United States Energy Association

CONSENSUS Program Webinar

Sustainable Water Management for Decarbonizing Fossil Power Generation

USEA

United States Energy Association

CONSENSUS PROGRAM

IN COOPERATION WITH

U.S. DEPARTMENT OF ENERGY | Fossil Energy

The CONSENSUS Program, founded in 2008, seeks to educate the public, policy makers, industry, and other stakeholders and build a consensus on the wide array of benefits of **C**arbon **C**apture **U**tilization & **S**equestration and Clean Coal technologies.

- **Briefings**
- **Workshops**
- **Reports**
- **Monthly News Clips**

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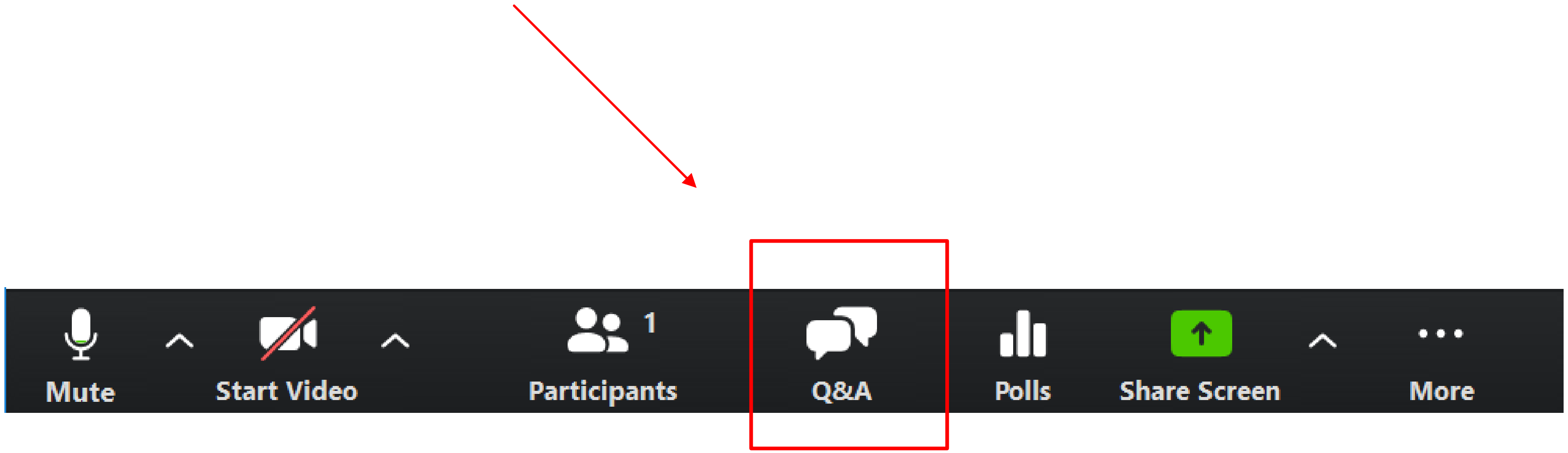
Q&A



Sustainable Water Management for Decarbonizing Fossil Power Generation

Today's Objectives

NATIONAL ENERGY TECHNOLOGY LABORATORY

1. **Introduce** DOE Water activities for fossil power generation
2. **Share** useful information related to the future and decarbonization
3. **Highlight** current Funding Opportunities
4. **Hear** and **learn** from you

Webinar Presenters

NATIONAL ENERGY TECHNOLOGY LABORATORY

Briggs White

Technology Manager, Water, Materials, Energy Storage

National Energy Technology Laboratory

Meagan Mauter

Associate Professor of Civil & Environmental Engineering

Stanford University

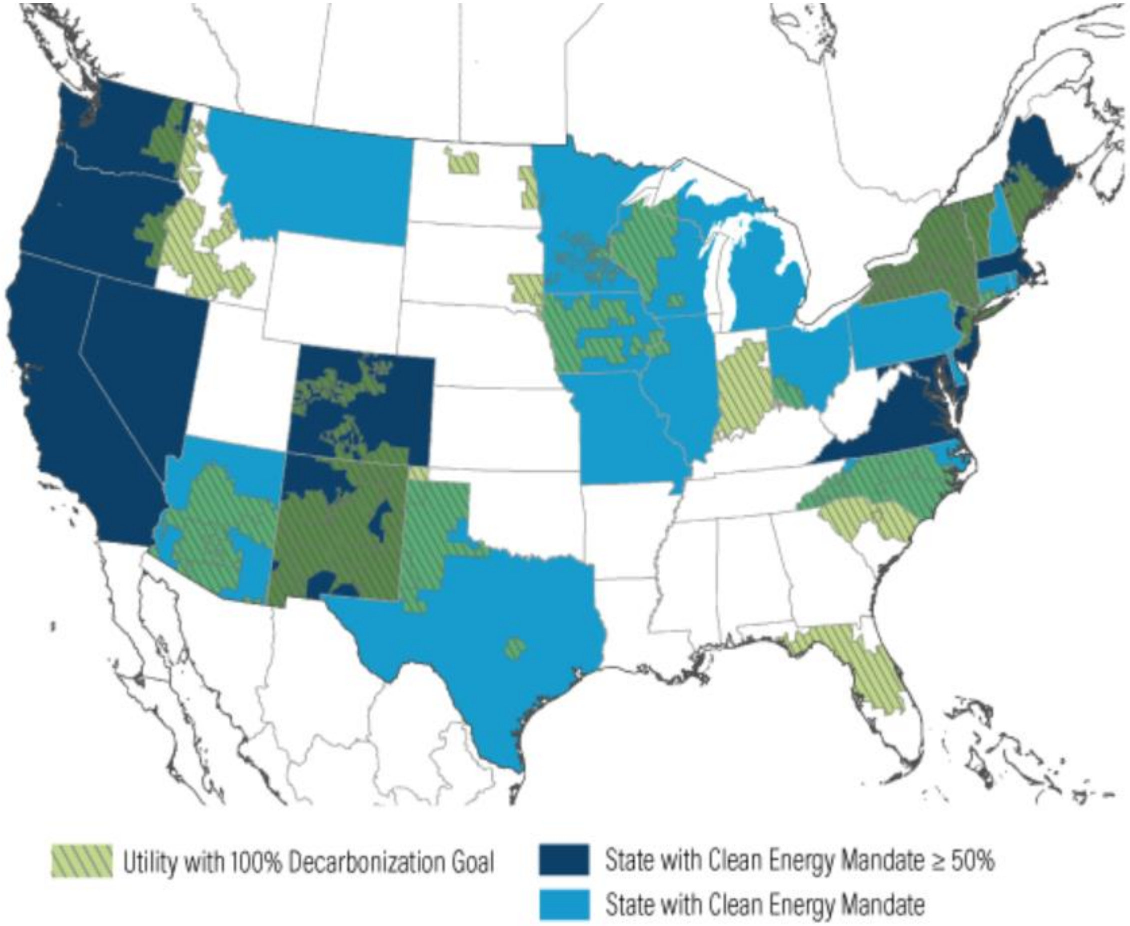
Timothy Skone

Senior Environmental Engineer

National Energy Technology Laboratory

U.S. States & Utilities Committing to De-Carbonization

U.S. States with Clean Electricity Mandates & Utilities with Decarbonization Goals, 2020



Source: WRI and Smart Electric Power Alliance, April 2020

Utility Name	Target	Target Year
Austin Energy	Net Zero Emissions	2050
Avista	100% Clean Energy	2045
DTE Energy	Net-Zero Emissions	2050
Duke Energy	Net-Zero Emissions	2050
Green Mountain Power	100% Clean Energy	2025
Hawaiian Electric	Net-Zero Emissions	2045
Idaho Power	100% Clean Energy	2045
Los Angeles Power	Net-Zero Emissions	2050
Madison Gas & Electric	Net-Zero Emissions	2050
New York Power Authority	100% Clean Energy	2040
Platte River	100% Clean Energy	2030
Public Service Electric & Gas	Net-Zero Emissions	2050
Sacramento Municipal Utility	Net-Zero Emissions	2040
Xcel Energy	100% Clean Energy	2050

Global Hydrogen & CCS Commitments

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2 *million metric tons per year*

The **first country** in North America to develop a hydrogen strategy

24.8 *million metric tons per year*

Looking to renewable hydrogen to **reduce gas imports** and **decarbonize** the heating sector

$8.2 billion strategy to target **6.5GW of hydrogen installed capacity** by 2030

Promised **€7 billion** to green hydrogen projects by 2030

3 *million metric tons per year*

1.7 *million metric tons per year*

$8.2 billion to invest in **green hydrogen** and $2.3 billion to foster **international partnerships**

0.8 *million metric tons per year*

0.8 *million metric tons per year*

The Neom facility to host the world's biggest green hydrogen project with **4GW of renewables powering** to produce **650 tons** of green hydrogen daily.

0.6 *million metric tons per year*

Provinces developing hydrogen-related **policies** while establishing **hydrogen cities.**

To build **three hydrogen-powered cities** by 2022

To make **H_2 affordable at $3/kg by** 2030 and $2/kg by 2050

3.4 *million metric tons per year*

Australia and Japan continue to cooperate on the Hydrogen Energy Supply Chain project toward the **world's first international liquid hydrogen supply chain.**

What does this mean for water management?

Water Intensity of Decarbonizing Thermoelectric Power Generation

NATIONAL ENERGY TECHNOLOGY LABORATORY

Presented by: Timothy J. Skone, P.E.

USEA Consensus Webinar: Sustainable Water Management for Decarbonizing Fossil Power Generation

January 13, 2021

Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

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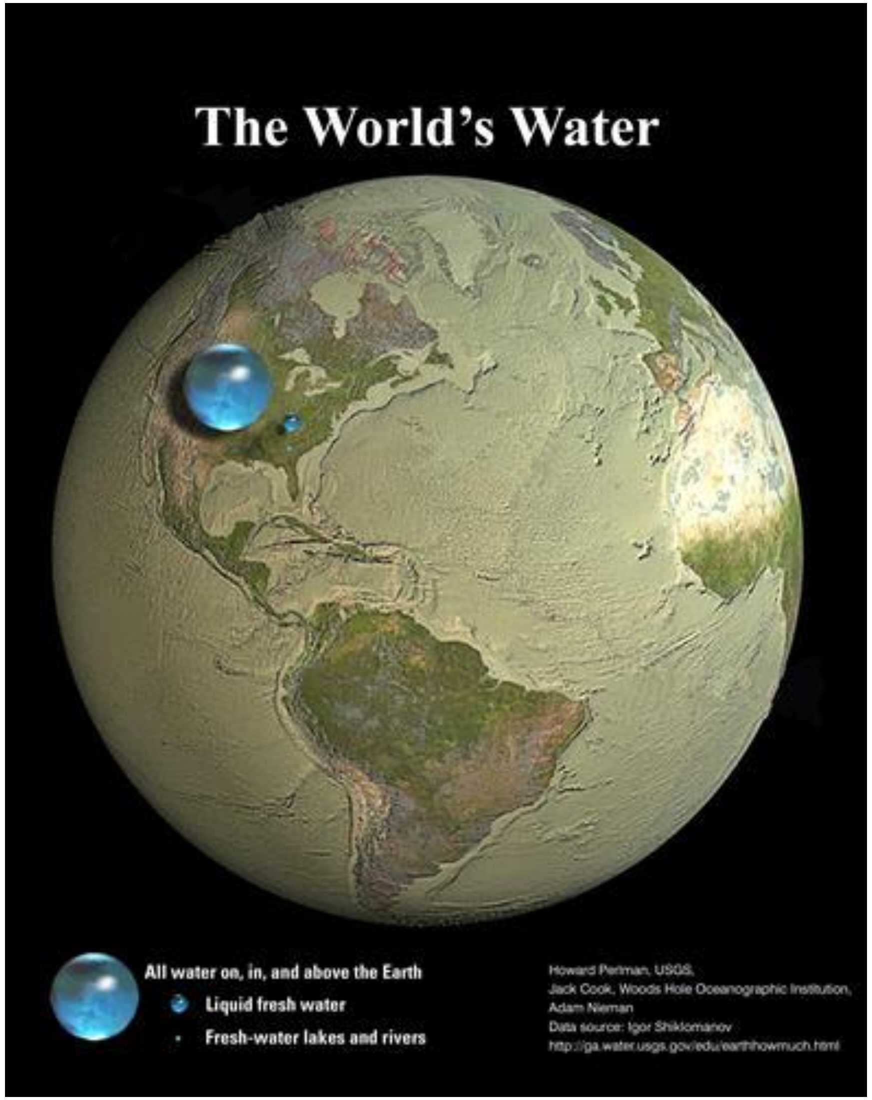
Water – A Limited Resource to Sustain Life



According to USGS, only 0.8% of the Earths water resources are suitable for supporting human and other life forms – Liquid Fresh Water.

According to USGS, only 0.007% of the Earths water resources or 0.9% of Liquid Fresh Water represents the water people and life of earth use every day come from surface water – Water in Lakes and Rivers.

Source: The Worlds Water, Howard Perlman, Hydrologist, USGS, Jack Cook, Woods Hole Oceanographic Institution, Adam Nieman, Igor Shiklomanov
https://www.usgs.gov/media/images/all-earths-water-a-single-sphere

Importance of Water Conservation

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Water is fundamental to life on our planet, but this precious resource is increasingly in demand and under threat.

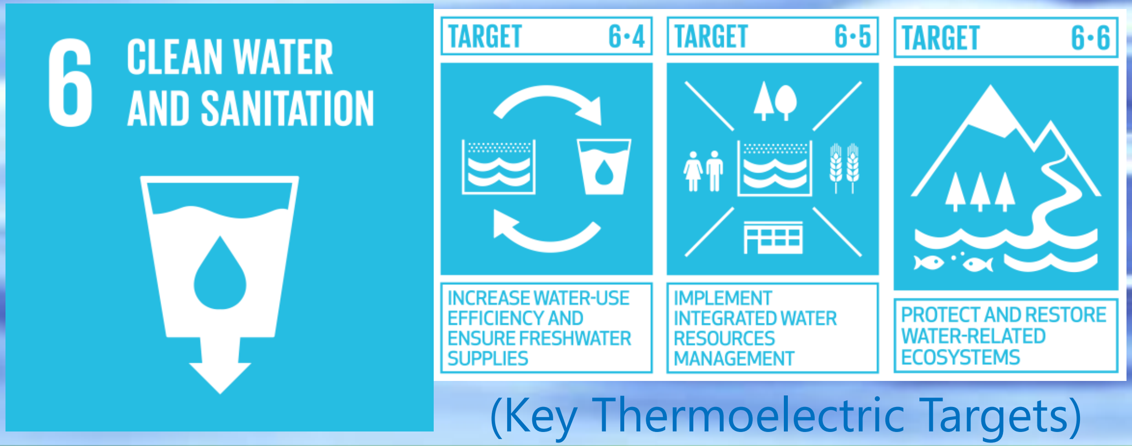
- United Nations Environmental Program

Climate change is changing our assumptions about water resources. As climate change warms the atmosphere, altering the hydrologic cycle, changes to the amount, timing, form, and intensity of precipitation will continue.

- U.S. Environmental Protection Agency

https://www.epa.gov/climate-change-water-sector

United Nations Sustainable Development Goal 6: Clean Water and Sanitation



(Key Thermoelectric Targets)

Discussion Topics

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1. **Role of Water in Electricity Production**
2. **Life Cycle Water Intensity of Electricity Production**
3. **Decarbonizing Thermoelectric Power Generation**
4. **Water Intensity of Thermoelectric Power Generation in a Decarbonized Future**
5. **Concluding Remarks & Opportunities**

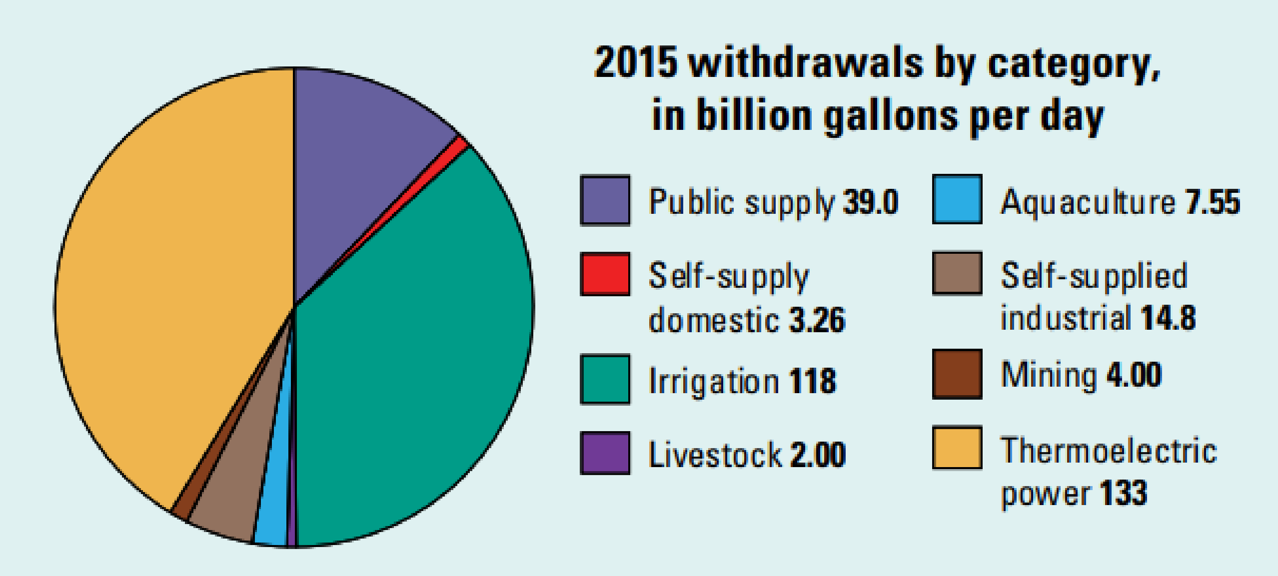
Role of Water in Electricity Production

Water Withdrawal – a National Perspective

Thermoelectric power was the largest industry responsible for water withdrawals in 2015, USGS

<u>Thermoelectric Water Withdrawal Statistics</u>

- 41% of U.S. Total
- 34% of U.S. Fresh Water
- 133 Billion Gallons per Day
- Nearly 100% is from Freshwater Sources (ground & surface)



Source: Dieter, C.A., Maupin, M.A., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2018, *Estimated use of water in the United States in 2015*: U.S. Geological Survey Circular 1441, 65 p., https://doi.org/10.3133/cir1441.

Role of Water in Electricity Production

Water Consumption – a National Perspective

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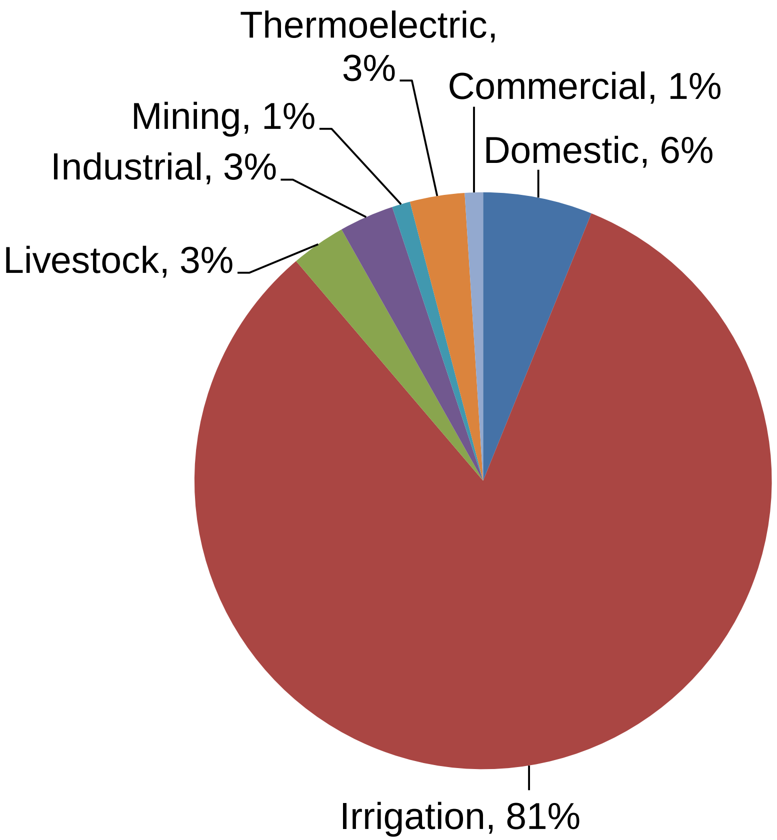
Irrigation is the largest industry responsible for water consumption in 1998, USGS*

Thermoelectric Water <u>Consumption Statistics</u>

- **4% of U.S. Fresh Water**
- **4 Billion Gallons per Day (2015)**
- **2.6 Billion Gallons per Day (2018)**

Water consumption decreased due to retirement and reduction in thermoelectric power production electricity generation.

U.S. Freshwater Consumption, USGS 1998



Sources: [2]USGS, Estimated Use of Water in the United States in 1995, USGS Circular 1200, 1998

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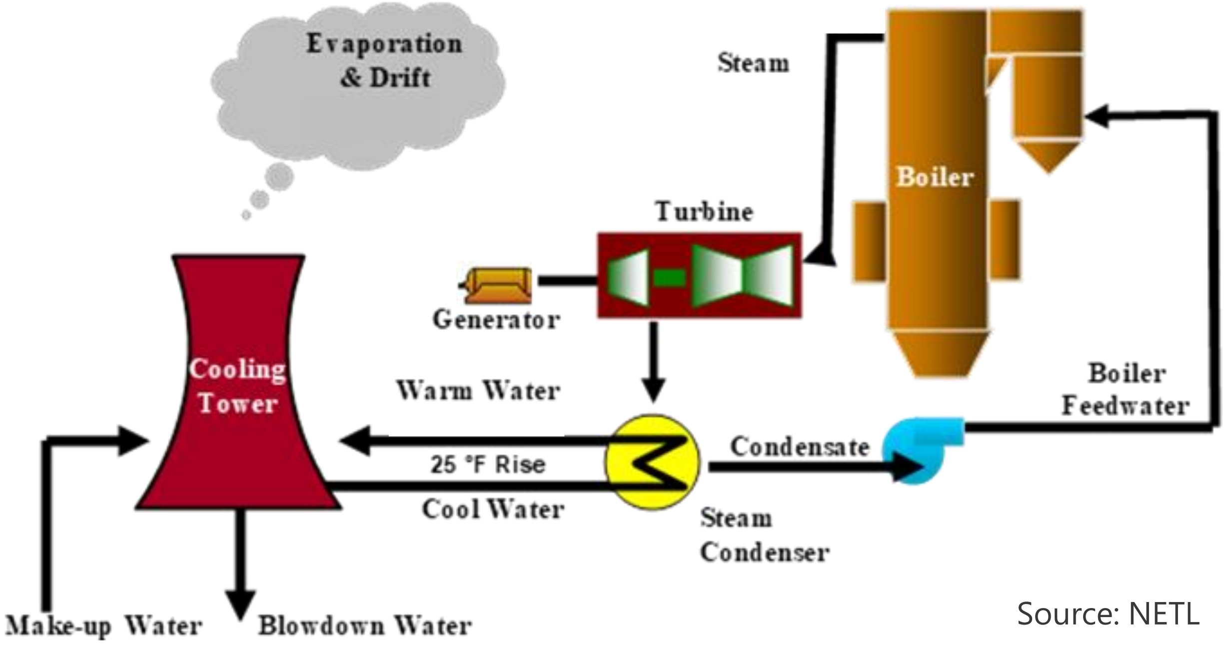
* USGS did not publish corresponding statistics for water consumption for 2015.

Role of Water in Electricity Production

How is water used in thermoelectric power plants?

- **Water is heated in a boiler to produce steam that turns a turbine and generator to produce electricity.**
- **After electricity generation, the steam is condensed using a separate cooling water stream.**
- **Cooling water stream is either directly discharged back to the source body of water (once-thru cooling) or recycled (recirculating cooling tower) to lower the water temperature to improve heat transfer.**

Simplified Thermoelectric Power Generation Overview



Source: NETL

Role of Water in Electricity Production

How is water used in thermoelectric power plants?

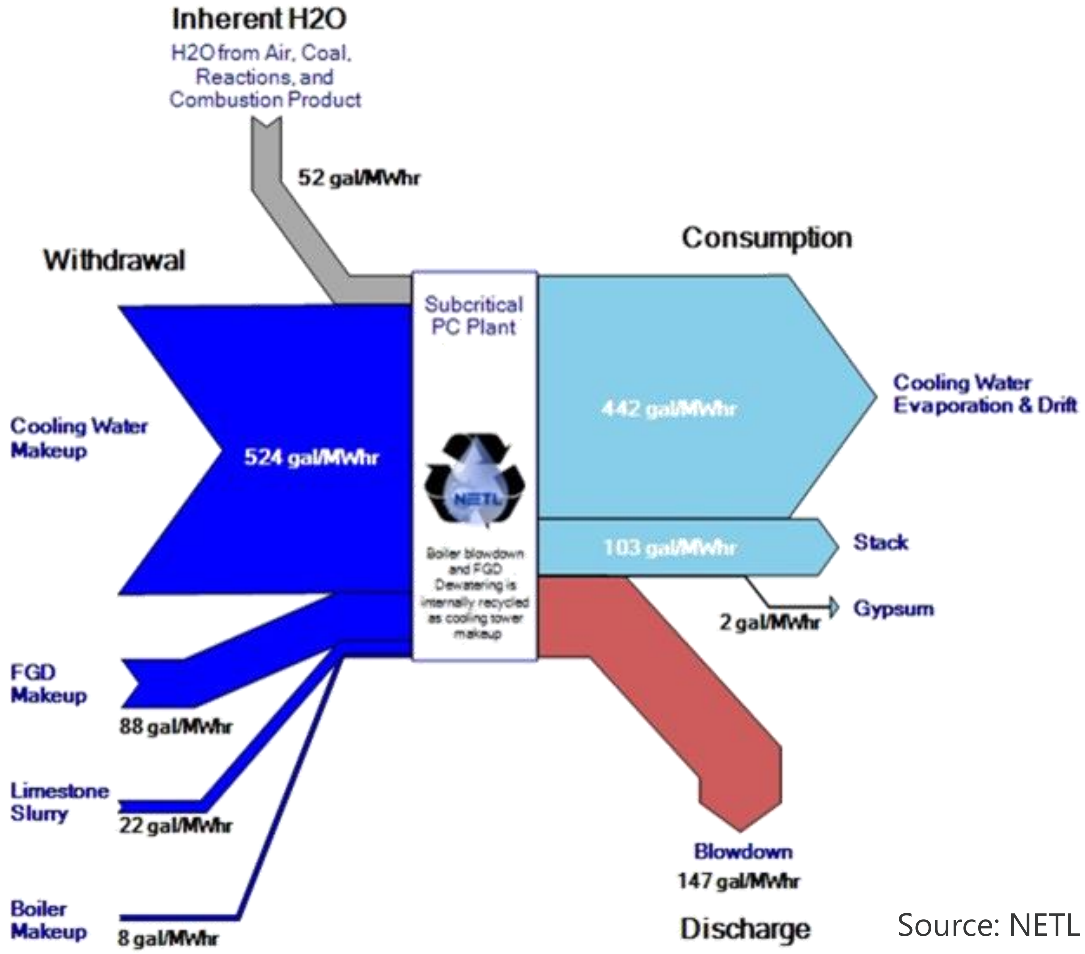
Cooling Water Management Strategies

Technology	Water Withdrawal (gal/MWh)	Water Consumption (gal/MWh)	Water Management Cost
Once-through Cooling	20,000	0	$
Recirculating Cooling Tower	600	500	$$$
Dry Cooling	0	0	$$$$$*

* Dry Cooling uses fans to move air over a heat exchanger to cool the water in a closed loop system. Fan operation increases the parasitic load and operating costs of the plant (decrease plant efficiency) as a trade-off to conserve to regional water resources.

Example Thermoelectric Water Balance

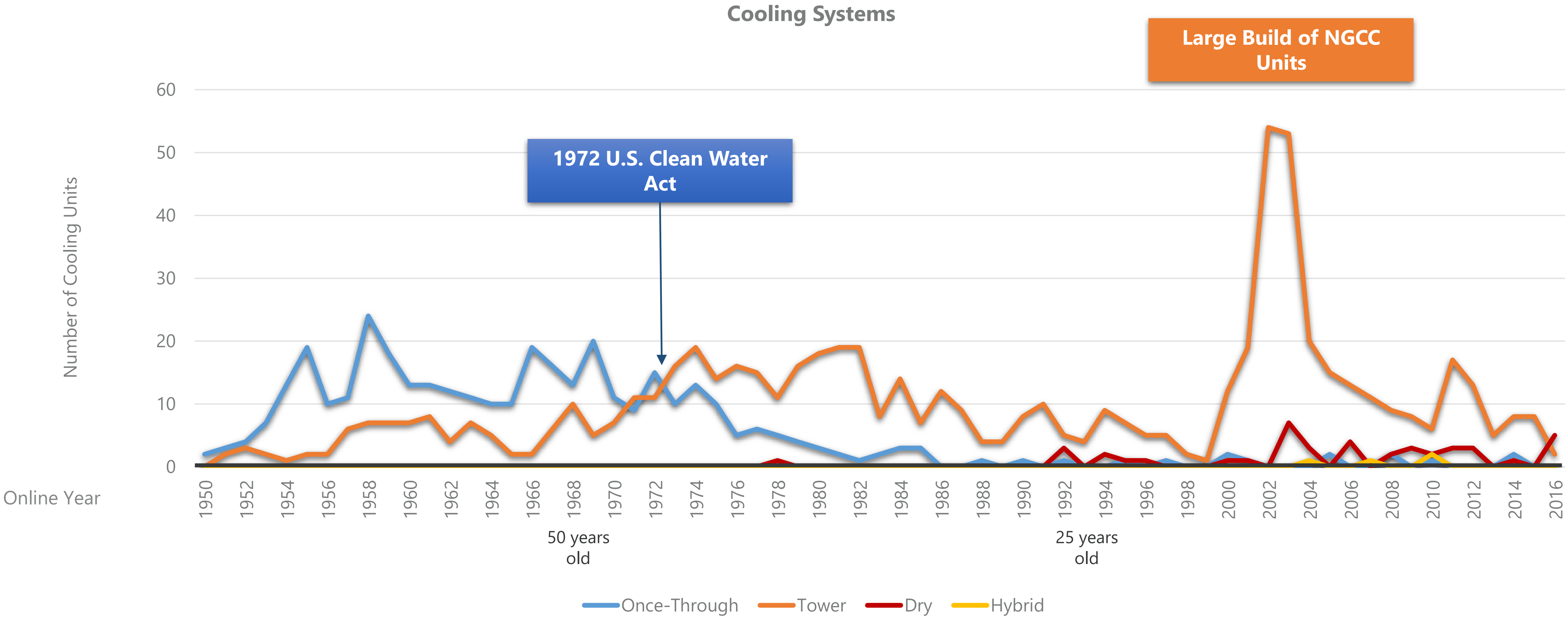
(Subcritical Coal-fired Power Plant with Recirculating Cooling Tower)



Source: NETL

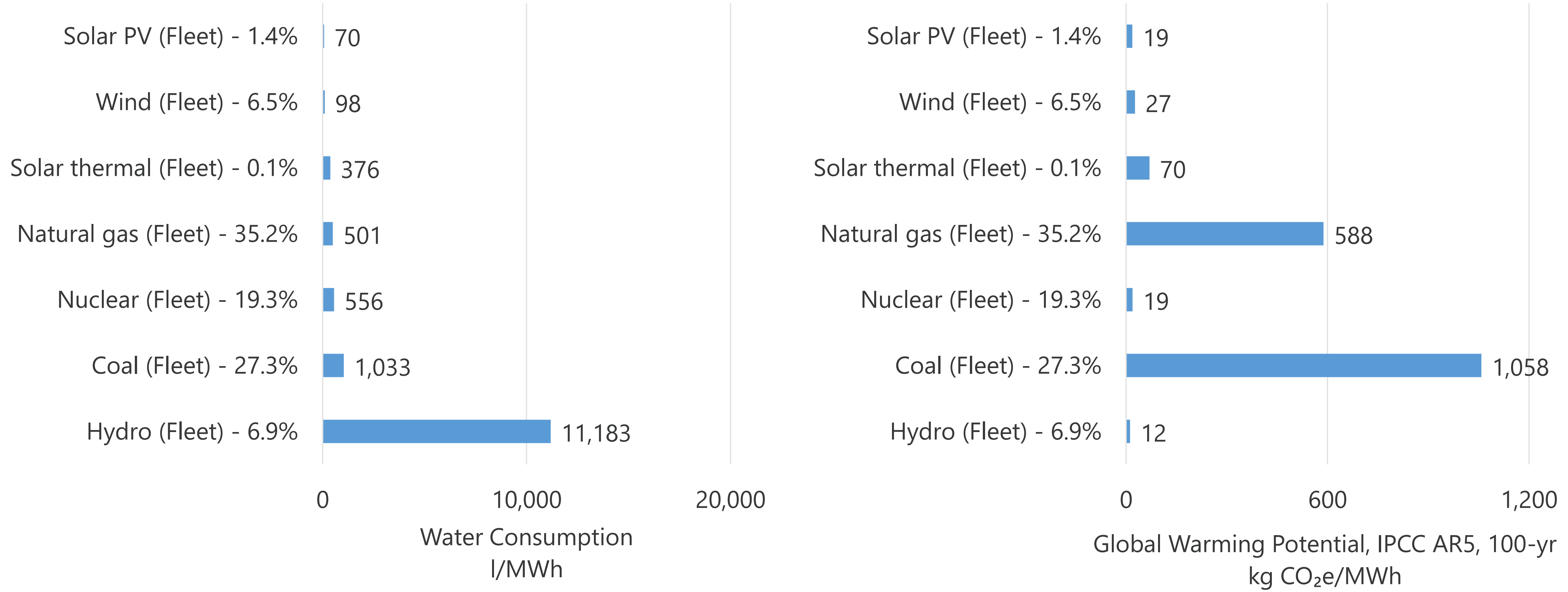
Role of Water in Electricity Production

Thermoelectric Cooling Units by Type and Year of Installation



Life Cycle Water Intensity of Electricity Production

Water Intensity: Water Consumption (L/MWh) & Global Warming Potential (kg CO_2e/MWh)



Percentages next to technology name are the percent of 2018 generation.

Decarbonizing Thermoelectric Power Generation

Strategies for Carbon Reduction

- **Carbon Capture, Utilization and Storage (CCUS)**
- **Biomass Cofiring**
- **Advanced Conversion Technologies (Fuel Cells and Hydrogen to Power)**

Note: List is not intended to be exhaustive of all reduction opportunities for carbon reduction of thermoelectric power production (e.g., technology plant designs, co-product production, efficiency improvements of existing plants, etc.).

Decarbonizing Thermoelectric Power Generation

Carbon Capture, Utilization and Storage (CCUS/CCS)

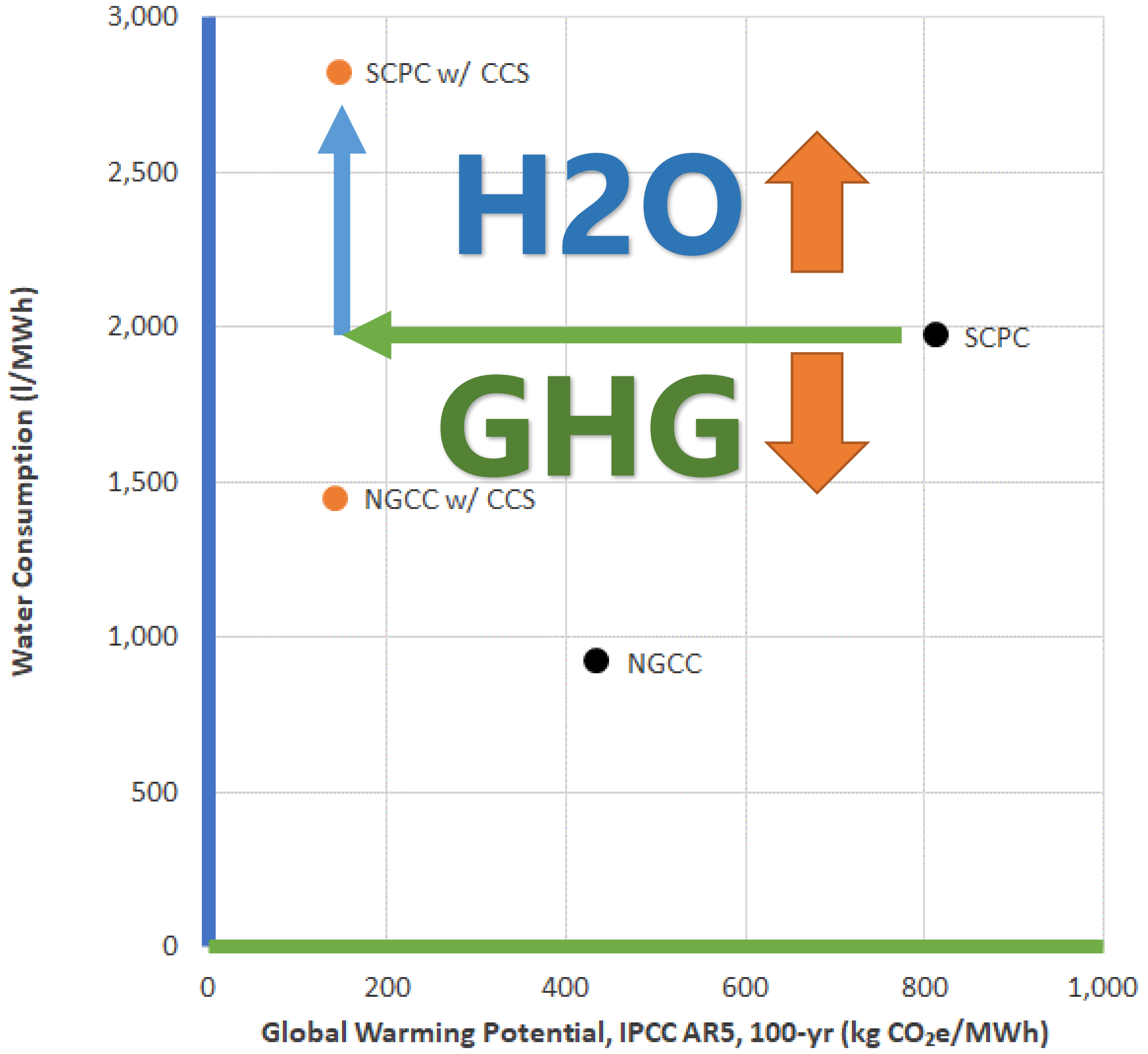
Post-combustion removal of carbon dioxide from the combustion (flue) gas for alternative use and/or storage – *prevents the release of carbon dioxide to the atmosphere.*

Additional water is needed for the increased parasitic load on the power plant to operate the carbon capture and compression systems.

Percent Change in Life Cycle GHG Emissions and Water Consumption

(Positive (+) % change = Increase; Negative (-) % change = Decrease)

Decarbonization Technology	GWP	H2O
Supercritical Pulverized Coal (SCPC) w/CCS	- 82%	+ 43%
Natural Gas Combined Cycle (NGCC) w/CCS	- 67%	+ 58%



Decarbonizing Thermoelectric Power Generation

Biomass Cofiring (with bituminous coal)

Biomass removes carbon dioxide from the atmosphere during photosynthesis (growth). Carbon contained in biomass does not contribute to global warming when released to the air.

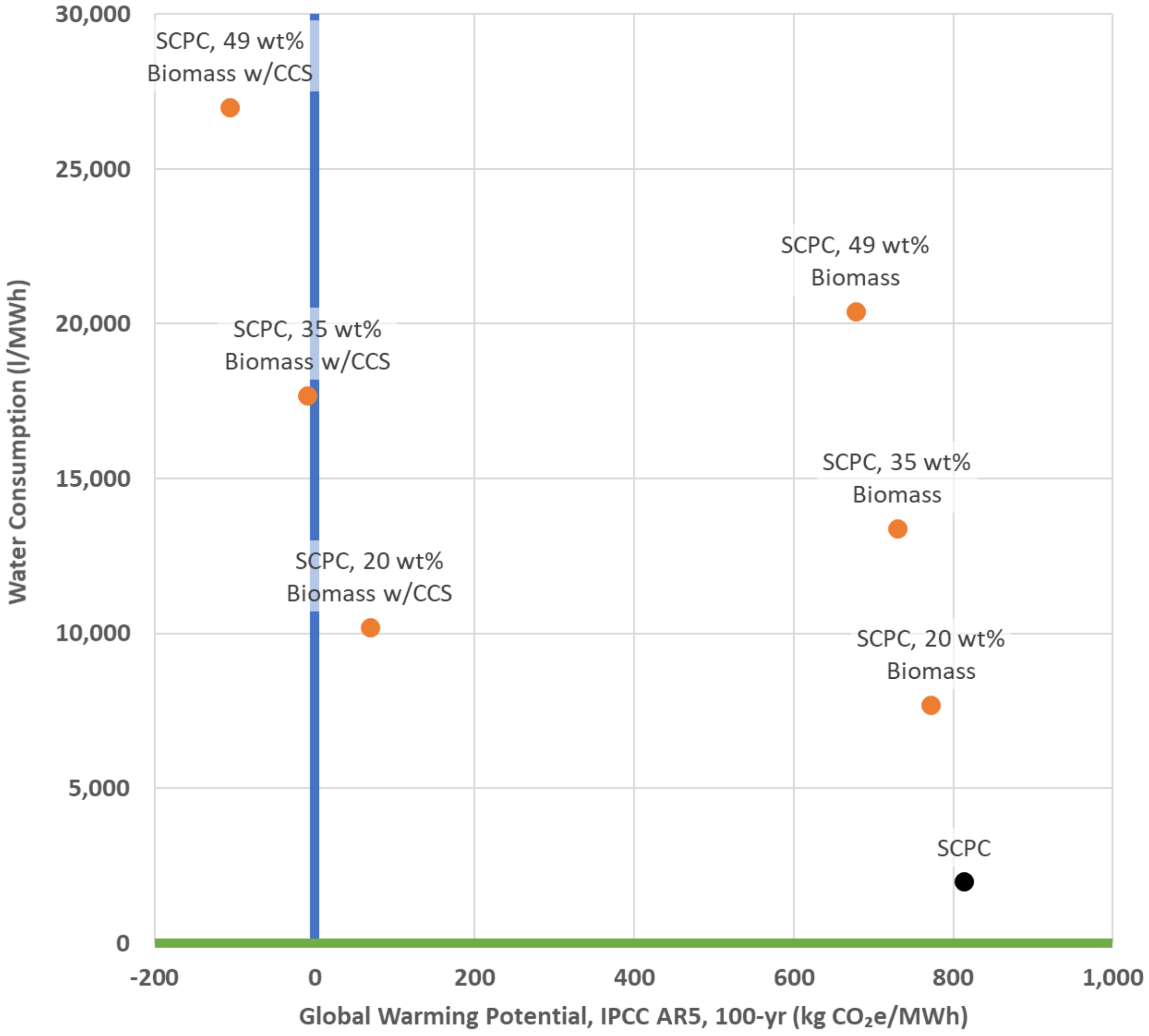
Additional water is needed for biomass growth and for CCS the increased parasitic load on the power plant to operate the carbon capture and compression systems.

Percent Change in Life Cycle GHG Emissions and Water Consumption

(Positive (+) % change = Increase; Negative (-) % change = Decrease)

Decarbonization Technology	GWP	H2O
SCPC with Cofiring 20 wt% Biomass	-5%	+290%
SCPC with Cofiring 35 wt% Biomass	-10%	+580%
SCPC with Cofiring 49% Biomass	-17%	+936%
SCPC with Cofiring 20 wt% Biomass w/CCS	-91%	+418%
SCPC with Cofiring 35 wt% Biomass w/CCS	-101%	+798%
SCPC with Cofiring 49% Biomass w/CCS	-113%	+1,271%

All Technology Options are Compared to a Supercritical Pulverized Coal (SCPC) Power Plant



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Decarbonizing Thermoelectric Power Generation

Advanced Conversion Technologies (Fuels Cells and Hydrogen to Power)

Solid oxide fuel cells (SOFC) produce electricity by a chemical reaction instead of combustion. Recirculating cooling towers are used for heat transfer and are the primary source of water consumption.

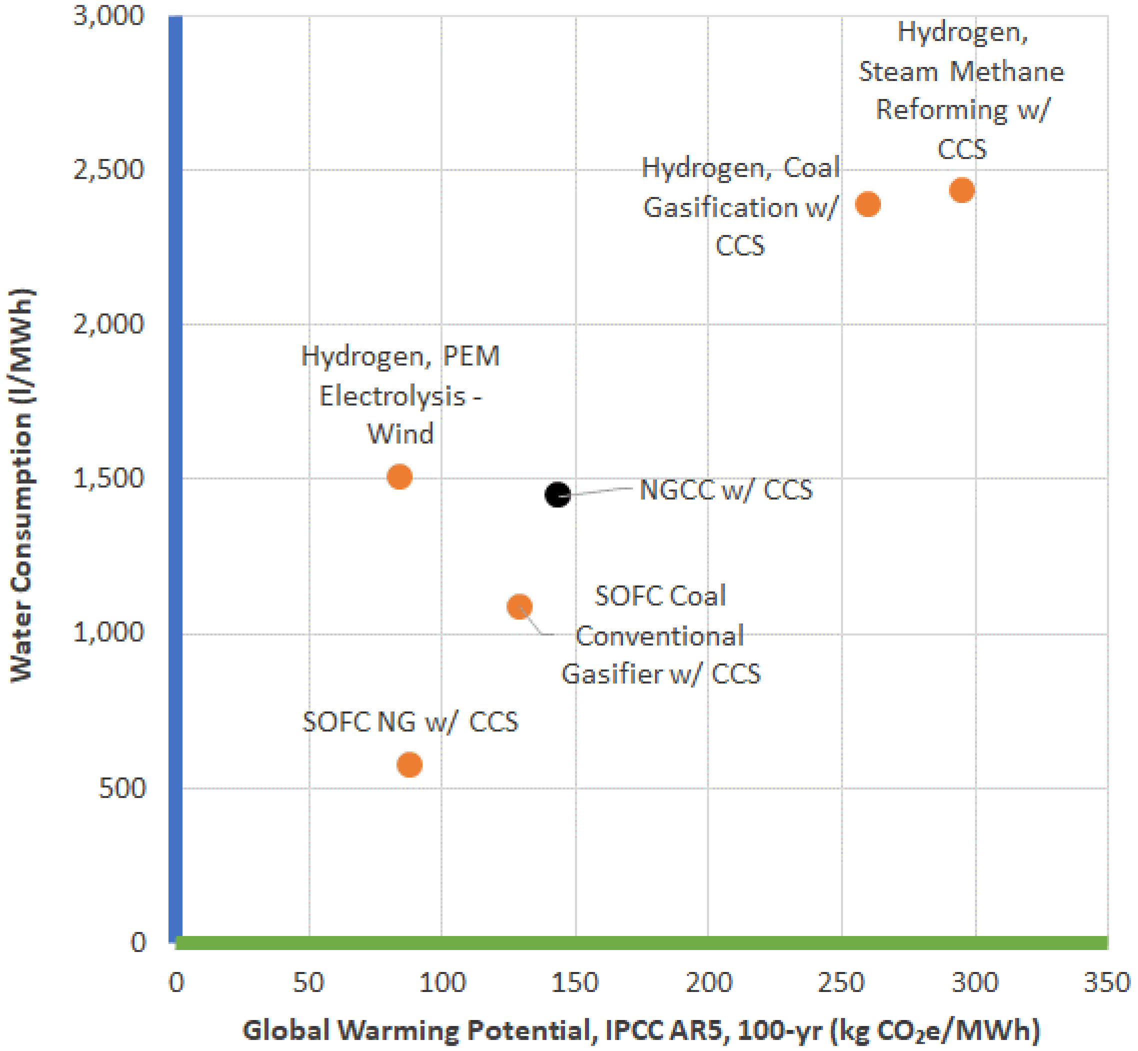
Hydrogen production and combustion both consume water. Hydrogen production by electrolysis also requires water as a material input in addition to cooling of combustion gases.

Percent Change in Life Cycle GHG Emissions and Water Consumption

(Positive (+) % change = Increase; Negative (-) % change = Decrease)

Decarbonization Technology	GWP	H2O
SOFC Coal Conv. Gasifier w/CCS	-10%	-25%
SOFC Natural Gas (NG) w/CCS	-39%	-61%
Hydrogen, Steam Methane Reforming w/CCS	105%	68%
Hydrogen, Coal Gasification w/CCS	81%	65%
Hydrogen, PEM* Electrolysis, Wind Powered	-41%	4%

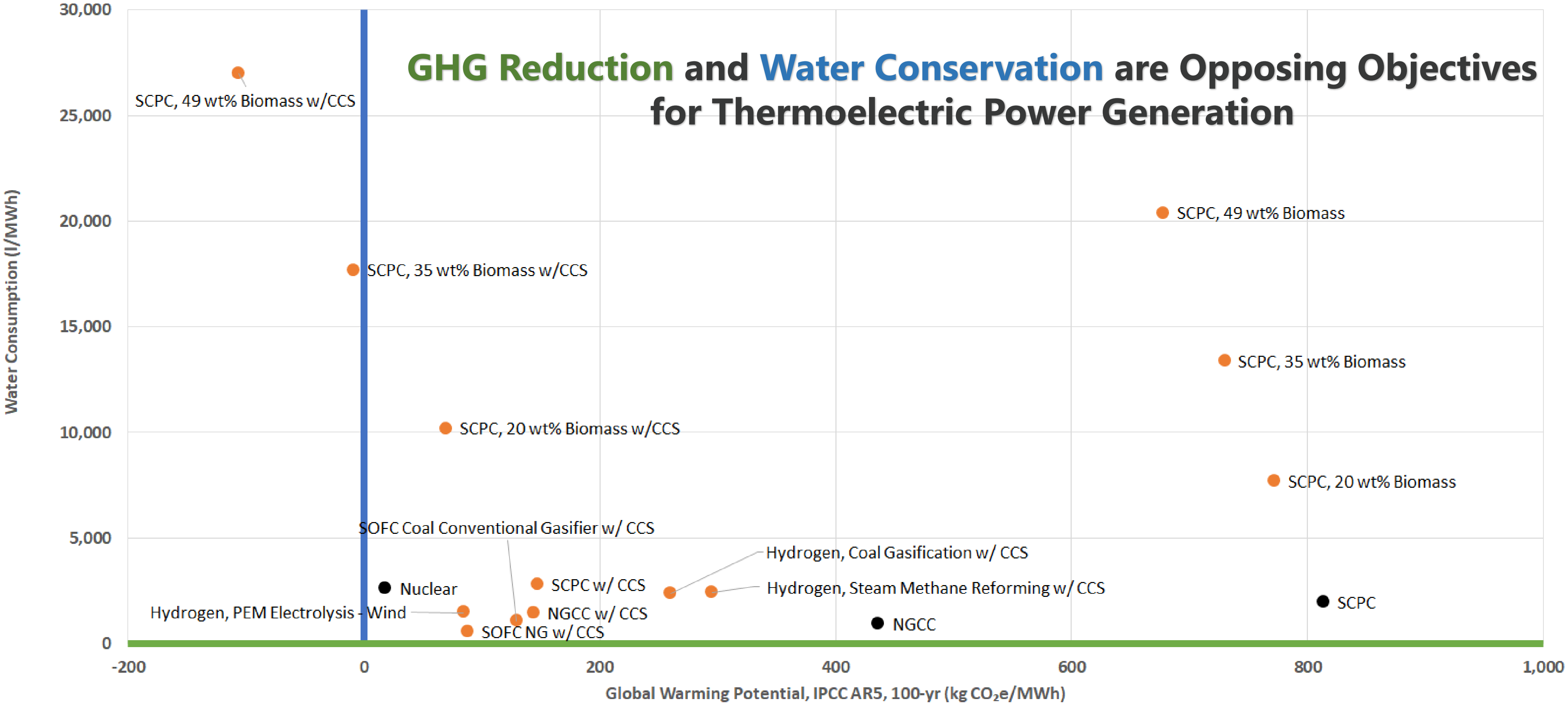
All Technology Options are Compared to a Natural Gas Combined Cycle (NGCC) Power Plant w/CCS



*PEM = Polymer Electrolyte Membrane

Water Intensity in a Decarbonized Future

Future is uncertain – What technologies will the enter the market to meet future needs?



Concluding Remarks and Opportunities

Key Messages

- **Future is <u>Uncertain</u> – Growing Demand for Energy is <u>Certain</u>**
- **Decarbonizing the Economy is a Priority**
- **Decarbonizing Thermoelectric Power is a Priority**
- **Decarbonizing Thermoelectric Power Increases Water Intensity**

GHG ↓ H2O ↑

- **Low Carbon Strategies Call for a Reduction in Fossil-based Thermoelectric Power without Carbon Management**
- **Economic and Life Cycle Environmental Performance will Drive Technology Change to Meet Future Priorities**
- **Sustainable Water Practices Remain a Priority Today and into our Future!**

Concluding Remarks and Opportunities

Key Challenge and Opportunities

Challenge

- Meeting Growing Energy Demands
- Significantly Reducing GHG Emissions (Carbon Intensity)
- Sustainably Managing Water Resources to Support Life (Water Intensity)

Opportunities (Water Reduction)

Concluding Remarks and Opportunities

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Key Challenge and Opportunities

Challenge

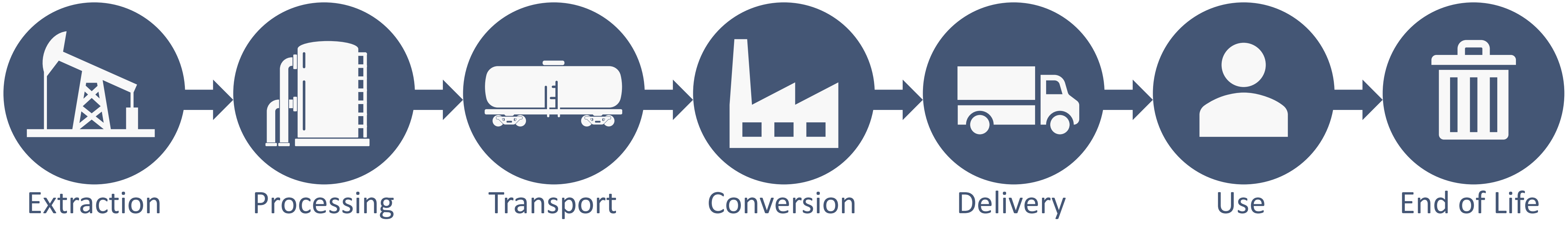
- Meeting Growing Energy Demands
- Significantly Reducing GHG Emissions (Carbon Intensity)
- Sustainable Managing Water Resources to Support Life (Water Intensity)

Opportunities (Water Reduction)

- Existing Power Plant Water Reduction Strategies
- Dry Cooling Cost Reduction and Performance Improvements
- Alternative Water Use
- Hybrid Thermoelectric and Renewable Power Plants
- Innovation
  - demand destruction, regional water scarcity alignment, hydrogen (?), advanced power plant concepts, etc.

Energy Life Cycle Analysis

Cradle-to-grave environmental footprint of energy systems



Mission

Evaluate existing and emerging energy systems to guide R&D and protect the environment for future generations

Vision

A world-class research and analysis team that integrates results which inform and recommend sustainable energy strategy and technology development

LCA Life Cycle Analysis
• energy sustainability •

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Continuing evolution of energy-water systems

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NAWI

Secure the nation's water supply through energy efficient and cost-effective water desalination

*90% of non-traditional water sources achieve **pipe parity***

Pipe parity is defined by the end user

A non-traditional source water achieves pipe parity when the marginal cost and energy intensity of full lifecycle water supply is less than or equal to that of the next available source for a **specific end user.**

Power

Water used in the electricity sector, especially for thermoelectric cooling.

Resource Extraction

Water used to extract resources, including mining and oil and gas exploration and production.

Industrial

Water used in industrial activities not included elsewhere.

Municipal

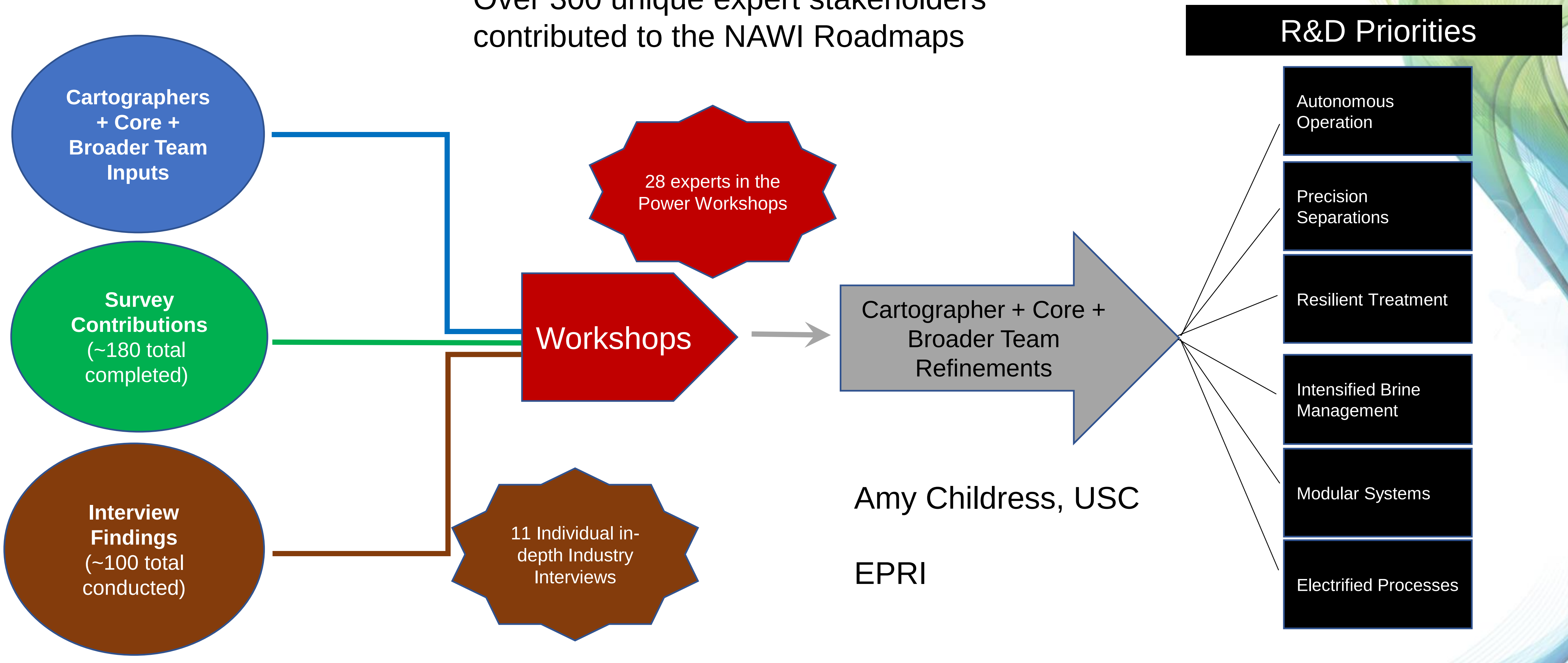
Water used by public water systems (publicly and privately owned) to supply customers in their service area.

Agriculture

Water used in the agricultural sector, especially for irrigation.

NAWI Data Collection and Analysis Process

Over 300 unique expert stakeholders contributed to the NAWI Roadmaps



Amy Childress, USC

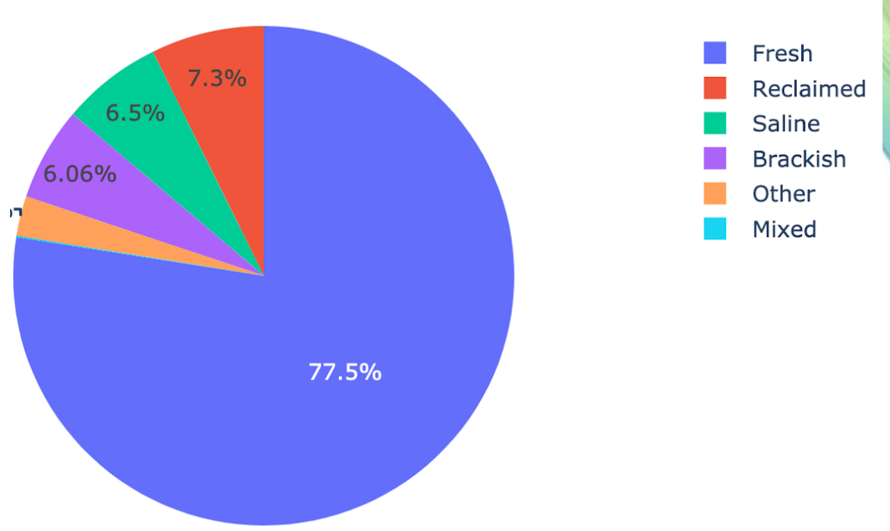
EPRI

Publication forthcoming in Q1 2021

Drivers of non-traditional water use in power

- Inadequate or low-reliability fresh water cooling supply

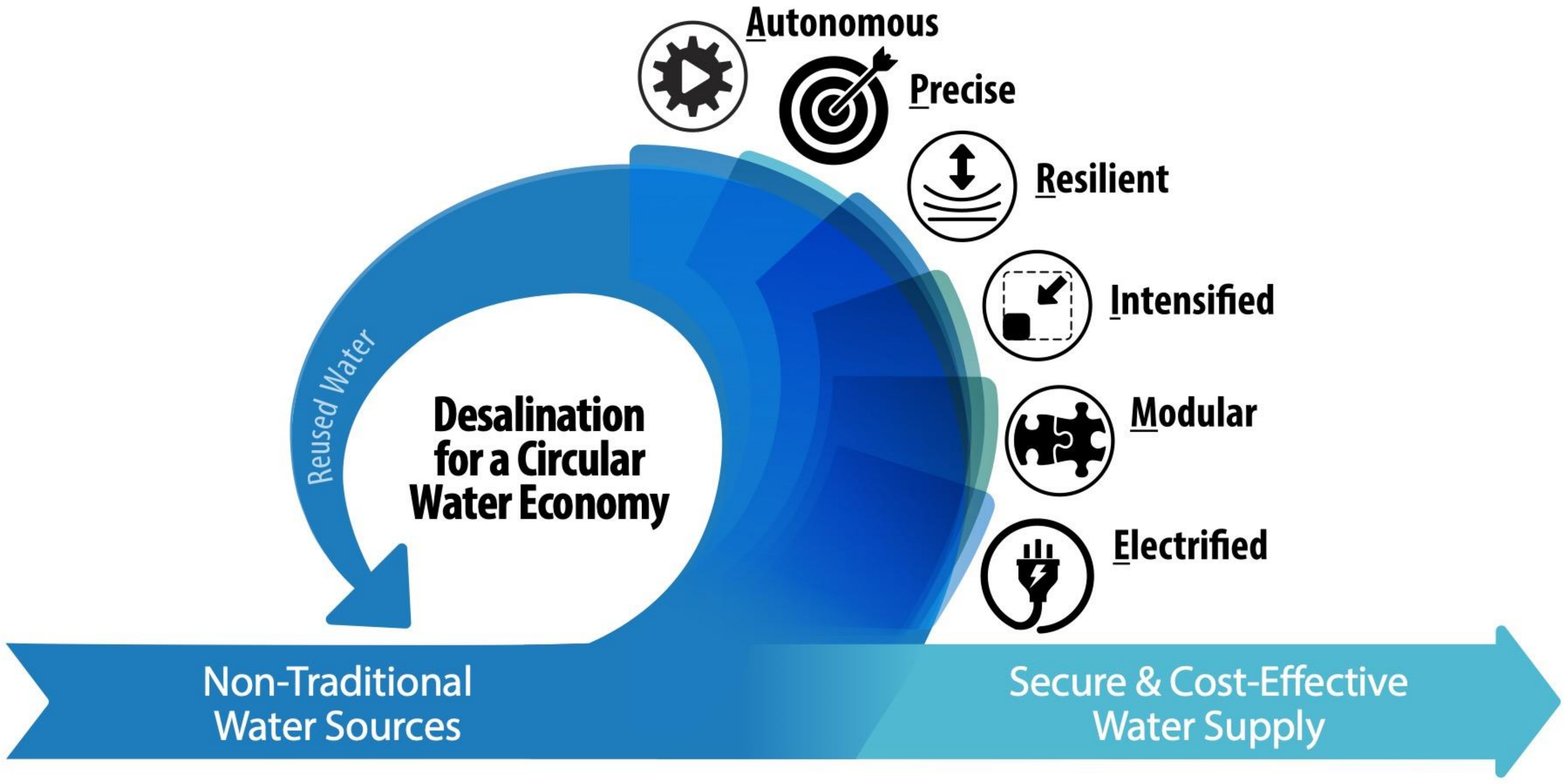
- Regulatory compliance via avoided discharge (ZLD)



Treatment Challenges at Generation Facilities

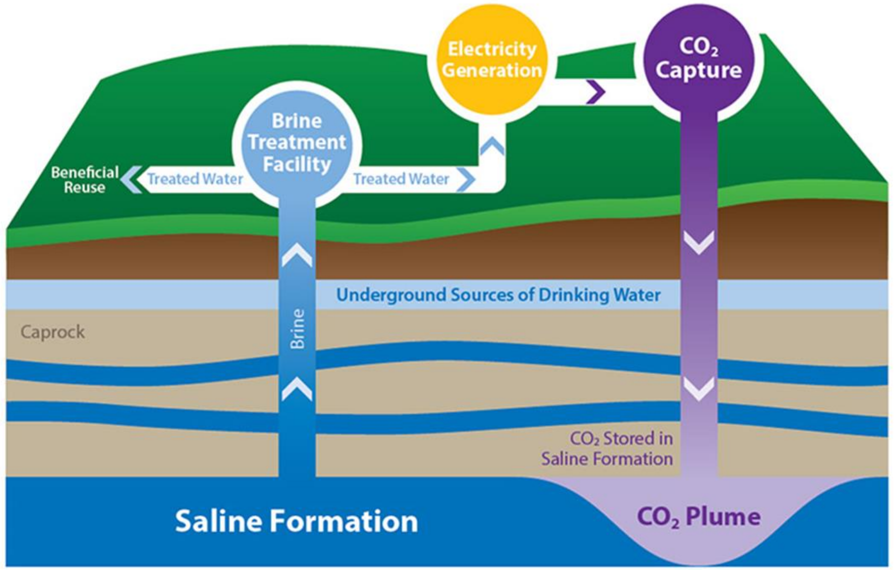
- Seasonal shifts between cooling water and coal sources necessitate highly adaptable treatment trains
  - Variable concentrations of foulants/scalants (e.g., silica, chloride, fluoride, nitrate)
  - Variable concentrations of regulated trace metals (e.g., As, Se, Hg)
- Non-steady-state operating conditions increase risk of cascading failures and necessitate highly coordinated water treatment and power operations
  - (e.g., ZLD systems dependent on steam)
- Rapidly evolving economic and regulatory environments incentivize adoption of low capital cost treatment trains

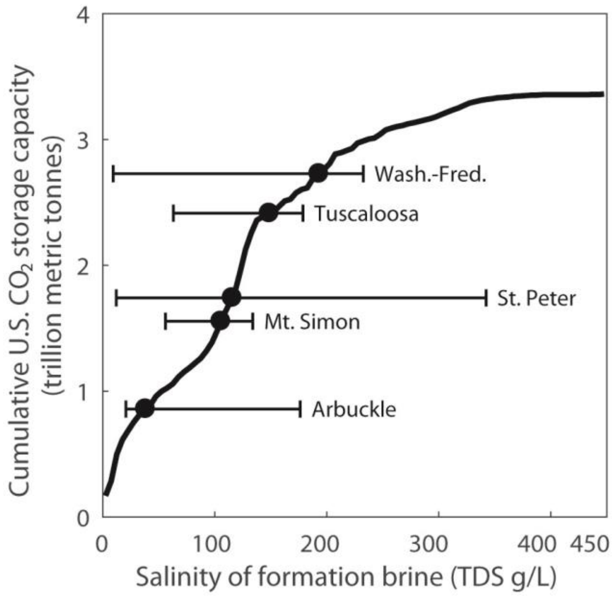
A-PRIME innovation needs to enable a circular water economy and deliver pipe parity

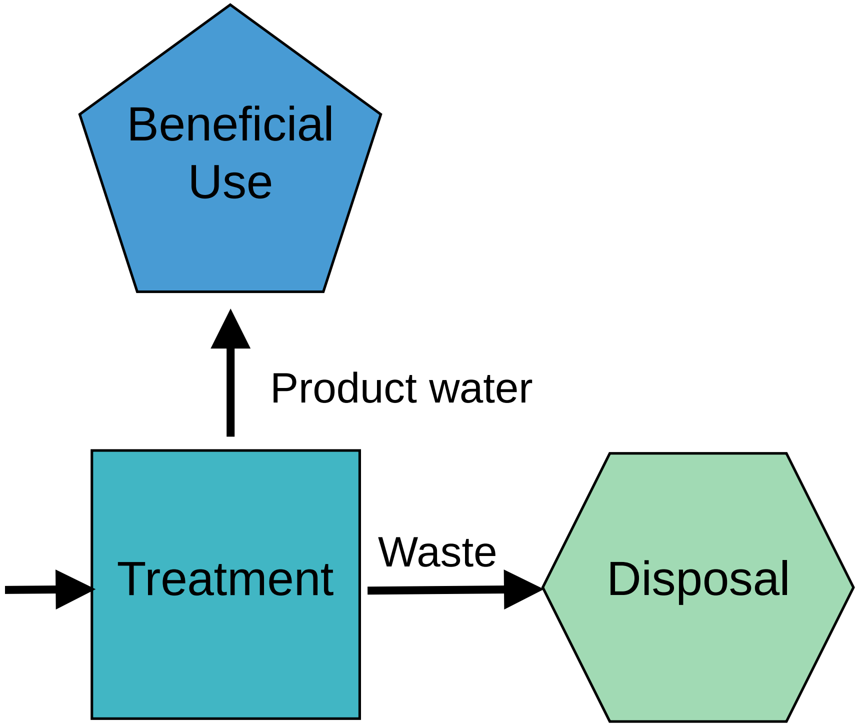


90% of non-traditional water sources achieve pipe parity

Large scale CO_2 storage will require large scale brine management

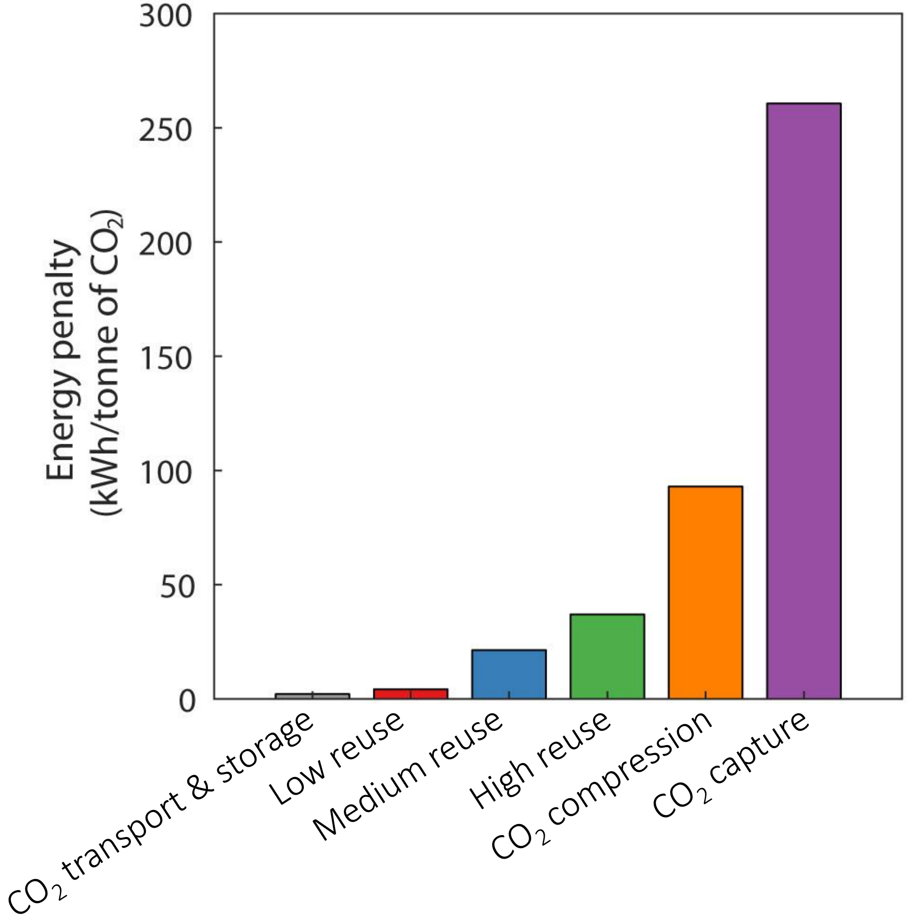






Bartholomew and Mauter, Under Review

Energy penalty of extensive brine dewatering an order of magnitude greater than CO_2 transport and storage



CO_2 capture and compression reduces plant generation efficiency by 10%; brine management by another 0.1-2%

Brine management energy consumption is an order of magnitude greater than CO_2 transport and storage; transporting CO_2 long distances may make "carbon sense", if not "economic sense".

The energy demand of brine management can be reduced by selecting reservoirs with low salinity, developing energy efficient separations technologies for high salinity brine, identifying large scale disposal options.

Bartholomew and Mauter, Under Review

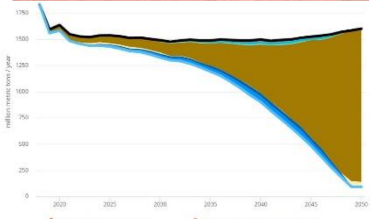
Energy and water systems are undergoing a “5D” paradigm shifts that enhance their interdependencies

Diversification

Introduce non-traditional sources

Decentralization

Partially displace centralized supply with local supply



Decarbonization

Minimize direct and embedded CO_2 emissions

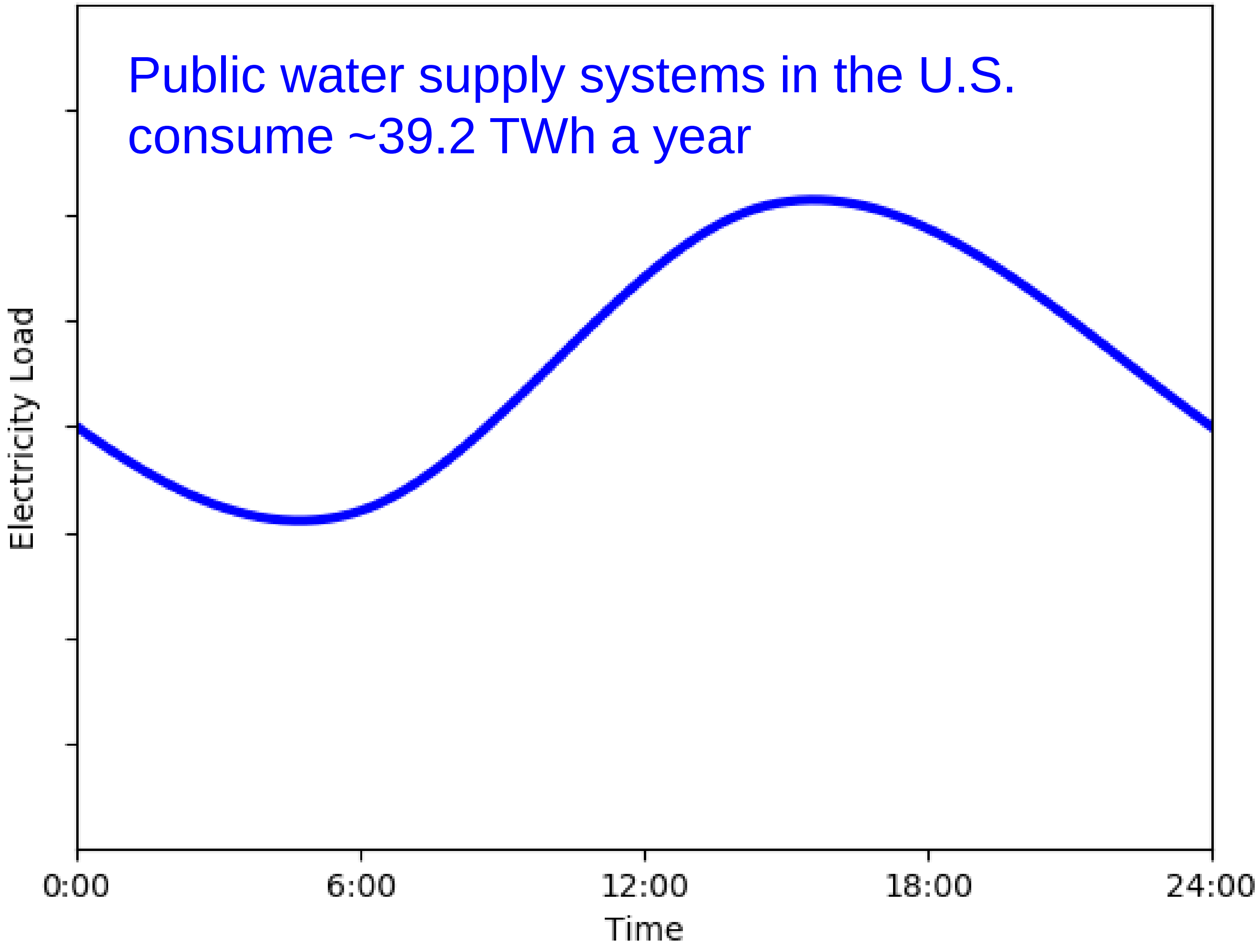
Decoupling

Enlarge storage capacity to decouple supply and demand

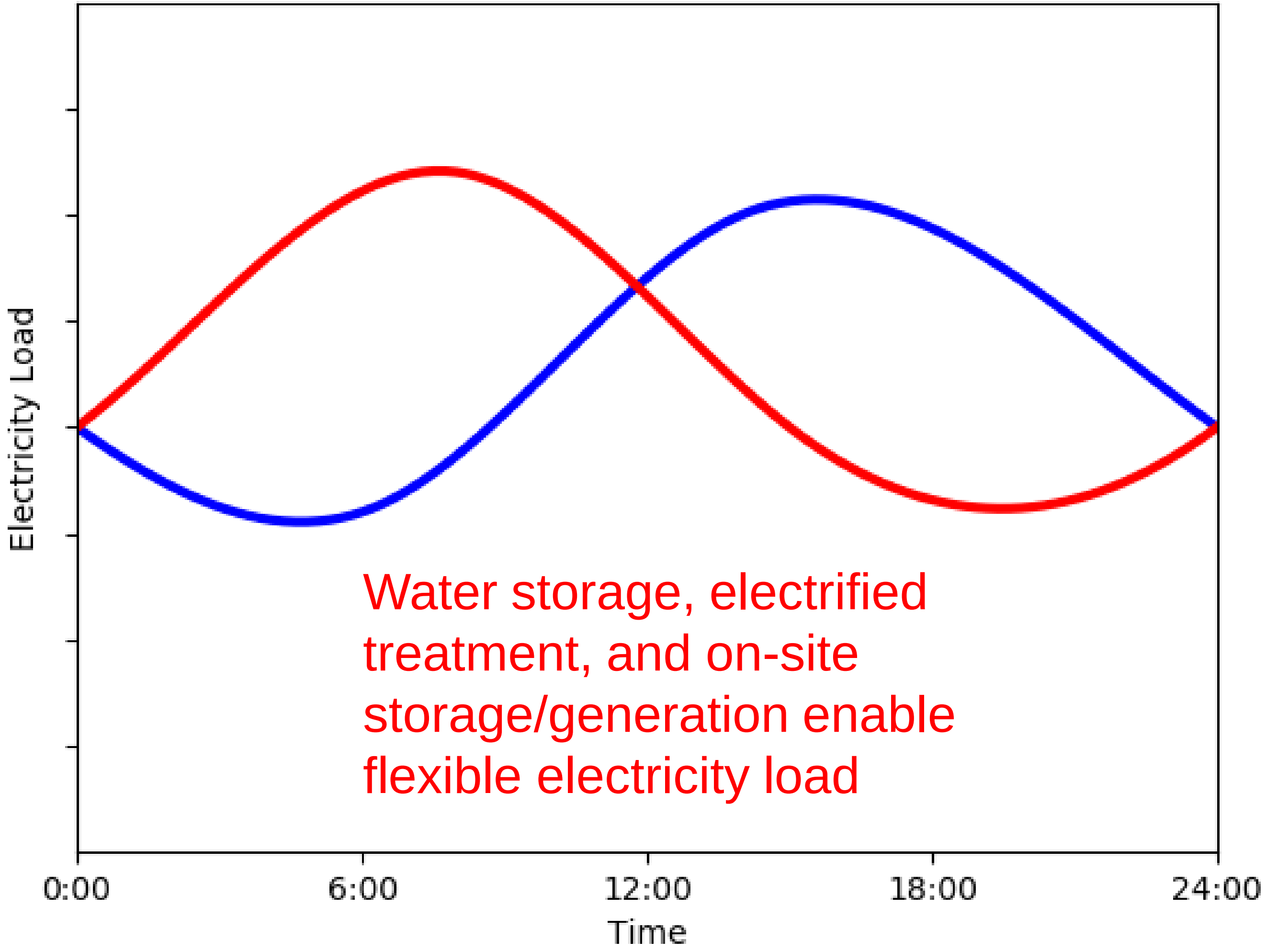
Demand Softening

Implement efficiency improvements

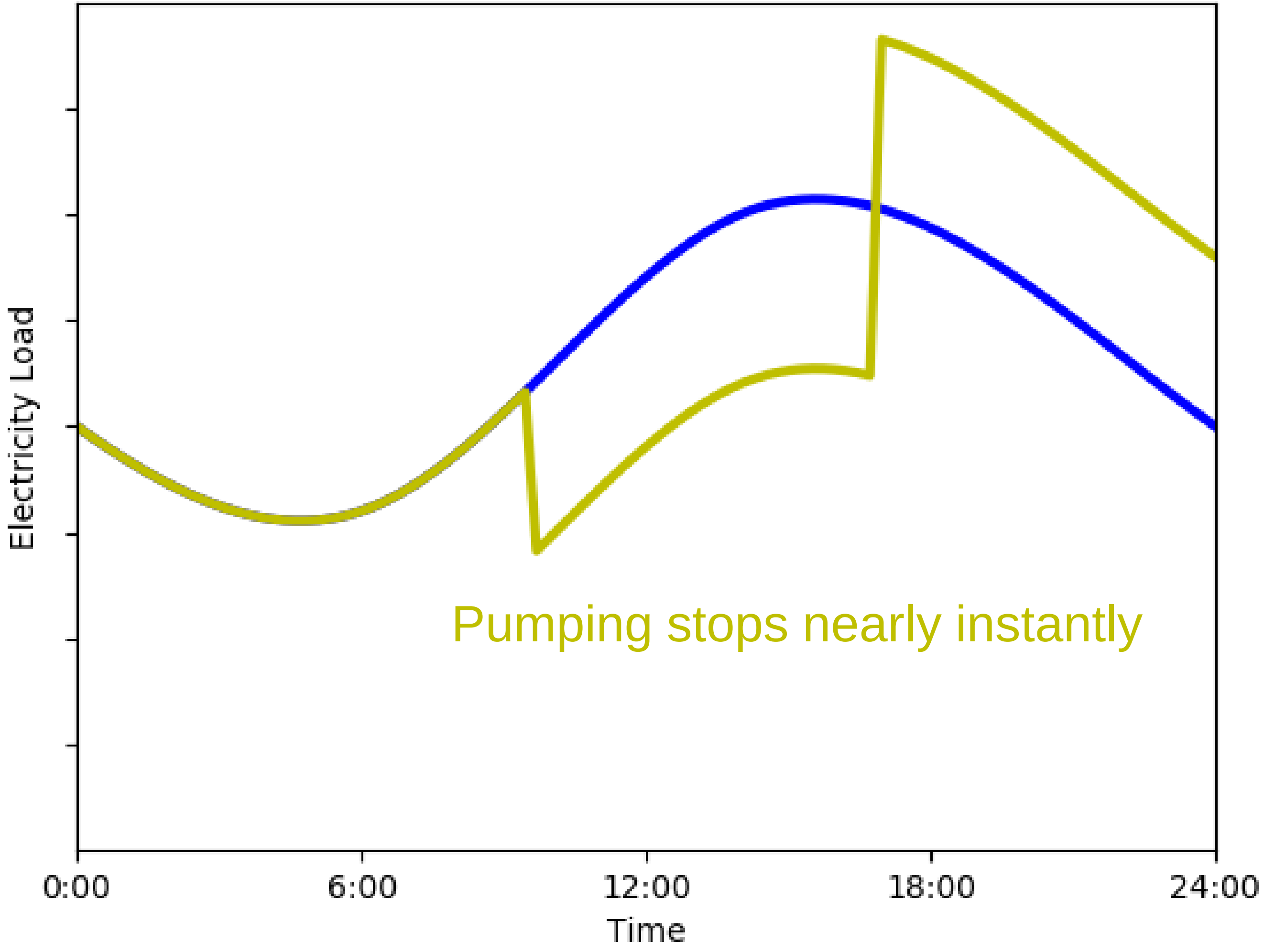
Water systems are ideal DR participants:
Large electricity consumption



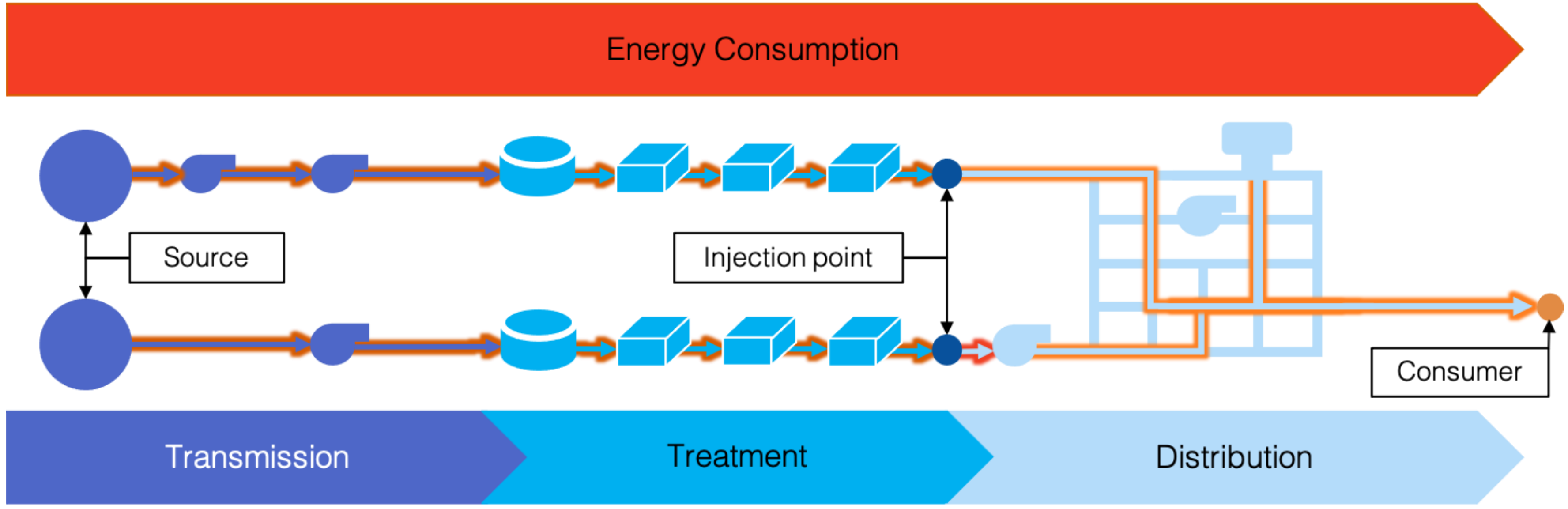
Water systems are ideal DR participants:
Time-flexibility in electricity consumption

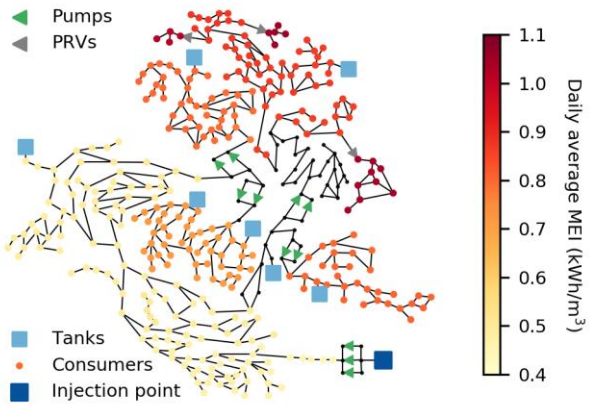


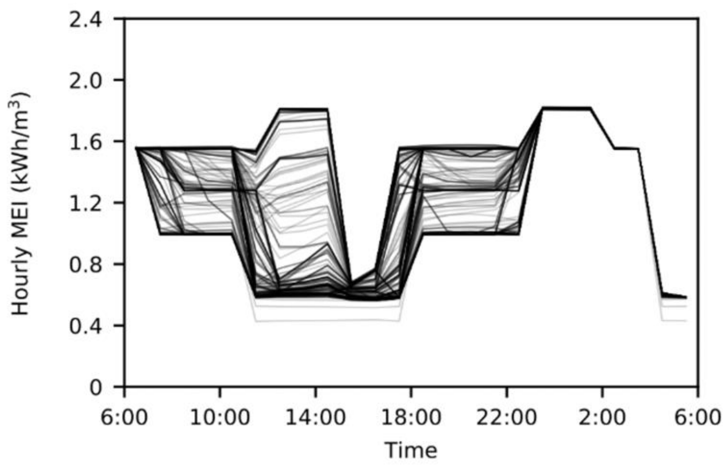
Water systems are ideal DR participants:
Short response time



DR Participation throughout water supply chain







 Yang and Mauter, Applied Energy, 2020; ASCE JWRPM, 2020, Under Review

Predictions for the Water-Energy Nexus in 2020's

- Remaining coal plants face increasingly stringent water quality discharge standards
- Plants more frequently tap non-traditional water sources
- Water becomes an important selection criteria for decarbonization pathways
  - Transition to decarbonized sources radically changes spatial-temporal distribution of cooling water consumption
  - Geologically sequestering carbon requires massive hypersaline brine treatment capacity
  - Increased water consumption by biofuel crops
- Water utilities become a viable DR provider, as well as a place to "spend" excess electrons

Summary of Needs & Opportunities

- Energy-Water Analysis of Integrated Systems (Plant, Region, Nation)
- Improvements for Existing Plants
- Dry Cooling
- Non-traditional Water Treatment
- Treatment of CCS Brines
- Reuse and Effluent Treatment, ZLD
- Enable hydrogen economy
- Innovation (business models, DR, Hybrids, etc.)

WATER MANAGEMENT R&D

Portfolio aligns with existing markets, relevant also to new gas / H2 applications

Market Segments

- **Existing Fleet**
  - **Coal**
  - **Gas**
- **Next Generation Plants**
  - Coal
  - **Next Gen NGCC**
  - **Hydrogen**
  - Gas SCO_2

Technical Challenge Areas

- **Flexible operation and performance optimization**
- Workforce enhancement
- Condition based management
- Asset management
- Cybersecurity
- **Water use optimization**
- **Emissions control**

Funding Opportunity Announcement

DE-FOA-0002399

Objectives

- **Title: Water Management for Thermal Power Generation**
- **Objective: Design, construct, and operate engineering-scale prototypes integrated with power plants.**
- **3 Source Waters:** FGD wastewater, cooling tower blowdown, ash pond and landfill leachate, CCS brines, brackish groundwater, produced waters, agricultural, or municipal wastewater
- **Funding: $1.1M DOE per award + 20% cost share. 3 awards**
- **Closing Date: 1/29/2021**
- **Teaming Partner List Available**

Questions & Answers

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