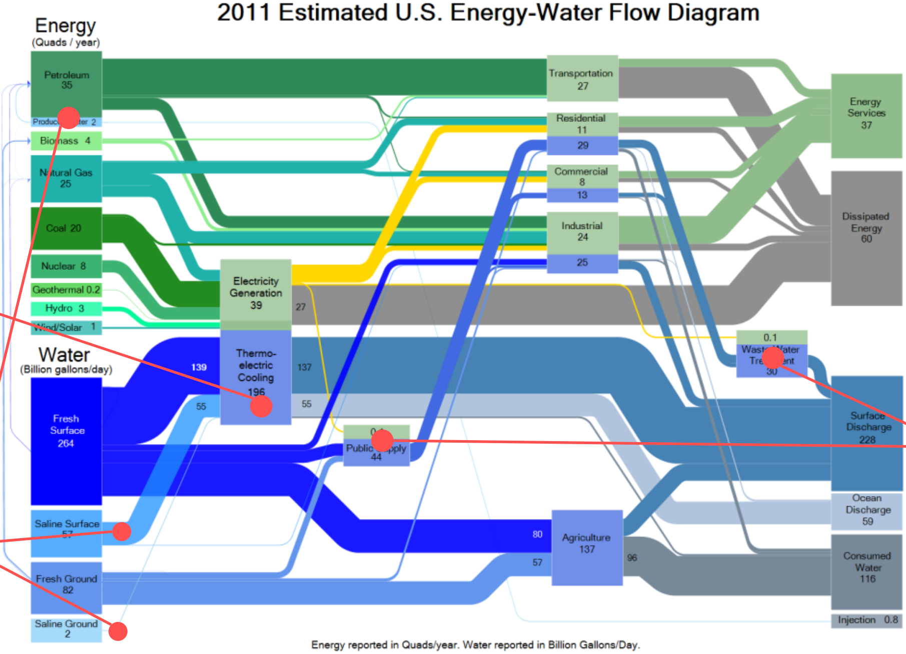
Energy Technology Pathways

Forces on System

Climate Change (Mitigation and Adaptation)

Technology Solutions

2011 Estimated U.S. Energy-Water Flow Diagram



Water-Efficient Cooling

Energy-Optimized Treatment, Management, and Beneficial Use of Nontraditional Waters

Sustainable Low-Energy Water Utilities

Policy and Institutional Changes

Land Use & Land Cover Change

Stakeholder and Consumer Preferences

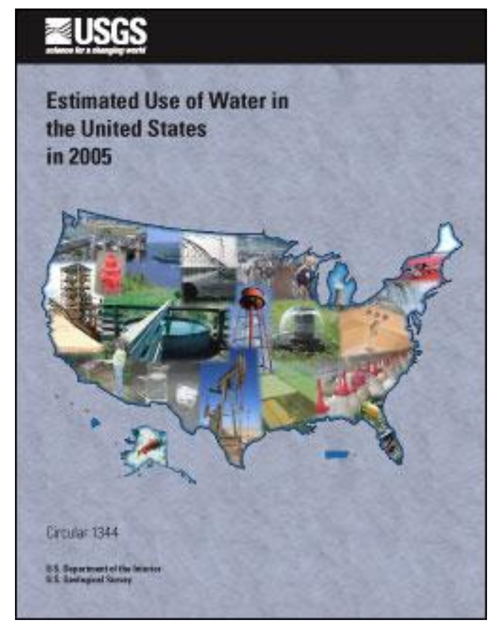
Population/ Migration

Urbanization & Infrastructure Dynamics

Regional Economic Development

Main Data Sources

- Energy
  - Energy Information Administration(EIA) 2011 Annual Energy Review (AER)
    - Describes energy consumption by fuel type and across all sectors
    - Aggregated at state level
    - Published annually
- Water
  - U.S. Geologic Survey's (USGS) 2005 Water Use Circular
    - Describes water use by water source type and across all sectors
    - Aggregated at county level
    - Published on a 5 year cycle



Additional Data Sources and Calculations

- Water for energy illustrative examples
  - Water for and water from Petroleum and Natural Gas production
    - EOR, hydraulic fracturing, produced water

Data Source	Year of Est.	From:	To:
Ceres: *Hydraulic Fracturing & Water Stress: Growing Competitive Pressures for Water*. 2013	2011-12	Fresh surface and Fresh ground water	Natural gas and Petroleum (Hydraulic Fracturing)
Argonne National Laboratory: *Consumptive Water Use in Production of Ethanol and Petroleum.* 2011	2007	Fresh surface and fresh ground water	Petroleum (primary, secondary, EOR)
Argonne National Laboratory: *Produced Water Volumes and Management Practices in the U.S.* 2009	2007	Produced Water	- Injection for disposal - Petroleum and Natural Gas (enhanced recovery) - Surface discharge - Unreported

Enhanced Oil Recovery (EOR) Calculations

- Water for Enhanced Oil Recovery (EOR)
  - Table 9 from 2011 ANL report: Water Injection in Oil Production by Recovery Tech.

	Oil Production (2005)	*Water Injection*	
Recovery Technology	mln gal oil/d	gal water/gal crude	Mln gal water/d
EOR CO2 Miscible	9.8	13	127.4
EOR CO2 Immiscible	0.1	13	1.3
EOR Steam	12	5.4	64.8
EOR Combustion	0.6	1.9	1.1
Other EOR	4.7	8.7	40.9
Secondary Water Flooding	108.7	8.6	935
Primary Recovery	9.6	0.2	1.9
total	145.5		1172
Weighted Average water injections		**8.0**	

  - In 2007, 3.47 million bbl/d of oil was produced in the U.S (ANL, 2011)
  - (3.47 million bbl/d) * (42 gals/bbl) * (8 gals water/gal crude) = **1.2 BGD**
  - The ratio of fresh surface to ground water used for petroleum and natural gas production is unknown.

Hydraulic Fracturing Calculations

- Water for Hydraulic Fracturing
  - Ceres, using *FracFocus* data, calculated that 65.8 BG of water was used over a 21 month time frame between September 2011 and August 2012
    - 65.8 Billion Gal / 603 days = 0.1 BGD
    - *FracFocus*
  - Ceres estimated that *FracFocus* well numbers were 60% under reported
    - 0.1 BGD / 0.4 = **0.25 BGD**
  - The ratio of fresh surface to fresh groundwater used for hydraulic fracturing is unknown. The ratio of water used for hydraulic fracturing in Petroleum production to Natural Gas production is unknown.

Produced Water Calculations

- Produced water and management pathways
  - From Table 5. U.S Produced Water by Management Practice for 2007 (ANL, 2009)

Volumes Generated

Total Generated	Total managed	Unreported
2.4 BGD	2.1 BGD	0.3 BGD

Management Pathways

Injection for Enhanced Recovery	Injection for Disposal	Surface Discharge
1.2 BGD	0.8 BGD	0.1 BGD

  - The ratio of produced water used for Petroleum production to Natural Gas production unknown
  - The produced water landscape has likely changed dramatically with the increase in shale oil and shale gas production

Additional Data Sources and Calculations (Cont.)

- Energy for water illustrative examples
  - Public supply

Data Source	Year of Est.	From:	To:
Electric Power Research Institute (EPRI): *Electricity Use and Management in the Municipal Water Supply and Wastewater Industry*. 2013	2011	Electricity Generation	Public Supply

- EPRI applied methodology to data from the Environmental Protection Agency's (EPA) Drinking Water and Ground Water Statistics Report

  - Wastewater treatment

Data Source	Year of Est.	From:	To:
Electric Power Research Institute (EPRI): *Electricity Use and Management in the Municipal Water Supply and Wastewater Industry*. 2013	2008	Electricity Generation	Wastewater treatment

- EPRI applied methodology to data from EPA's Clean Watershed Needs Survey report

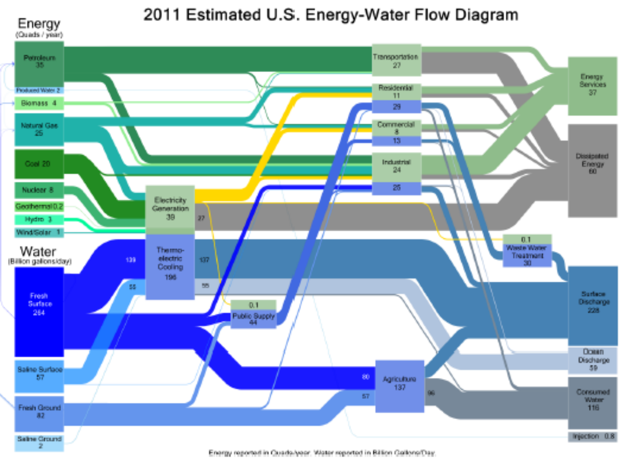
Generalizing Data Issues

- Data issues
  - Lack consistency from year to year
  - Only collected for a limited time frame
  - Only collected for a specific location or facility types
  - No available data
- Data issues make it difficult to:
  - Describe a system for a specific year
  - Perform time series analysis and examine trends
  - Generalize across various facilities (e.g. wastewater treatment plants, thermoelectric cooling plants)
  - Attribute energy and water use to a specific user
- Possible reasons for data issues
  - Collection and methodology changes over time
  - Lack of funding
  - Difficulty in attribution (e.g. water for irrigating biofuels)

Appendix A from *The Energy-Water Nexus: Challenges and Opportunities*

Appendix A. Sankey Diagram Details and Assumptions

The Water/Energy Sankey diagram is comprised of both energy and water sources, sinks, and flows. Energy is measured in quadrillion Btus (Quads) per year. The diagram shows energy consumption by end use sectors as well as a respective sectors wasted energy. The majority of energy data is from EIA's 2011 Annual Energy Review (AER). Along with energy, the diagram shows end use sectors water withdrawals from various sources and whether the water is discharged after use or consumed. Water is measured in billions of gallons per day (BGD). The methodologies and sources of information are detailed in the sections below. The appendix covers the diagram from left to right.



EIA reports energy consumption for five sectors: transportation, residential, commercial, industrial, and electric power. USGS reports water use differently, reporting sector withdrawals by: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power. Our analysis combines irrigation, aquaculture, and livestock water withdrawals as agriculture withdrawals. Mining withdrawals not associated with oil and gas extraction are combined with the industrial sectors. The residential sector on the diagram corresponds to the residential energy category from EIA and the domestic water category from USGS. The agriculture sector in the diagram represents the irrigation water category from USGS minus the volume of water estimated for biofeedstock production. The water used for hydraulic fracturing, enhanced oil recovery, and biomass feedstock production is represented as direct withdrawals on the far left of the diagram.

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Fresh Ground	Thermoelectric cooling	0.5*

A.3.2 Public Supply

Energy (0.1 Quad/year, 2011)

Definition: The amount of energy needed for pumping and aeration of publically available water.

Calculation: The electricity needed for public supply is estimated using a methodology applied to data from the U.S. Environmental Protection Agency's Fiscal Year 2011 Drinking Water and Ground Water Statistics report (EPRI 2013).

In 2011, 39.2 billion kWh was used for public water supply and treatment (EPRI 2013), which converts to 0.13 Quads/year.

Energy Flows to End Use Sectors		
From:	To:	Quads/year
Electricity Generation	Public Supply	0.1

Water (44 BGD, 2005)

Definition: Public supply refers to "water withdrawn by public and private water suppliers that provide water to at least 25 people or have a minimum of 15 connections. Public-supply water is delivered to users for domestic, commercial, and industrial purposes. It is also used for public services" (USGS 2009).

Calculation: The amount public supply is calculated by adding fresh surface and ground water withdrawals. No saline withdrawals are included.

Public supply deliveries are equal to end use sector withdrawals from the public supply. Commercial and industrial sector deliveries from the public supply are estimated using the percentages below. End use sector withdrawals are estimated using:

- Residential sector delivery = 58% (USGS 2009) x total public supply (USGS 2009)
- Commercial sector delivery = 30% (USGS 1998) x total public supply (USGS 2009)
- Industrial sector delivery = 12% (USGS 1998) x total public supply (USGS 2009)
- Residential deliveries in 2005 / total public supply in 2005 = 58%
- 12% Industrial sector deliveries are assumed to have remained constant since 1995.
- Commercial sector deliveries = 100% - 58% - 12%

Water Flows to End Use Sectors		
From:	To:	BGD
Public supply	Residential	25.6
Public supply	Commercial	13.3
Public supply	Industrial	5.3

A.2.4 Transportation

Energy (27 Quads/year, 2011)

Definition: "An energy-consuming sector that consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. Included are automobiles; trucks; buses; motorcycles; trains, subways, and other rail vehicles; aircraft; and ships, barges, and other waterborne vehicles. Vehicles whose primary purpose is not transportation (e.g., construction cranes and

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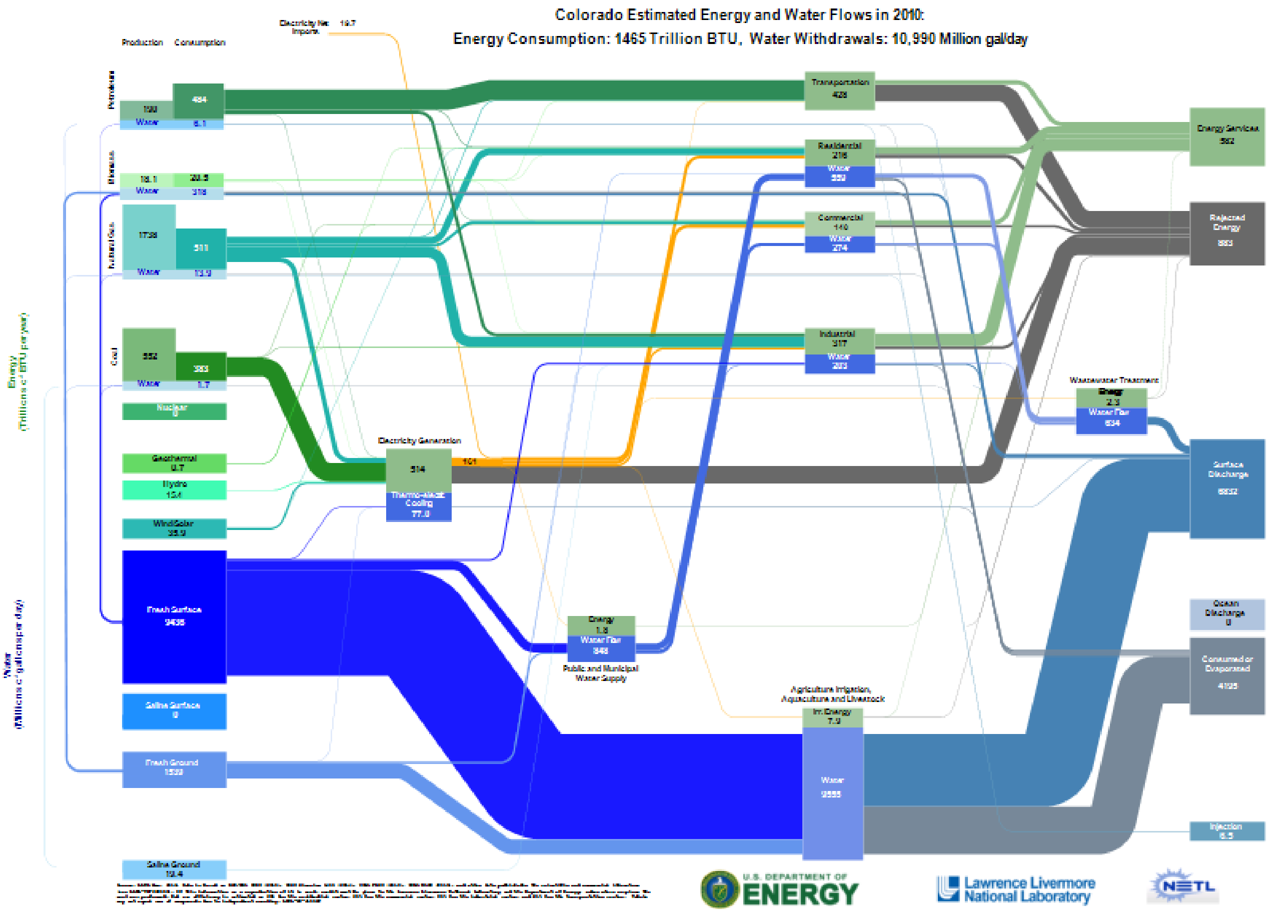
The Value of the Sankey Diagram

- Enables understanding of the system
- Helps identify:
  - Potential vulnerabilities in the system
  - Opportunities to address system vulnerabilities
- Helps prioritize:
  - Additional data collection
  - Technology R&D investment

State Level Diagrams

- DOE is currently developing state level Sankey diagrams for all 50 stats (Draft)

Figure 3-6 - Hybrid Energy-Water Sankey Diagram for Colorado



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Questions?