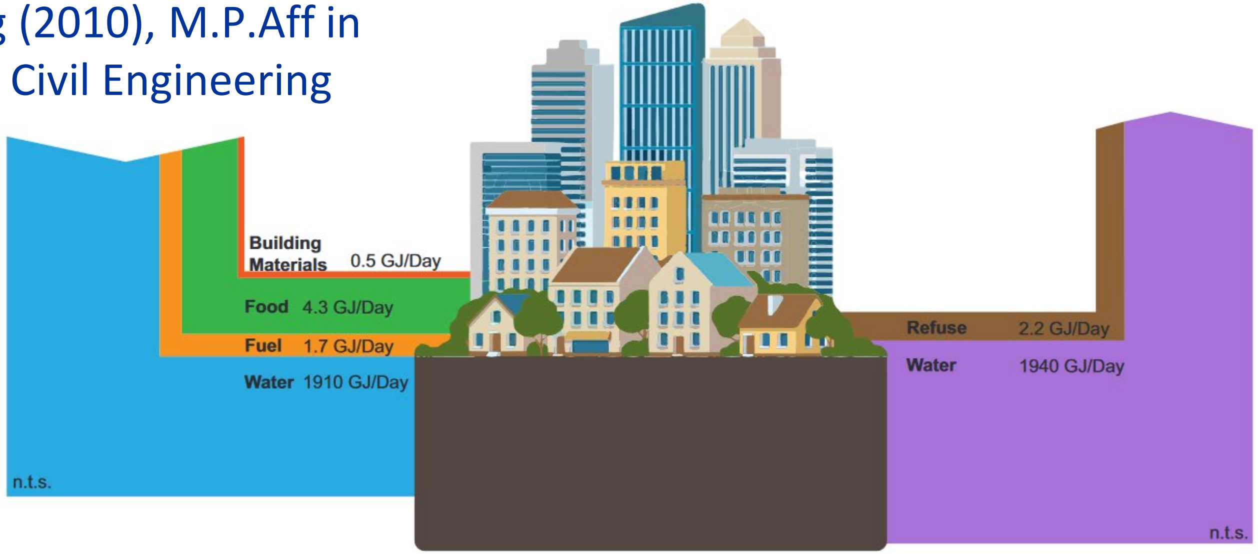
Energy-Water Nexus
Prof. Ashlynn Stillwell

Elaine F. and William J. Hall Excellence Faculty Scholar in Civil and Environmental Engineering

Dr. Stillwell's research focuses on creating sustainable water and energy systems in a policy-relevant context.

She earned a B.S. in Chemical Engineering from the University of Missouri (2006), and an M.S. in Environmental and Water Resources Engineering (2010), M.P.Aff in Public Affairs (2010), and Ph.D. in Civil Engineering (2013) from The University of Texas at Austin.



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Energy-Water Nexus

ENG 471: Energy and Sustainability Engineering Seminar

Ashlynn S. Stillwell

9/27/23

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WATER = ENERGY

Sustainability involves thinking beyond ourselves.

"Our decisions are clearly not made with our descendants in mind."
- Steve Weinberg, Nobel laureate, *Nobelity*, 2006

Energy, water, and the environment are pressing issues.

Top 10 Problems of Humanity in the Next 50 Years
[Rick Smalley, Nobel laureate]

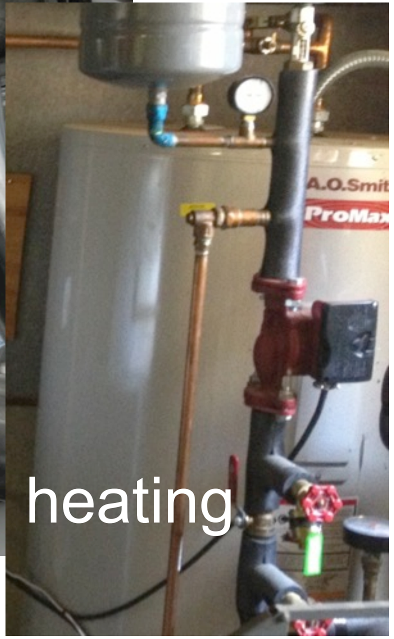
1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism and war
7. Disease
8. Education
9. Democracy
10. Population

"If you moved [energy] to the top of the list, and you imagined a world where that problem was now solved, … you would find that at least 5 of the remaining 9 problems on the list now had a path to a reasonable answer."
- Rick Smalley, Nobel laureate, *Nobelity*, 2006

Energy, water, and the environment are pressing issues.

ENERGY FOR WATER

We use energy for water.



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The water sector uses a lot of energy.

=

"Letting your faucet run for 5 minutes uses about as much energy as letting a 60-watt light bulb run for 14 hours."

[Lawrence Berkeley National Laboratory]

Different water sources have different energy requirements for treatment.

SURFACE WATER
220 kWh/Mgal

GROUNDWATER
620 kWh/Mgal

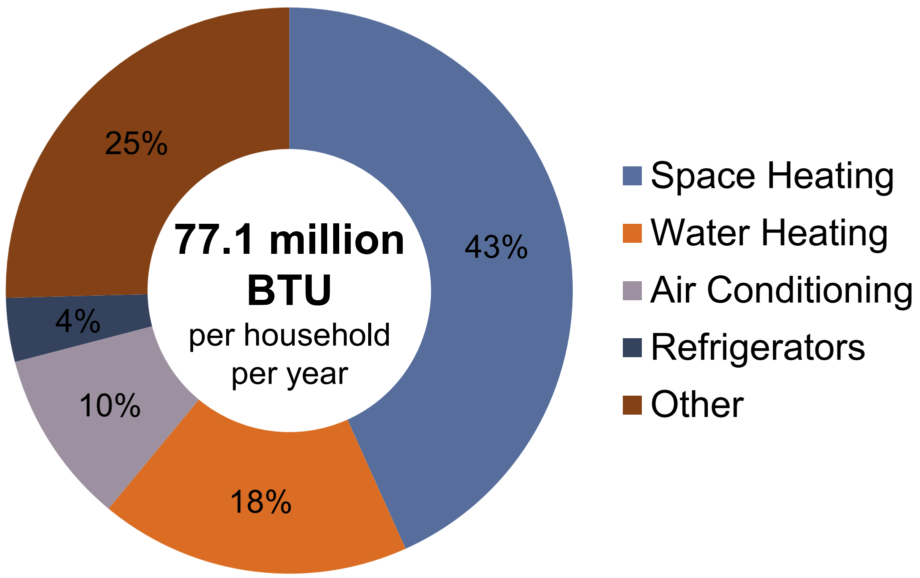
BRACKISH GROUNDWATER
6,800 kWh/Mgal

SEAWATER
13,100 kWh/Mgal

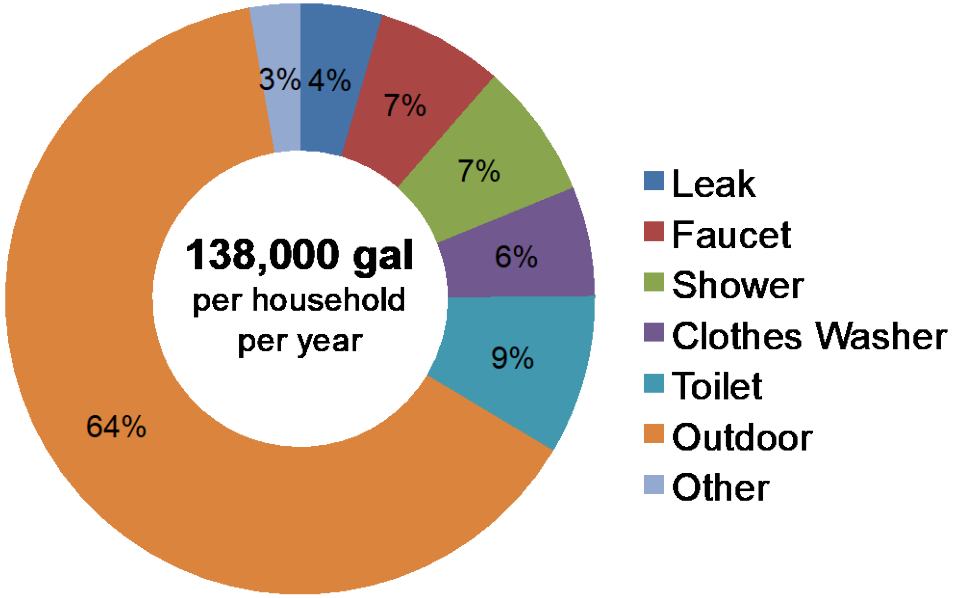
[Stillwell et al., 2011]

How we use water (especially hot water) is poorly understood.

U.S. Residential Energy Consumption
[EIA Residential Energy Consumption Survey, 2020]



U.S. Residential Water Consumption
[WRF Residential End Uses of Water, 2016]



Different wastewater treatment technologies have different energy requirements.

TRICKLING FILTER

950 kWh/Mgal

ACTIVATED SLUDGE

1,300 kWh/Mgal

ADVANCED WITHOUT NITRIFICATION

1,500 kWh/Mgal

ADVANCED WITH NITRIFICATION

1,900 kWh/Mgal

[Stillwell et al., 2011]

Different water approaches have different tradeoffs.

Pro: clean water
Con: more energy, $$$

Pro: matching quality with use
Con: energy, $$

Pro: storage
Con: environmental impacts, $$$$

CONSERVATION & EFFICIENCY

Pro: less energy
Con: $

WATER FOR ENERGY

We use water for energy.

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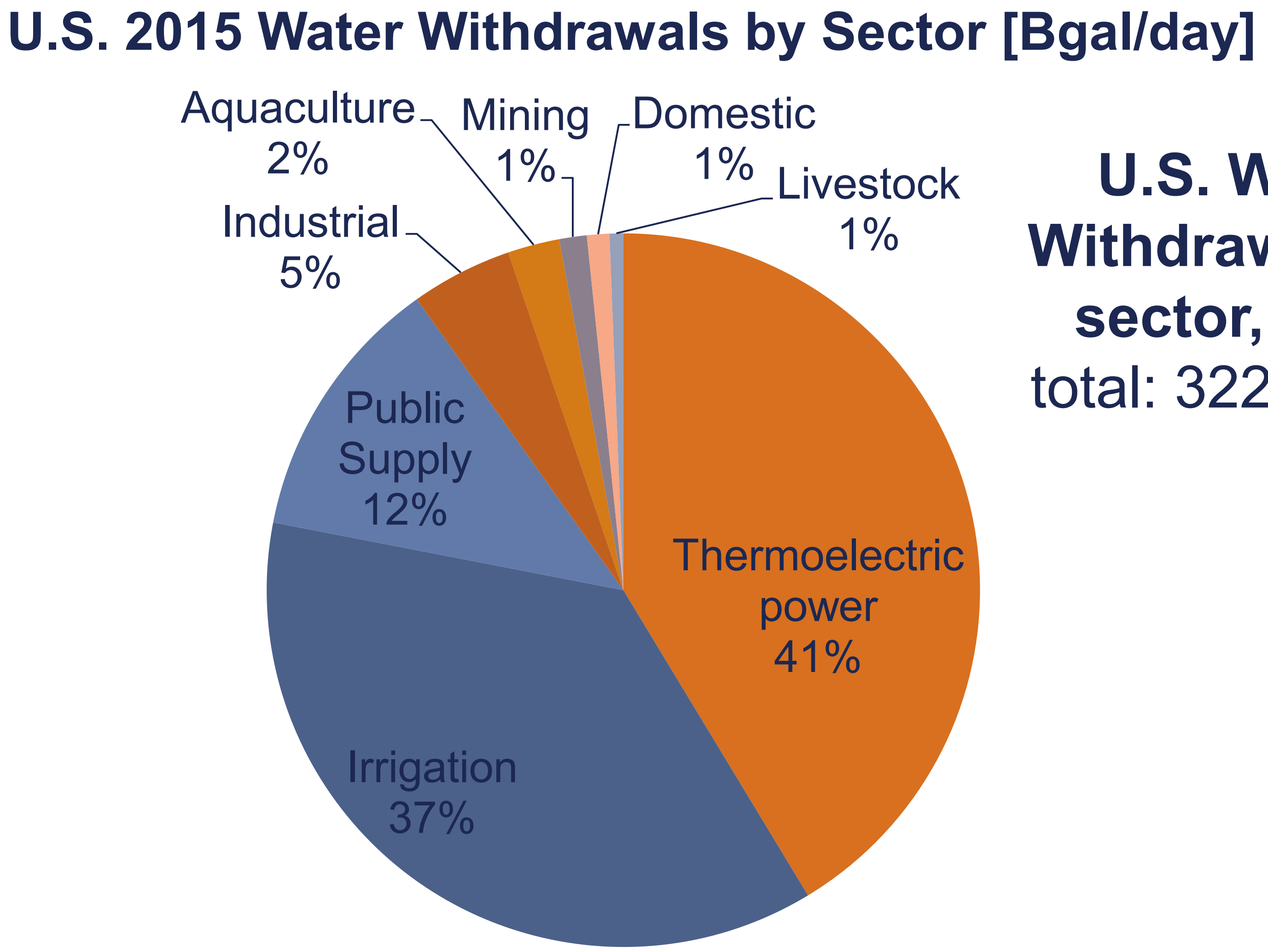
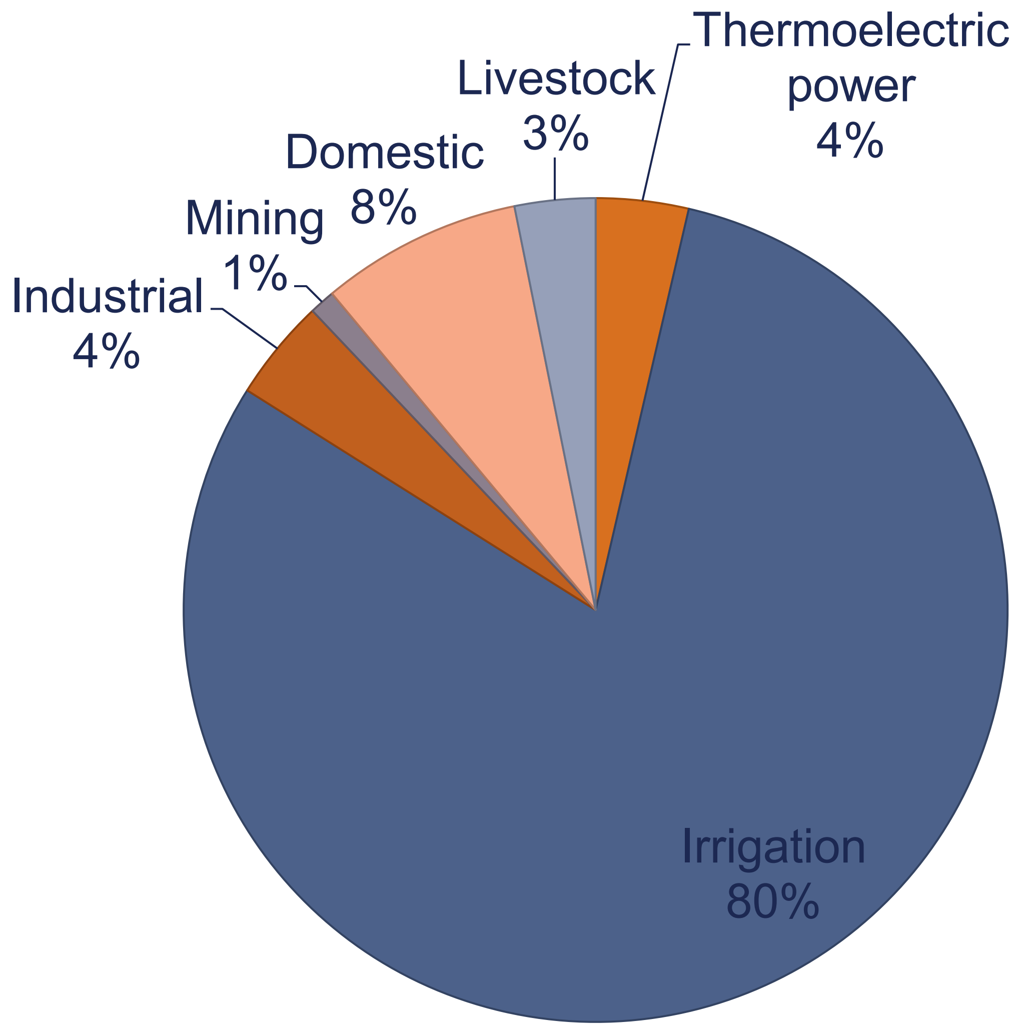
Water withdrawals are dominated by thermoelectric power plants.



U.S. Water Withdrawals by sector, 2015
total: 322 Bgal/d

[USGS, 2018]

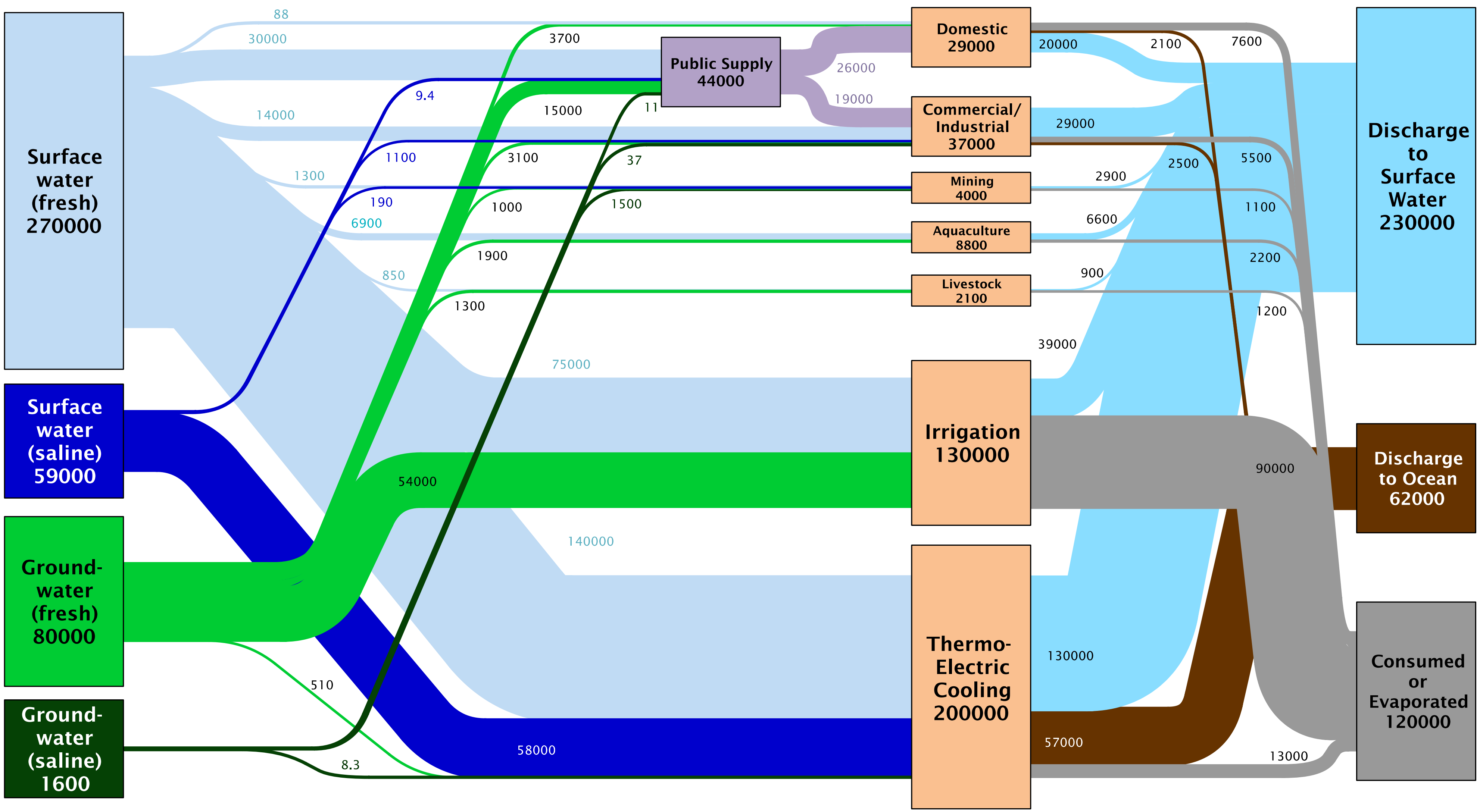
Water consumption is dominated by agriculture.



U.S. Water Consumption by sector, 1995
total: 100 Bgal/d

[USGS, 1998]

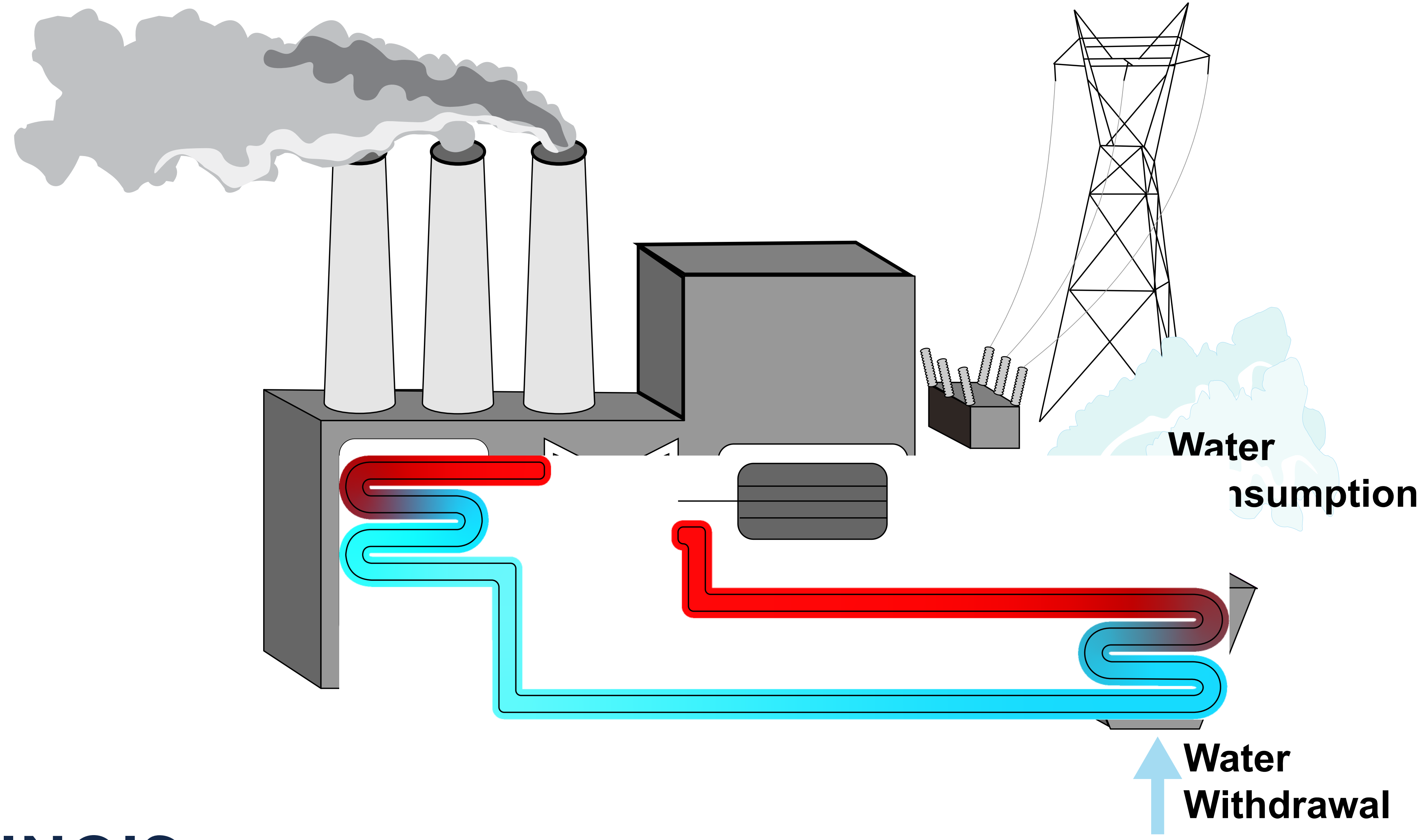
Estimated United State Water Flow in 2005: 410000 Million Gallons/Day



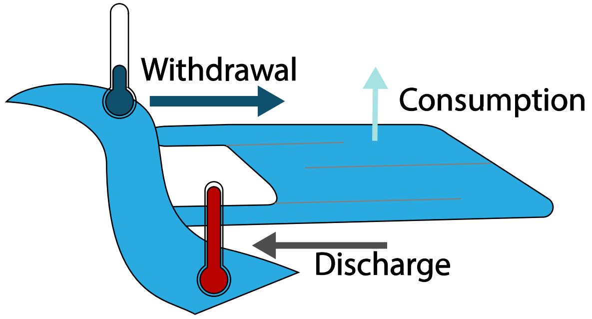
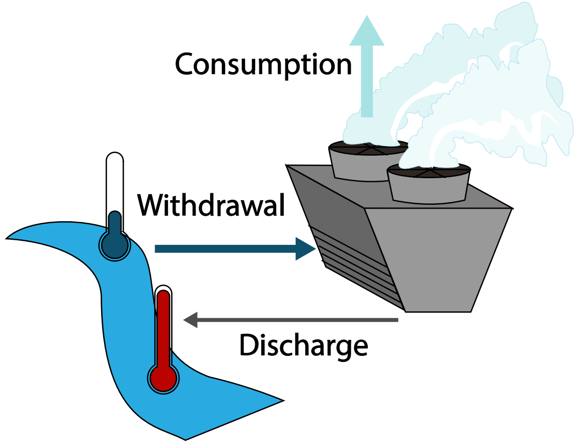
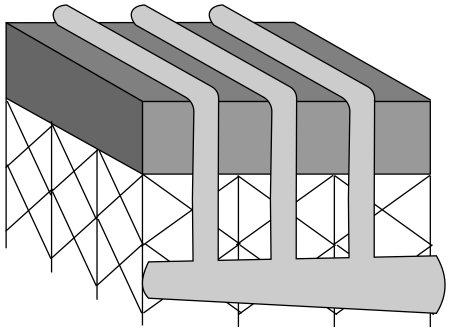
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772

[LLNL, 2011]

Thermoelectric power plants require cooling.



Different cooling technologies can be used for power plant cooling.

	Once-through	Recirculating	Dry
			
Natural Gas Combined Cycle (Macknick et al., 2012)	Withdrawal: 11,380 gal/MWh Consumption: 100 gal/MWh	Withdrawal: 255 gal/MWh Consumption: 205 gal/MWh	Withdrawal: 2 gal/MWh Consumption: 2 gal/MWh

Different electricity fuels have different water requirements.

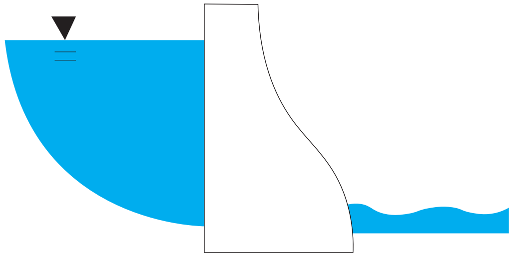
*Withdrawal and consumption for closed-loop cooling**

*minimum technology for new power plants

Coal
withdrawal: 539 gal/MWh
consumption: 487 gal/MWh

Natural Gas
withdrawal: 265 gal/MWh
consumption: 217 gal/MWh

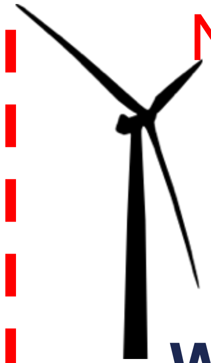
Nuclear
withdrawal: 1,150 gal/MWh
consumption: 758 gal/MWh

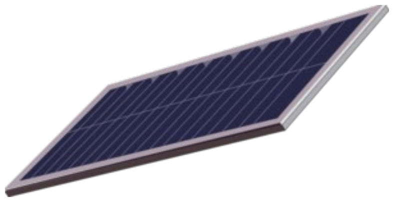


Hydropower
consumption: 1,617 gal/MWh

Geothermal
consumption: 270 gal/MWh

Not dispatchable





Wind & PV
withdrawal: 0 gal/MWh
consumption: 0 gal/MWh

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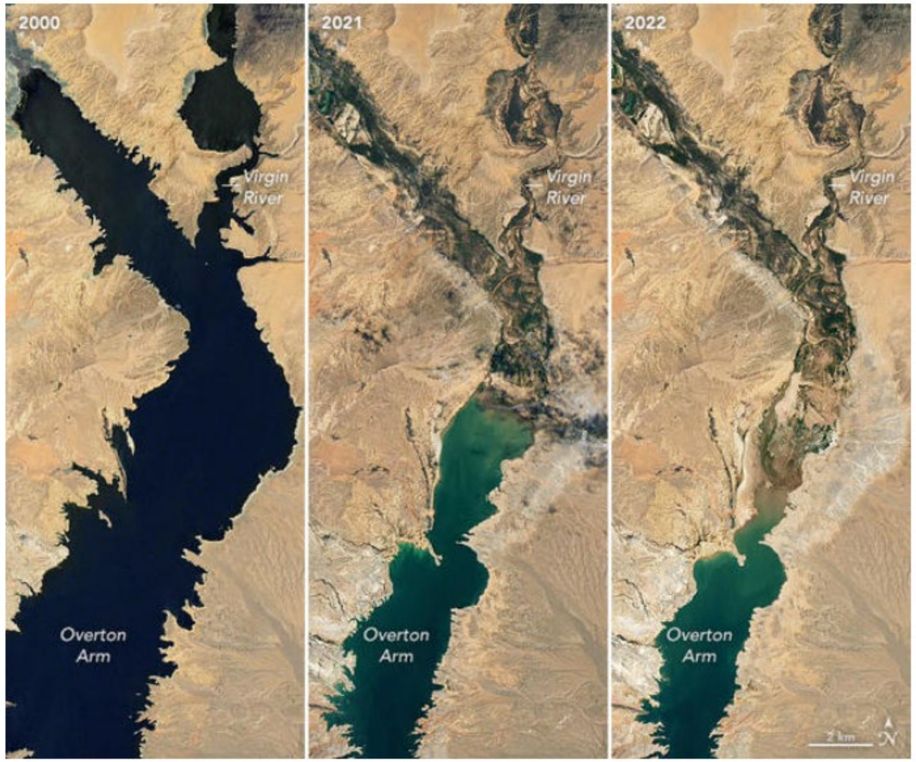
[Peer et al., 2016; Grubert, 2012; Macknick et al., 2012]

Higher water temperatures and lower water levels threaten electricity generation.

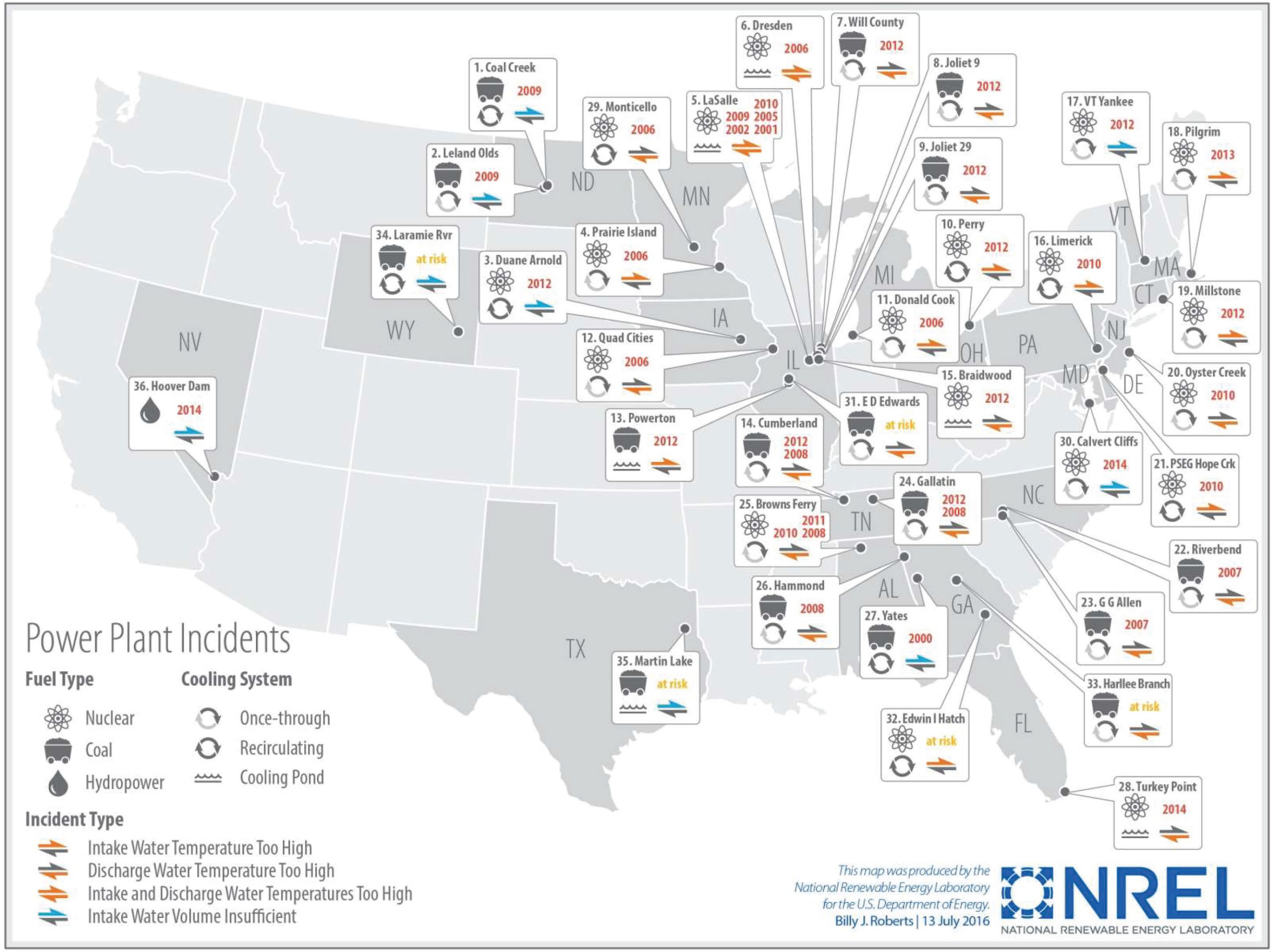
Lake Mead's water level has never been lower. Here's what that means.

BY EMILY MAE CZACHOR
UPDATED ON: SEPTEMBER 4, 2022 / 9:25 AM / CBS NEWS



This composition shows the difference in water levels at Lake Mead from July 6, 2000 to July 3, 2022.

NASA EARTH OBSERVATORY



[CBS News, 2022; NREL, 2016]

Different transportation fuels have different water requirements.

Gasoline & Diesel
withdrawal: 0.55 gal/mile
consumption: 0.08 gal/mile

Electricity
withdrawal: 7.8 gal/mile
consumption: 0.24 gal/mile

Natural Gas
withdrawal: 1.7 gal/mile
consumption: 0.06 gal/mile

H_2

Hydrogen
withdrawal: 13 gal/mile
consumption: 0.42 gal/mile

Biofuels
withdrawal: 0.49 gal/mile
consumption: 0.30 gal/mile

Irrigated Biofuels
withdrawal: 16 gal/mile
consumption: 11 gal/mile

[King & Webber, 2008]

Hydraulic fracturing increases water requirements over conventional natural gas.

Conventional Natural Gas
consumption: 0.2 gal/MMBTU

Natural Gas from Hydraulic Fracturing
(average for Texas)
consumption: 3.0 gal/MMBTU

Lignite Coal
consumption: 16 gal/MMBTU

[Grubert et al., 2012]

Different energy approaches have different tradeoffs.

Pro: no water
Con: less efficiency, space, $$$

CO_2

carbon capture
and sequestration

Pro: less carbon
Con: more water, less efficiency, $$$

CONSERVATION & EFFICIENCY

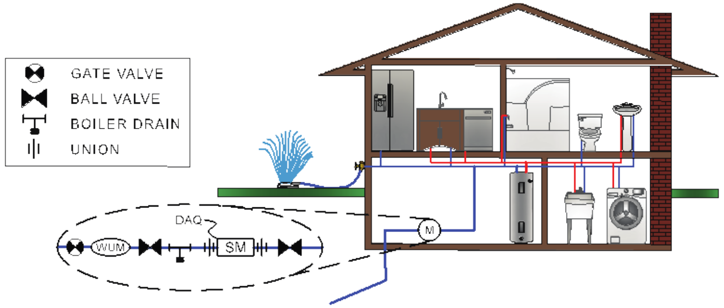
Pro: less water, less carbon
Con: $

renewables

Pro: no carbon, no water
Con: not dispatchable

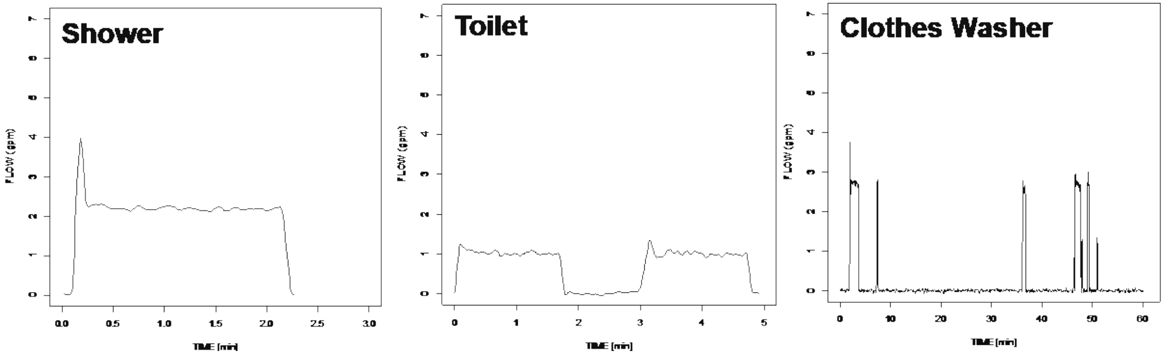
Managing (energy, water, infrastructure, climate change, risk, etc.) starts with measuring.

On-going research: Using data to inform sustainability.



Residential smart electricity metering

Residential smart water metering



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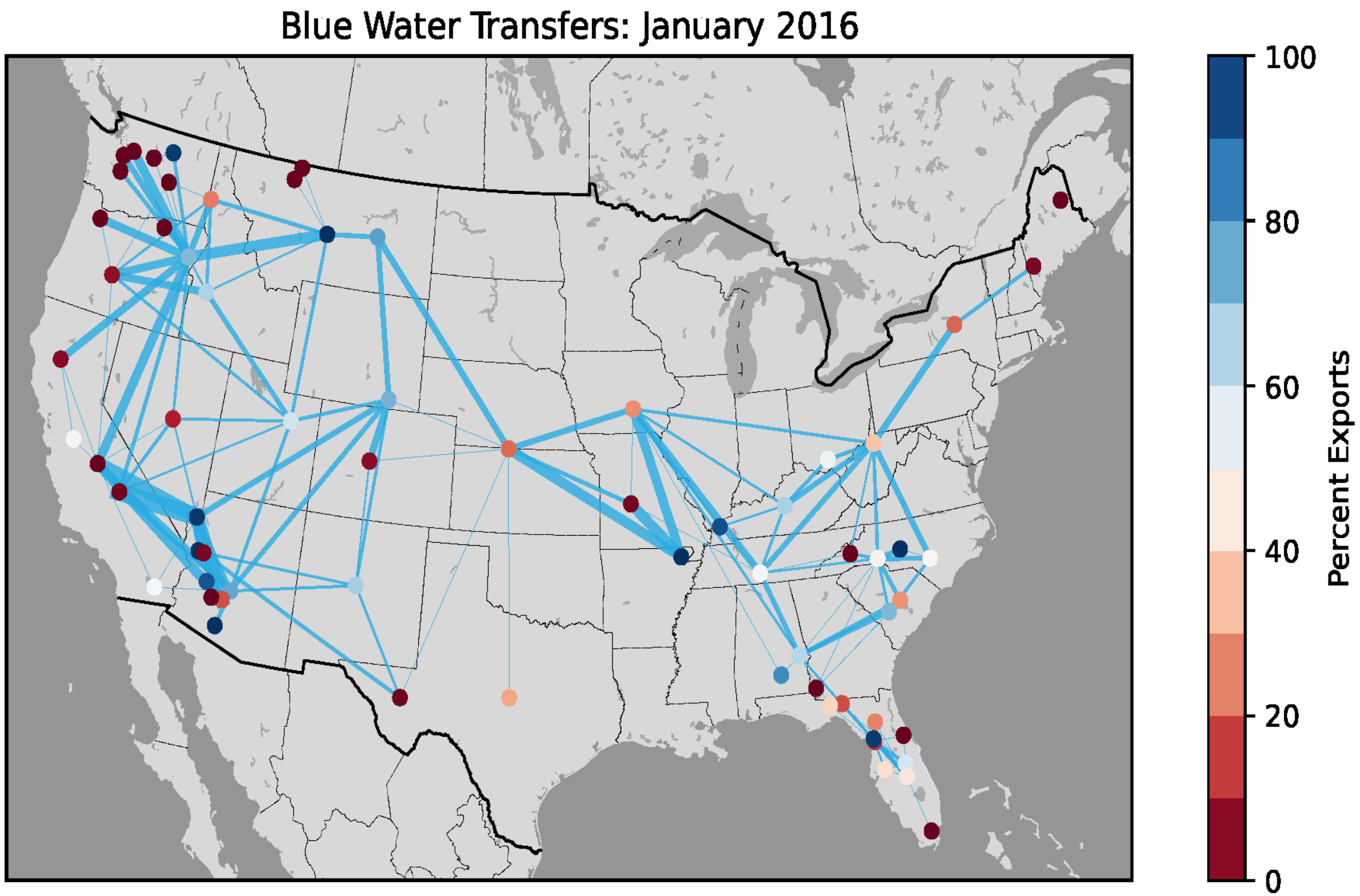
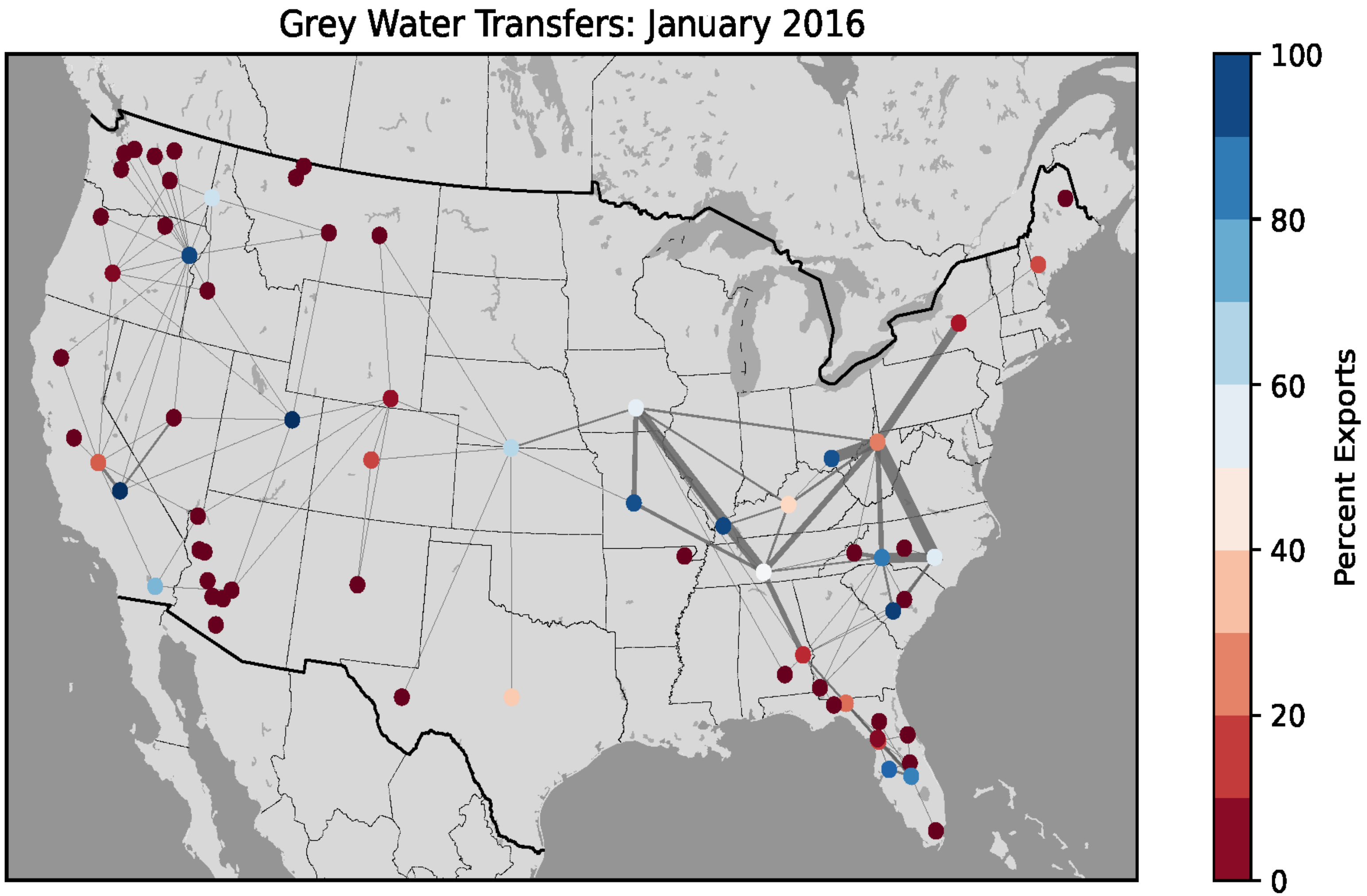
Virtual blue water transfer vary seasonally in both time and space.



[source: Nugent et al., 2023]

Virtual grey water transfers are dominant in the eastern U.S. where older once-through power plants are prevalent.



[source: Nugent et al., 2023]

WATER = ENERGY

CEE 433: Water Technology & Policy.

- Spring semester; 3-credit or 4-credit sections; T Th, 8:00-9:20
- Topics: hydrology; water law; infrastructure; financing; water and wastewater treatment; water markets and economics; water in energy, agriculture, food, bottled water
- Field trips, guest speakers

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