Energy in Water

Michael E. Webber

DoE Desalination Workshop

Dallas, TX

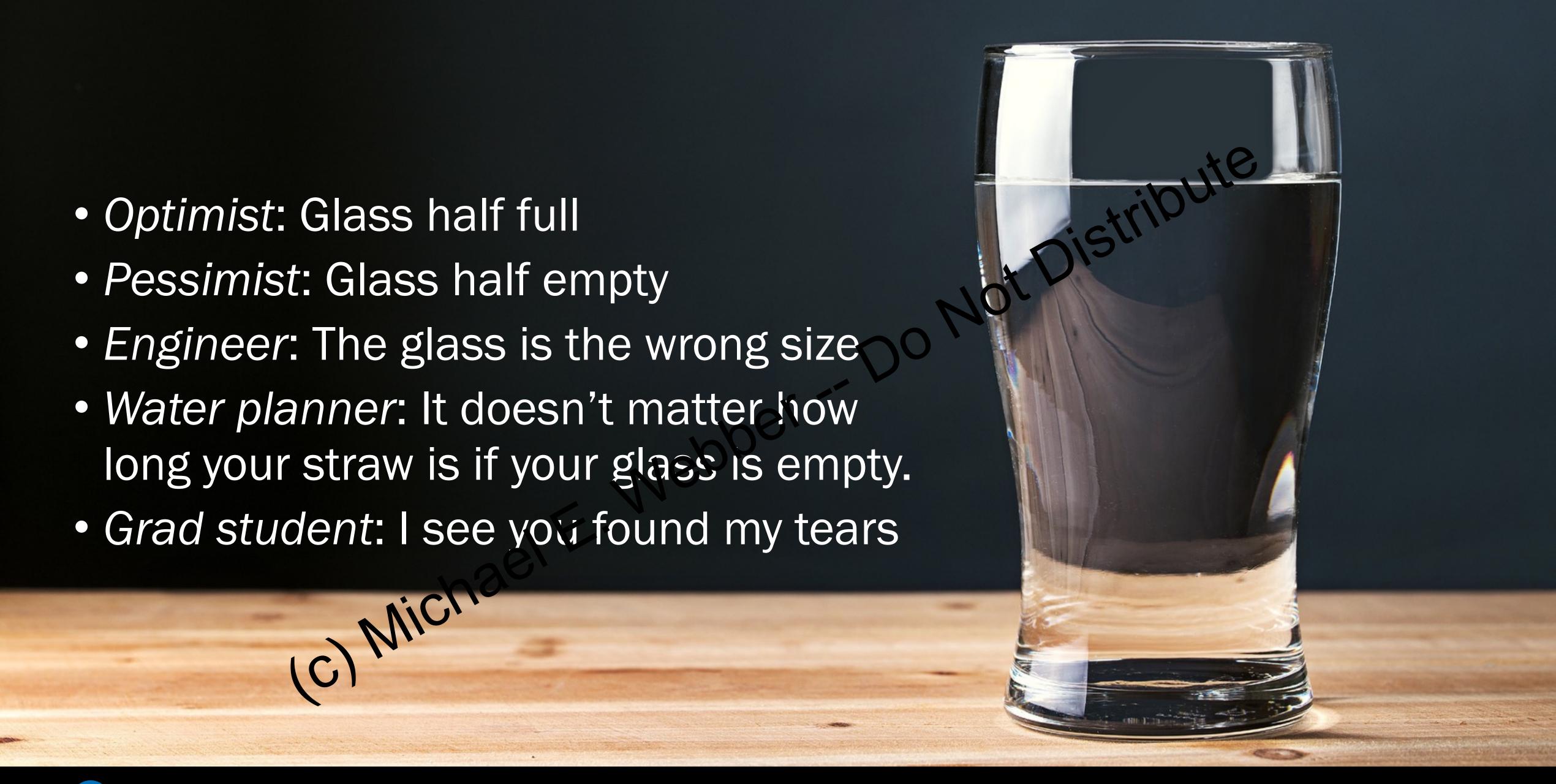
July 10, 2017



Webber Energy Group

We Use Water To Define Our Outlook On Life





Energy and Water Are Interconnected

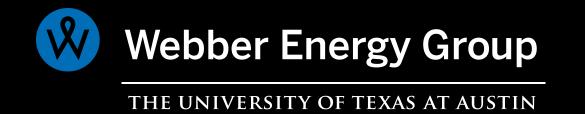
Dr. Michael Webber



Energy in Water July 10, 2017

The Nexus of Energy and Water is Particularly mportant

- We use energy for water
- We use water for energy
- Opportunity:
 - Infinite energy gives infinite water, and vice versa
- Bad news: cross-cutting vulnerabilities
 - Water problem accomes energy problem, and vice versa
- Good news: cross-cutting solutions



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Energy in Water

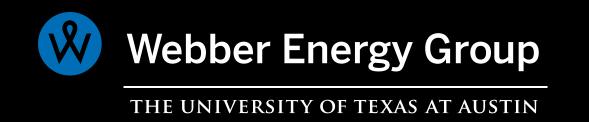
Energy Can Be Used To Improve Water Quality



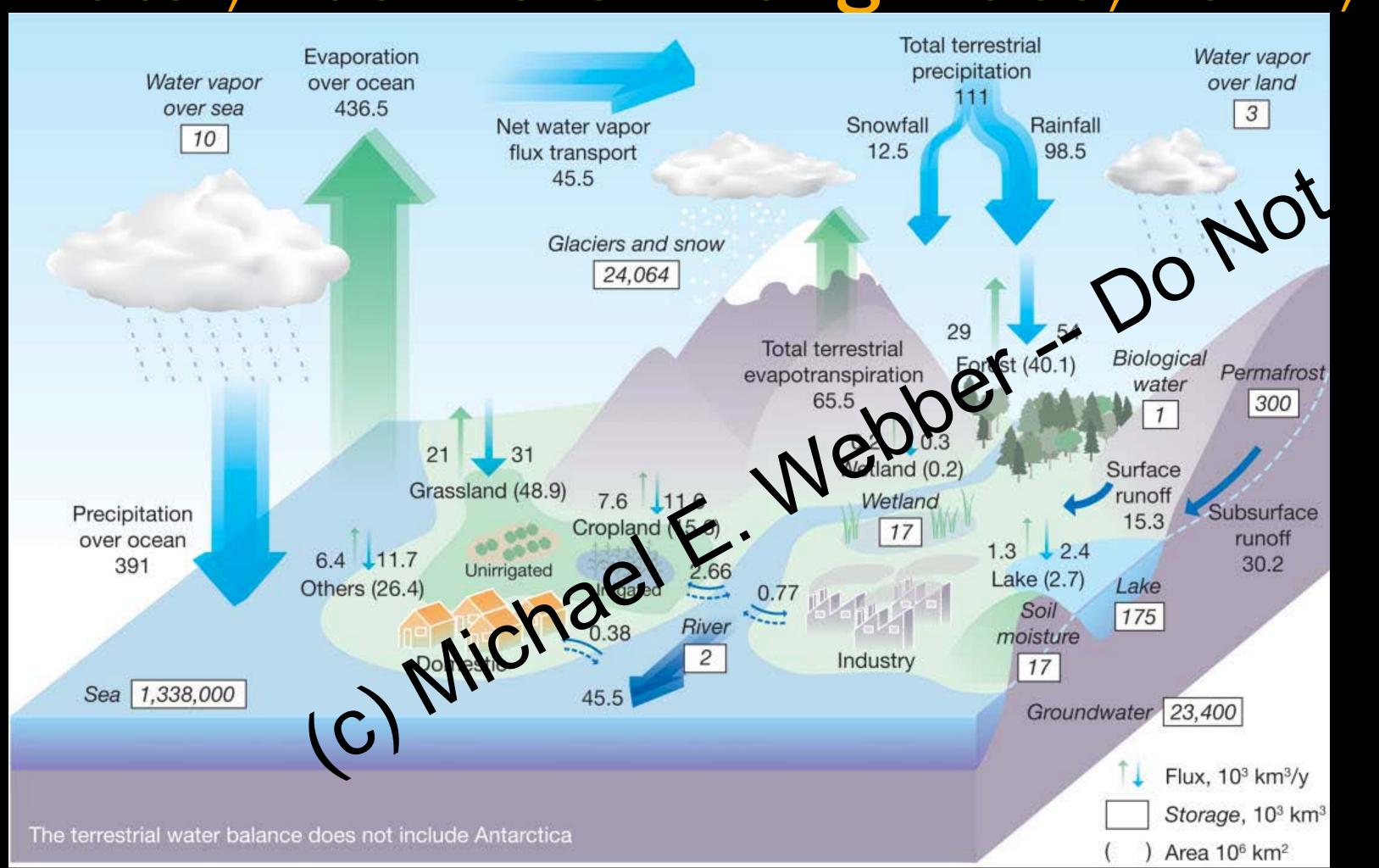
UPDATE: Boil-water advisory still in effect for parts of Atlanta

Becca J. G. Godwin - The Atlanta Journal-Constitution

Updated 8:27 a.m. Friday, July 7, 2017 Filed in Neighborhoods



The Hydrologic Cycle is Global and Has Plenty of Water, But In the Wrong Place, Form, or Time of Year



97.5% Saltwater 2.5% Freshwater

[Taikan Oki, et al., Science, August 25, 2006]

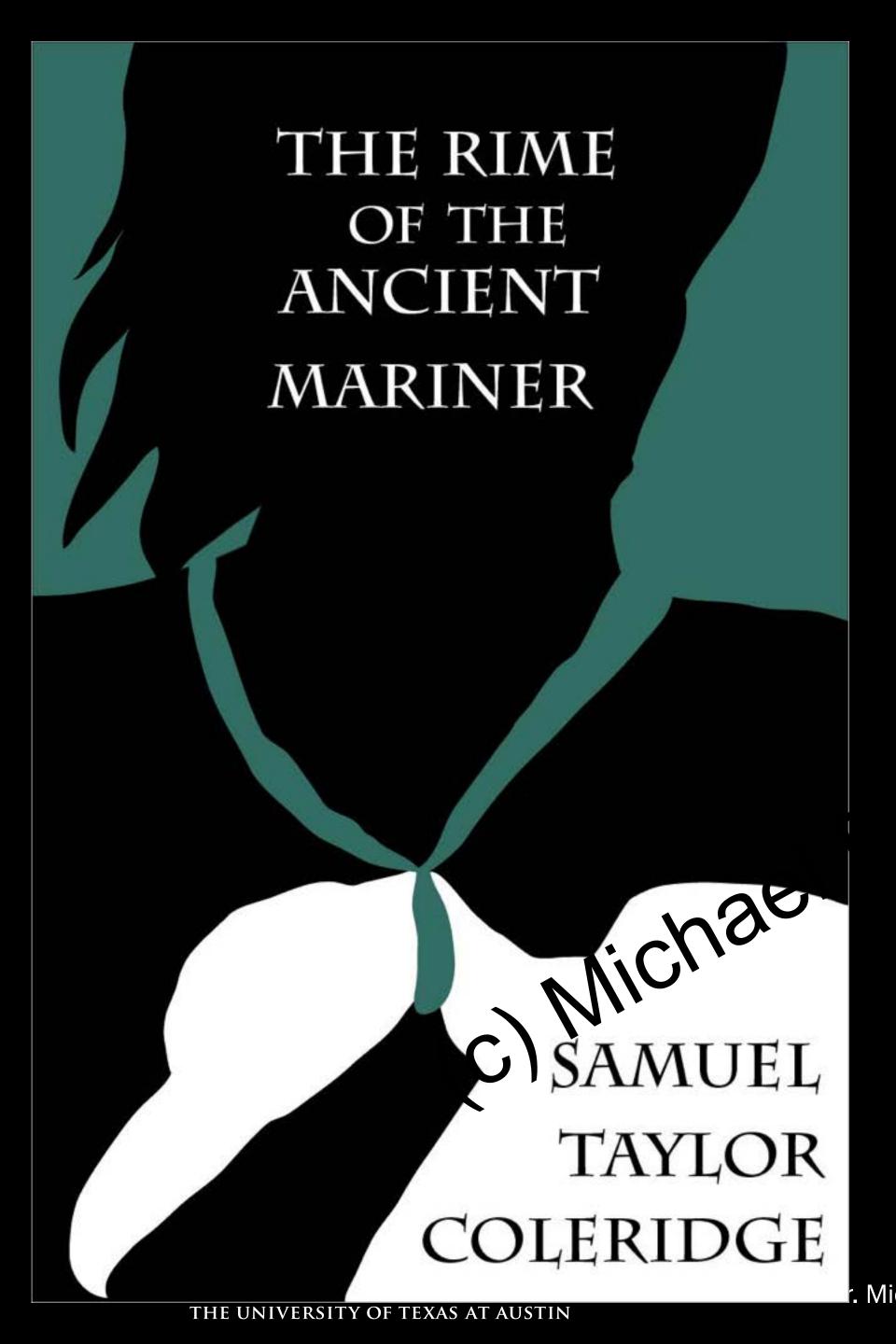


Some of Our Mythology, Art and Literature Captures The Torture of Water That Is Just Out of Reach Or Needs Treatment



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"Water, water, every where, Nor any drop to drink."

Samuel Taylor Coleridge, 1798



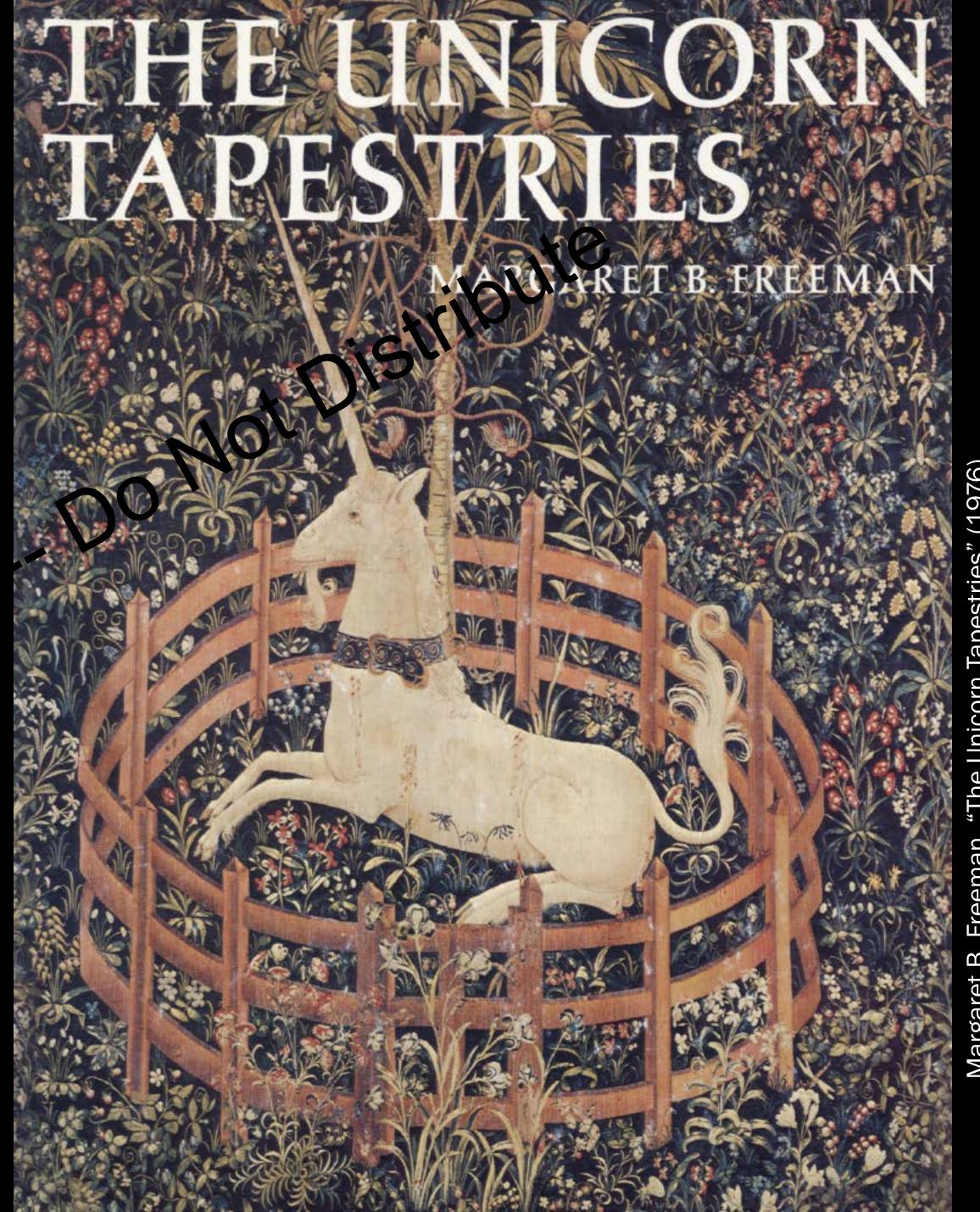
The mythical Greek Figure

Tantalus was punished with

eternal thirst and placed in a pond
whose water would recede out of
reach

Root of the word "tantalize"

Late 15th Century tapestries show the Hunt of the Unicorn





The Unicorn's Horn Made Water Safe To Drink

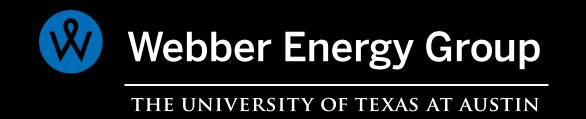
The Unicorn Dips His Horn into the Stream to Rid It of Poison



We Use Energy for Water

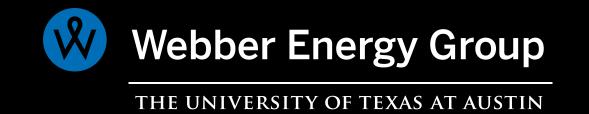
We either move the people to the water or move the water to the people

- Conveyance
- Pumping
- Treating
- Heating
- Chilling
- Pressurizing

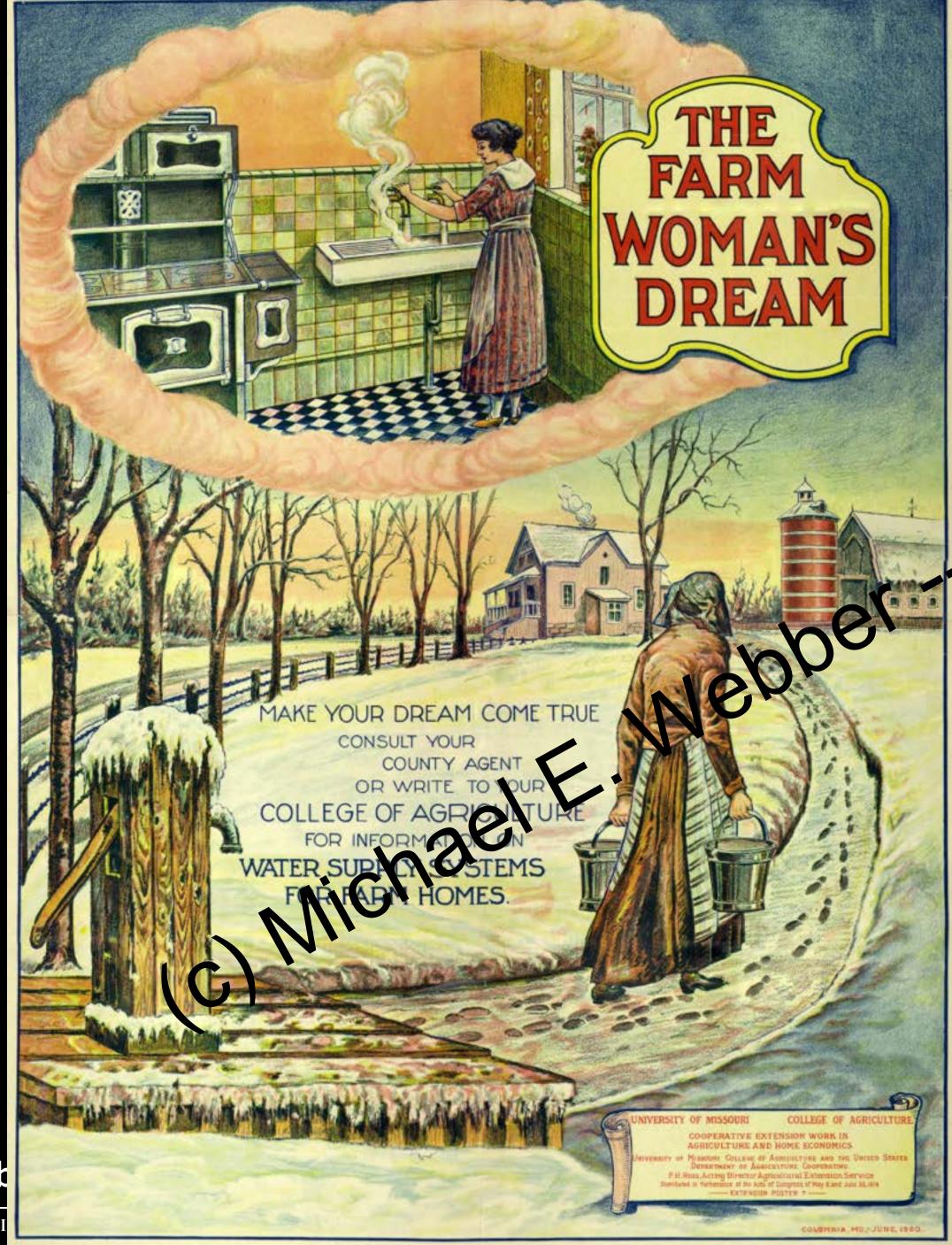


In Many Parts of the World, It Is The Woman's Responsibility To Fetch Water





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Less Than A Century Ago, That Woman Was American

Piped water systems liberate women

Source: Univ. of Missouri & U.S. Department Of Agriculture, 1920

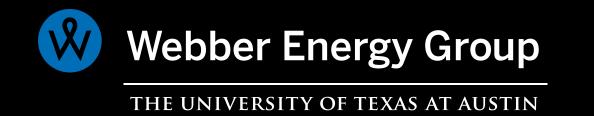


Energy in Water July 10, 2017 **15**

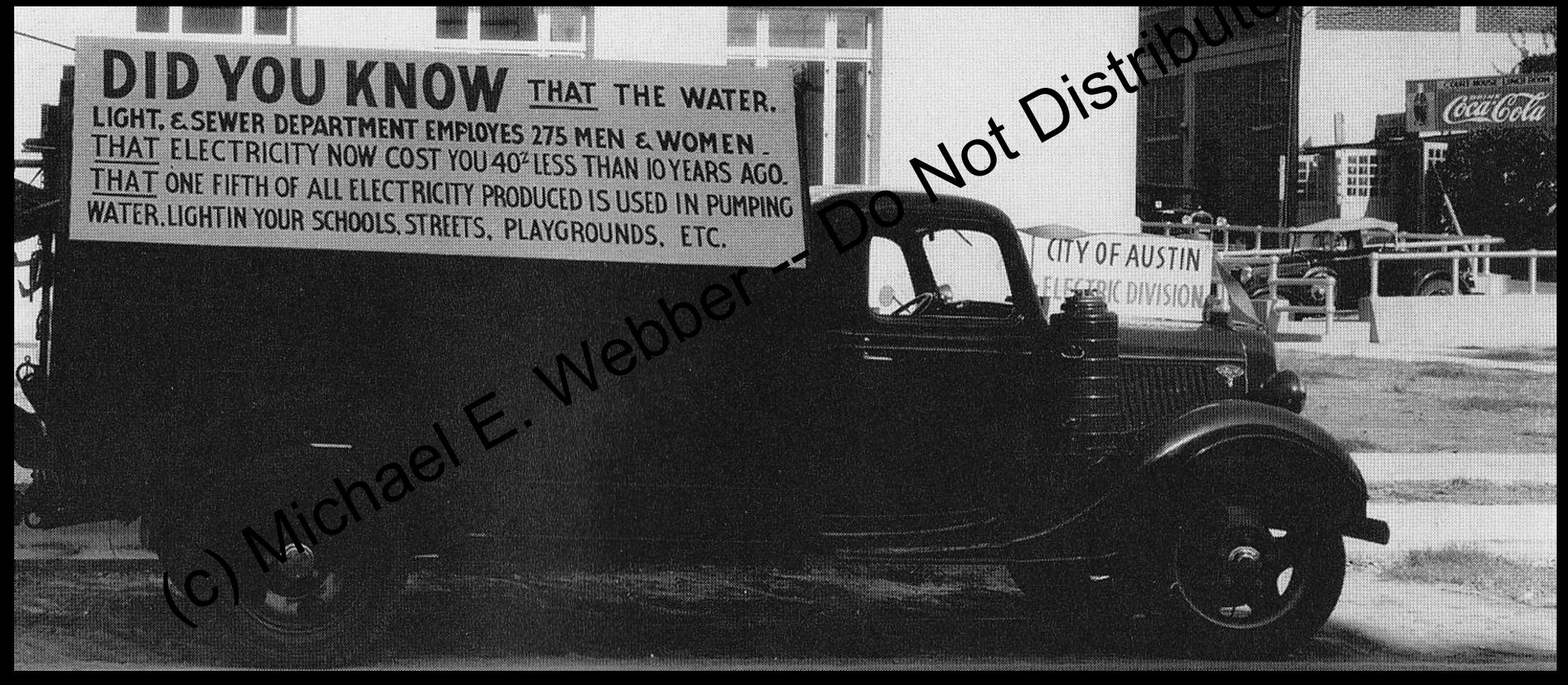
Pumping Water by Hand:

Yesterday's Chore Is Today's Fun





In the 1930s, 20% of All Electricity in Austin, Texas Was For Pumping Water And Lightin Streets



Source: Remembering Austin, Marsia Hart Reese, 2010

Dr. Michael Webber



13% of all energy is for steam and heating, treating and pumping water

Evaluating the energy consumed for water use in the United States

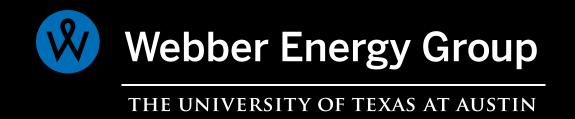
Kelly T Sanders and Michael E Webber

OP PUBLISHING

ENVIRONMENTAL RESEARCH LETTERS

Environ. Res. Lett. 7 (2012) 0340.

doi:10.1088/1748-9326/7/3/034034



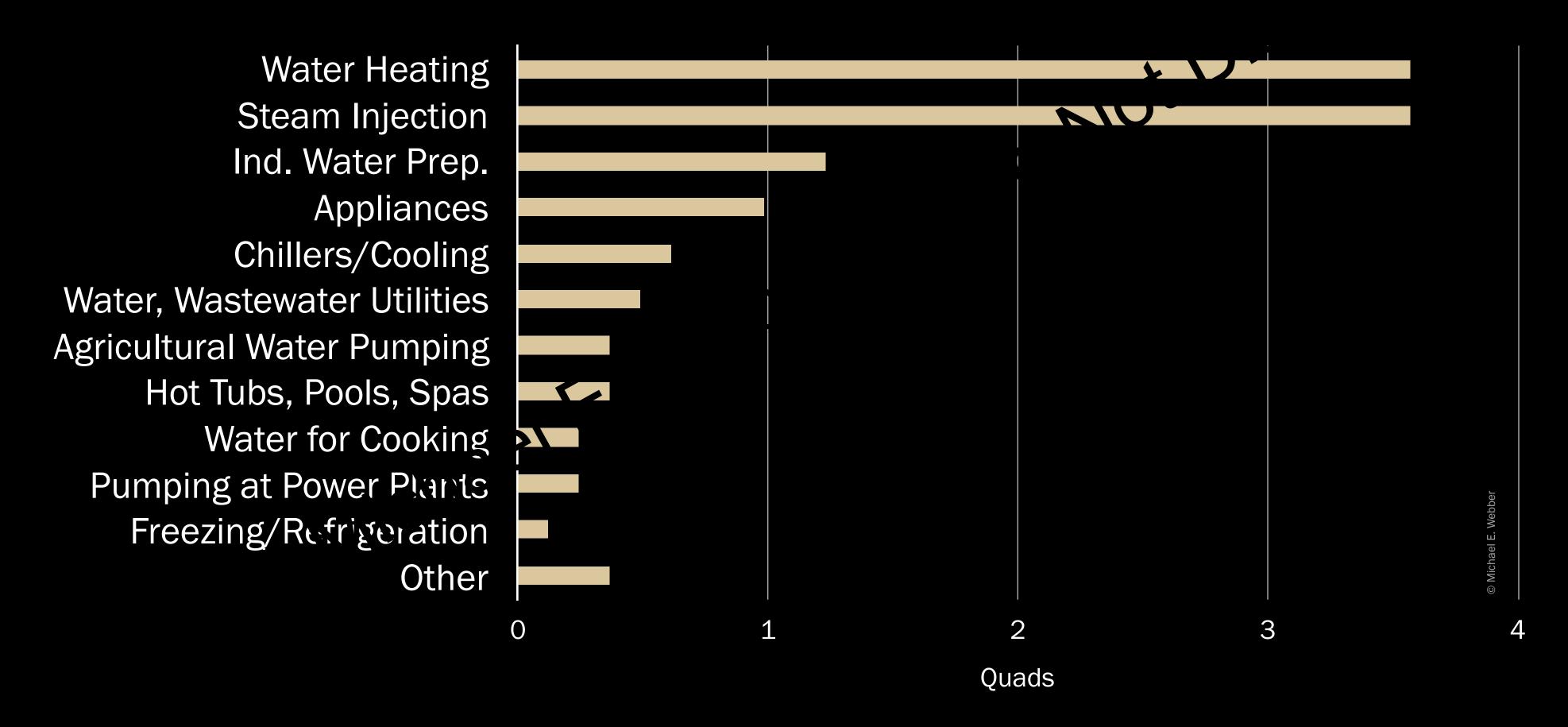
Source: Sanders & Webber, 2012

18 July 10, 2017 Dr. Michael Webber **Energy in Water**

Direct Water and Direct Steam Services: 12.3 Quads in the USA

U.S. Energy Consumption for Direct Water and Direct Steam Services

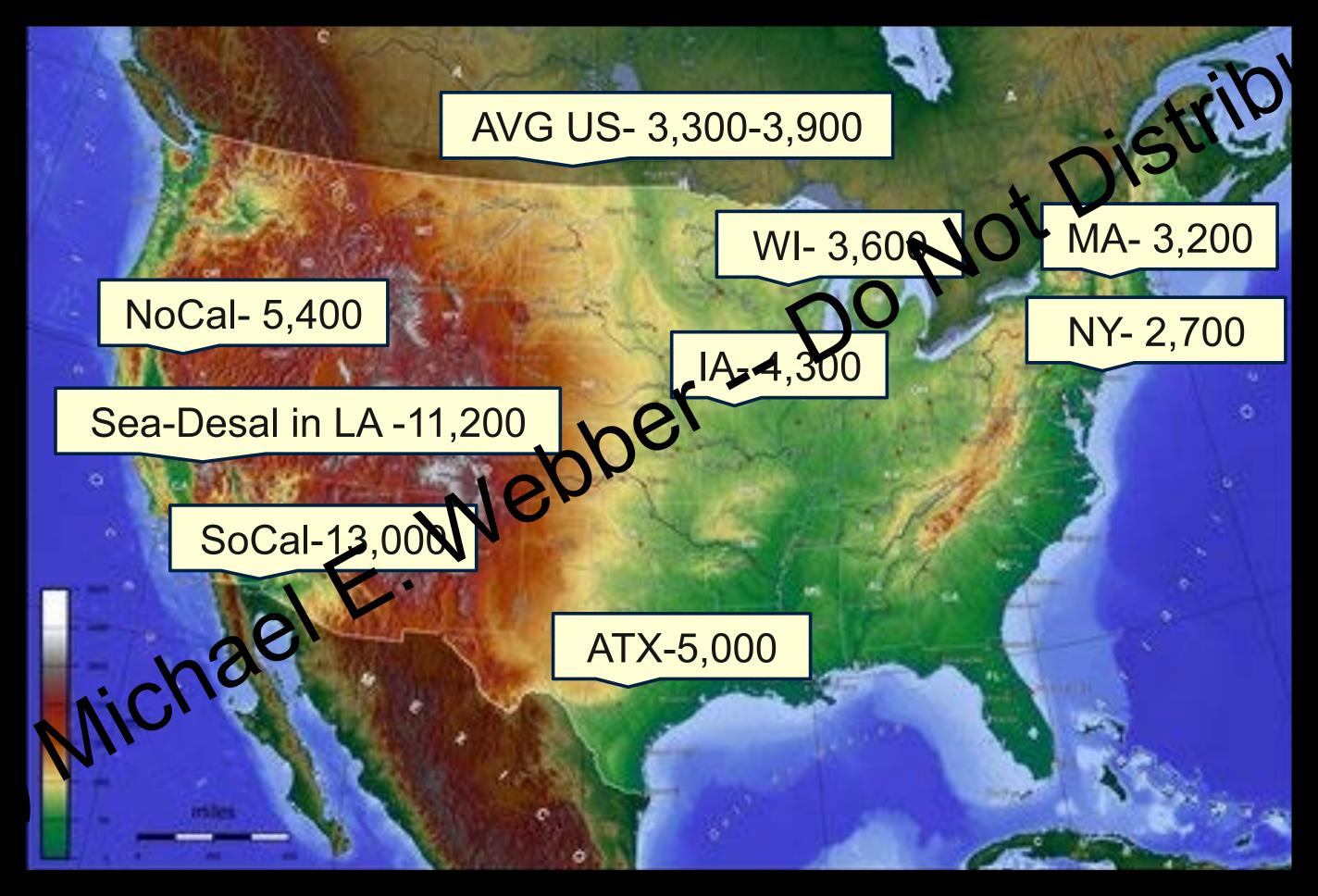
Source: Sanders & Webber (2012) • Graphic: Michael E. Webber, The University of Texas at Austin





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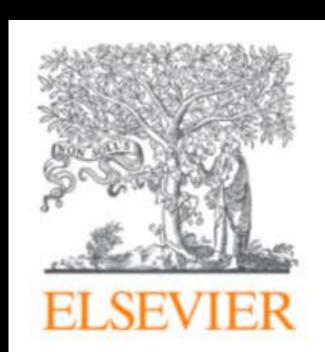
The Energy Intensity of Water Varies Nationally



*All values in units of kWh per million gallons, including water and wastewater treatment Figure courtesy K.T. Sanders, Source: DoE Buildings Energy Data Book



Water heating technologies also vary geographically: electric and gas dominate



Energy th 2011 Volume 81, 1 March 2015, Pages 317-327



Evaluating the energy and CO₂ emissions impacts of shifts in residential water beating in the United States

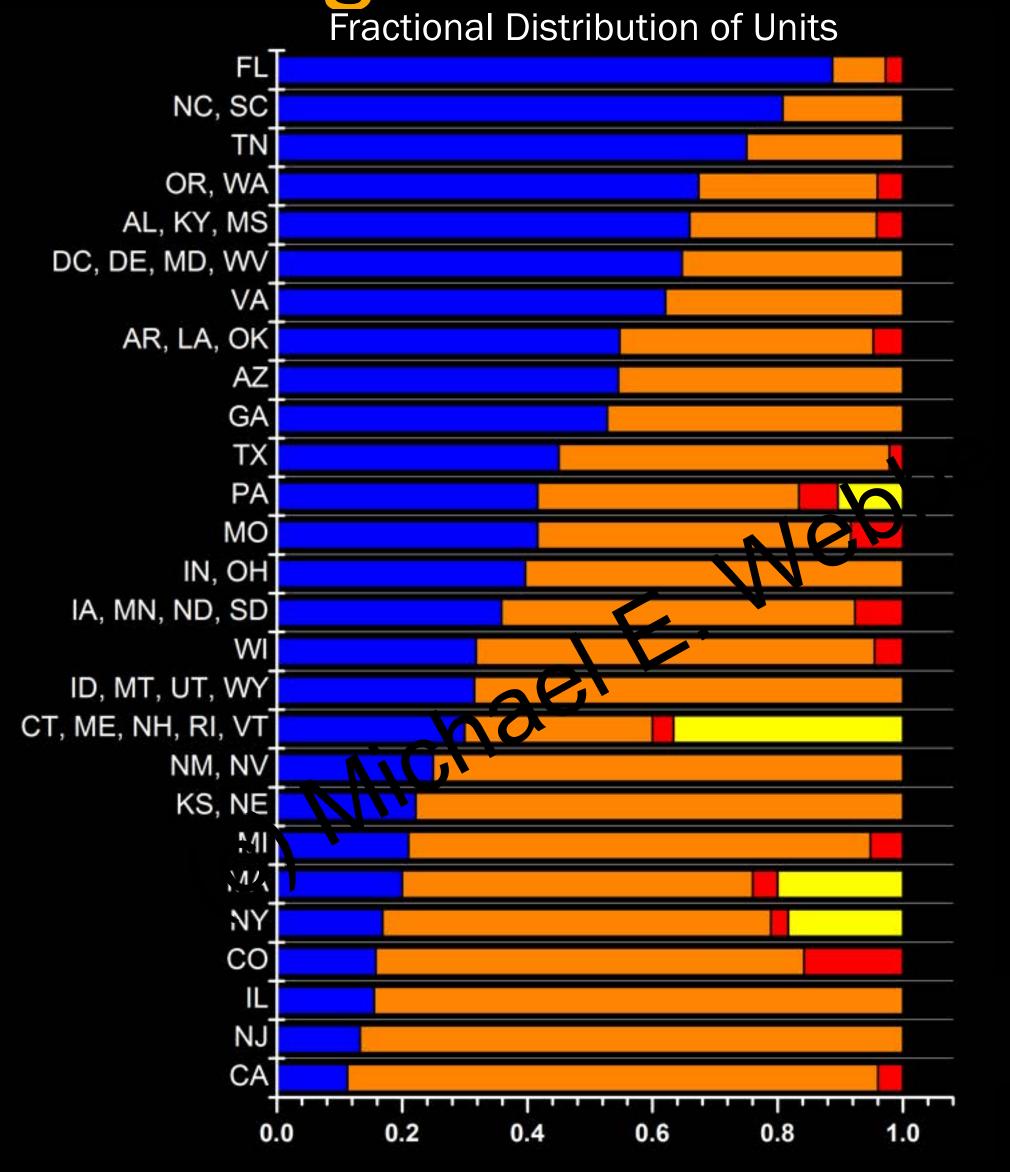
Kelly T. Sander M., Michael E. Webber b, *



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Water heating technologies also vary geographically:

electric and gas dominate



 US Water Heating Unit Inventory in 2009:

-Flectric: 41%

-Natural gas: 52%

-Fuel oil: 4%

-LPG: 7%

-Solar: Trivial

[Data: EIA RECS 2009]

Courtesy: Sanders (2013)



Energy for Desalination Varies

- Factors under consideration: Treatment capacity, source water salinity, product water salinity, flow rate, pressure, energy recovery, first year of operation of plant
- Key finding: 80% of specific energy consumption (SEC) is determined by
 - –Source water salinity
 - First year of operation
- The correlation between SEC and cost is weak

Predicting the Specific Energy Consumption of Reverse Oxnosis Desalination

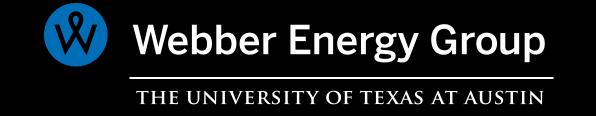
Ashlynn S. Stillwell 1,* and Michael E. Webber 2

Water 2016, 8, 601; doi:10.3390/w8120601



The Energy-Water Relationship is Already Under Strain

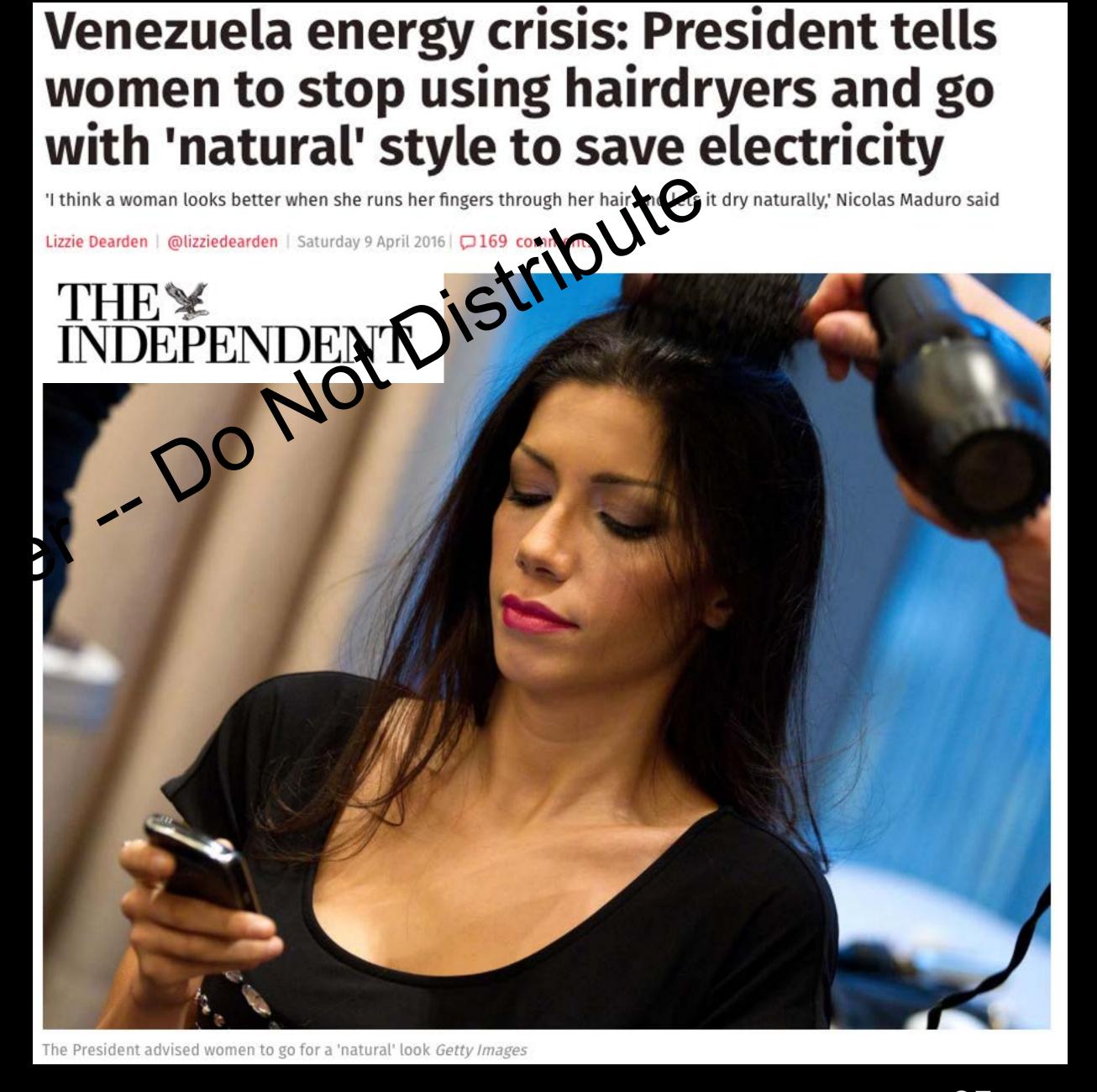
- Water Constraints Become Energy Constraints
- Energy Constraints Become Water Constraints

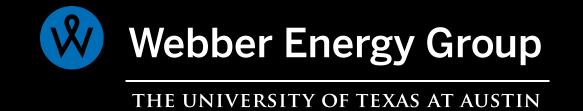


Drought Is Forcing Venezuelans To Give Up Their Hair Dryers

"The President of Venezuela has urged women to stop using hairdryers and offered alternative styling tips as the country's energy crisis continues."

Dr. Michael Webber





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Tea Kettles Are Very Power Intensive

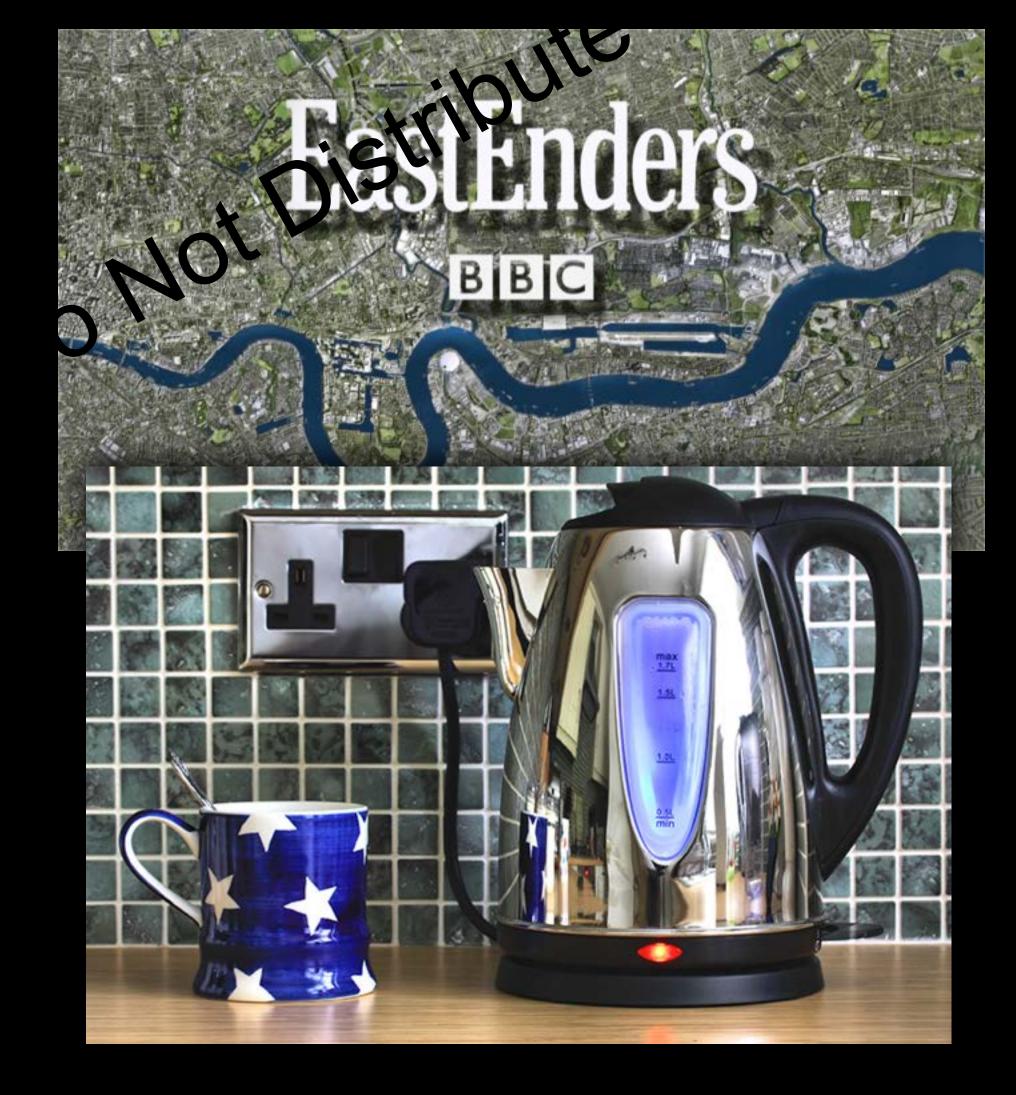


English Tea-Drinking Habits Strain The Grid

GEEK-CETERA (HTTP://WWW.GEEK.COM/CATEGORY/GEEK-CETERA/)

Tea time in Britain causes predictable, massive surge in electricity demand

- After a popular soap opera ends,
 1.75 million tea kettles are
 turned on almost simultaneously
- Surge in demand: 3 GW for 3-5 minutes
- Standby power ready from grid in UK and France





Energy Constraints Become Water Constraints

- Hurricane Ike in 2008 knocked out power to energy capital of the world...
- Water systems were shut down because of the power outages



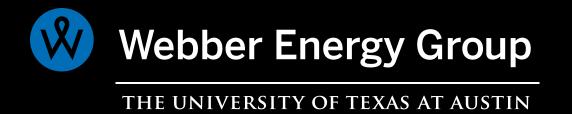
Energy Constraints Become Water Constraints

Not so long ago

Easy for usturn a know

Boil Water Notification

May 16, 2011 Due to loss of water pressure from a power outage at the water plant in the Ridgewood Village Water System the Texas Commission on Environmental Quality (VCEQ) has required our public water system Ridgewood Village Water System PWS #2270015 to notify all customers to boil their water prior to consumption as a precautionary measure.





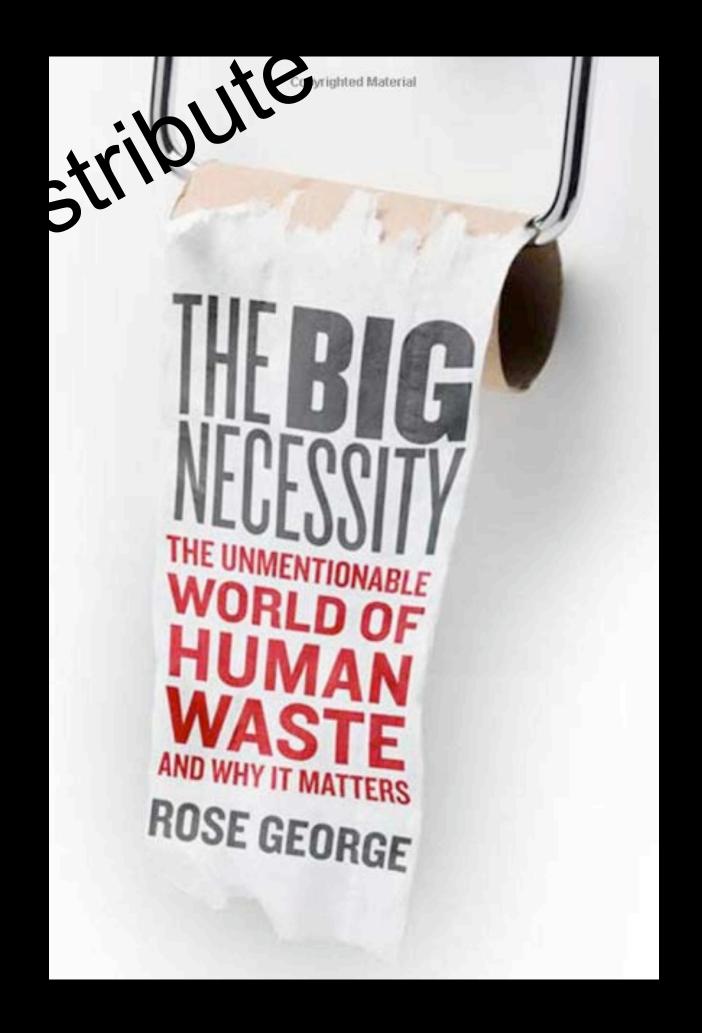
The Water Sector Can Be Used To Solve Energy Problems

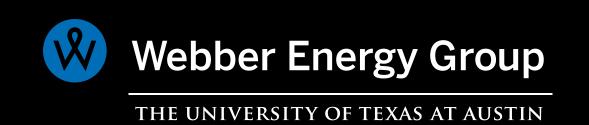
- Using Energy In Water
 - Energy recovery from WWTPs
 - Water for thermal energy storage
- Integrating Renewables with Water Treatment & Desalination
 - -Abundant saline/brackish water
 - -Abundant wind and solar raciation(with low electricity prices)
- Using excess flared gas from shale production for wastewater treatment



Wastewater Is A Resource

- Sanitation differentiates
 - —Healthy and wealthy = sanitation
 - –Sick and poor = no sanitation
- Reclaimed water
 - -Advanced treatment is less energy-intensive than desalination
- Water Re-use:
 - -"showers to flowers"
 - -Graywater for snowmaking
 - -"toilet to tap" (Singapore, ISS, ...)



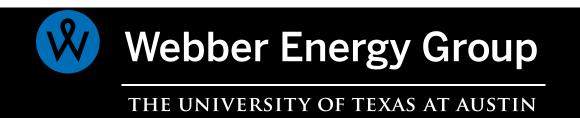


Wastewater Is A Resource

- Austin, TX: Produces biogas and 'Dillo Dirt from its wastewater
- Sandvika, Norway: uses heat in wastewater to
 - -Warm dozens of nearby buildings
 - -Defrost sidewalks and roadways

Energy Recovery from Wastewater Treatment Plants in the United States A Case Study of the Energy-Water Nexus

Ashlynn S. Stillwell 1,*, David C. Hoppock 2 and Michael E. Webber 3



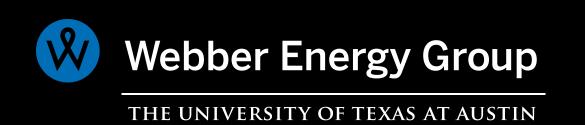
Wastewater Is A Resource

- University of Texas at Austin: uses reclaimed water for irrigation and chilling
- Saves significant energy and CO₂ emissions

An integrated energy, carbon, water, and economic analysis of reclaimed water use in urban settings: a case study of Austin, Texas

Ashlynn S. Sillwell, Kelly M. Twomey, Rusty Osborne, David M. Greene,

Dan W. Pedersen and Michael E. Webber



© IWA Publishing 2011 Journal of Water Reuse and Desalination 01.4 2011

There Is A Lot of Waste In The System

- Natgas leaks: ~1%
- Water leaks/losses: ~10-40%
- Electricity: more than half of all energy consumption lost as waste heat



Our Water System: What a Waste

By Michael E. Webber

MERICA has a water problem. To put it simply, the national network for providing safe, clean

This state of affairs, which is the focus of a summit meeting on Tuesday at the White House, threatens more than our drinking water supplies. Water is used in every sector of industry, grows our food, affects our health and props up our

The price of this neglect will be high. In Flint, Mich., the mayor has estimated that and industry.

Michael E. Webber, the deputy director of the Energy Institute at the University of Texas, Austin, is the author of the forthcoming "Thirst for Power: Energy, Water and Human Survival."

ncluding old, leaky pipes; archaic pricing; and a remarkable lack of data about how much water we use.

In cities across the country, billions of gallons of water disappear every day through leaky pipes. Houston alone lost 22 billion gallons in 2012. As the water expert David Sedlak at the University of California. Berkeley, has noted, the water system is facing a double whammy: It has reached the end of its service life just as climate change and population growth have increased its burdens. No wonder the civil engineers society gave the nation's drinking water systems a grade of D

Wastewater treatment systems are also it will cost as much as \$1.5 billion to fix or in serious need of upgrading. Flooding replace lead pipes. Over all, repairing our strains treatment plants and sewer syswater and wastewater systems could cost tems in many older cities, causing them to \$1.3 trillion or more, according to the discharge untreated sewage whenever American Society of Civil Engineers. We rainfall or snowmelt overwhelm them. Afneed to do this to improve water quality, ter Hurricane Sandy, treatment plants in protect natural ecosystems and ensure a the New York area backed up, with reliable supply for our cities, agriculture sewage flowing the wrong direction from drainage pipes. The New York Times The problem is a result of many factors, noted that in one neighborhood "a plume search that kicked off the shale boom. of feces and wastewater burst through the street like a geyser."

Droughts also jeopardize water supplies, causing cities in the West to reach farther or dig deeper to get their water. Outside Las Vegas, Lake Mead, fed by the

Colorado River, was recently measured at 39 percent of capacity.

These problems are compounded by an antiquated system of regulations, dysfunctional water markets, policies that encourage overpumping, and contracts that discourage conservation by requiring customers to pay for water they don't use. These approaches depress investment and inhibit innovation.

To fix our water systems, we need prices that lead to more rational water use and invite needed investment, data to track water resources and usage, and much more research and development.

Take prices, for example. Water prices should rise or fall according to supply and demand. The idea that the price should be the same in the dry season (when supplies are low and demand for irrigation is high) as the wet season (when supplies are high and demand is low) is nonsense.

Water utilities should take a page out of the energy sector's playbook. Electric utilities had been plagued for decades by

Cracked pipes, antiquated rules and dysfunctional markets.

many of the same difficulties. But now they are moving toward time-of-use pricing, with prices rising when demand is up, and inverted block pricing, where prices increase with consumption. Allowing these price shifts would change user behavior. Higher prices would encourage conservation and new technologies.

Regulations can ensure that the first few gallons per person per day are cheap or free, with escalating costs beyond that. Water for necessities such as drinking, cooking and hygiene should be affordable. Bevond that, water for lawns, filling swimming pools, washing cars and other uses should be more expensive

We also have to fix our data gaps. We are operating blind. Compared to sectors like energy, where robust statistics on prices, production and consumption are generated weekly, key information on water use and supply is missing or published only every few years.

We should increase the federal budgets for water monitoring. Establishing a Water Information Administration, just as the Department of Energy has an Energy Information Administration, to collect, curate and maintain up-to-date, publicly available water data would inform policy makers and the markets.

Congress should also significantly increase support for water research and development, making sure to include the private sector as a partner.

We need breakthroughs in water treatment technology that would enable larger-scale recycling and reuse of treated water, desalination, and aquifer storage and recovery. These improvements range from the mundane — better pumps and home appliances — to advanced nanomaterials for energy-efficient water treat-

The water industry's risk-averse culture has resisted innovation. Higher prices and government-backed research and development could help prompt a is what happened with hydraulic fracturing and horizontal drilling, two technologies advanced through government re-

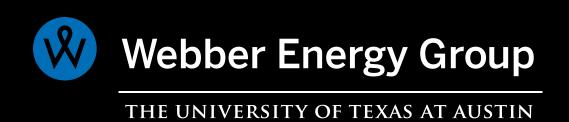
The water problem is daunting. But putting a sensible price on water to invite investment and encourage conservation, increasing the availability of information and doubling down on innovation can go a long way toward solving it.



We Could Make Our Energy and Water Systems Smarter

- Conventional meters are dumb
- Need smart meters:
 - –Use by time of day
 - —Use by function
 - Indoor vs. outdoor
 - Heated vs. unheated
 - Greywater vs. blackwater
 - Piped vs. collected
- Spending money on data saves money





Data Isn't Cheap: Case Study of Austin, TX Rollout of Smart Meters for Electricity

- Conventional billing: 2 meter readings/month
- Smart billing: Meter readings every 15 mins (2700
- Example: Austin, TX (750,000 people; 2012)
 - -Hardware budget for smart meters: ~\$50M
 - -Software budget for data & hilling: ~\$50M
- Saves money
 - -Fewer employees for meter reading
 - -Better grid regability (shorter downtime)



Kristoferb





Data Will Become More Important Than Ever

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Big Data Enables Rise of Artificial Intelligence

of Cheap Oil

Updated March 30, 2017 1:51 p.m. ET

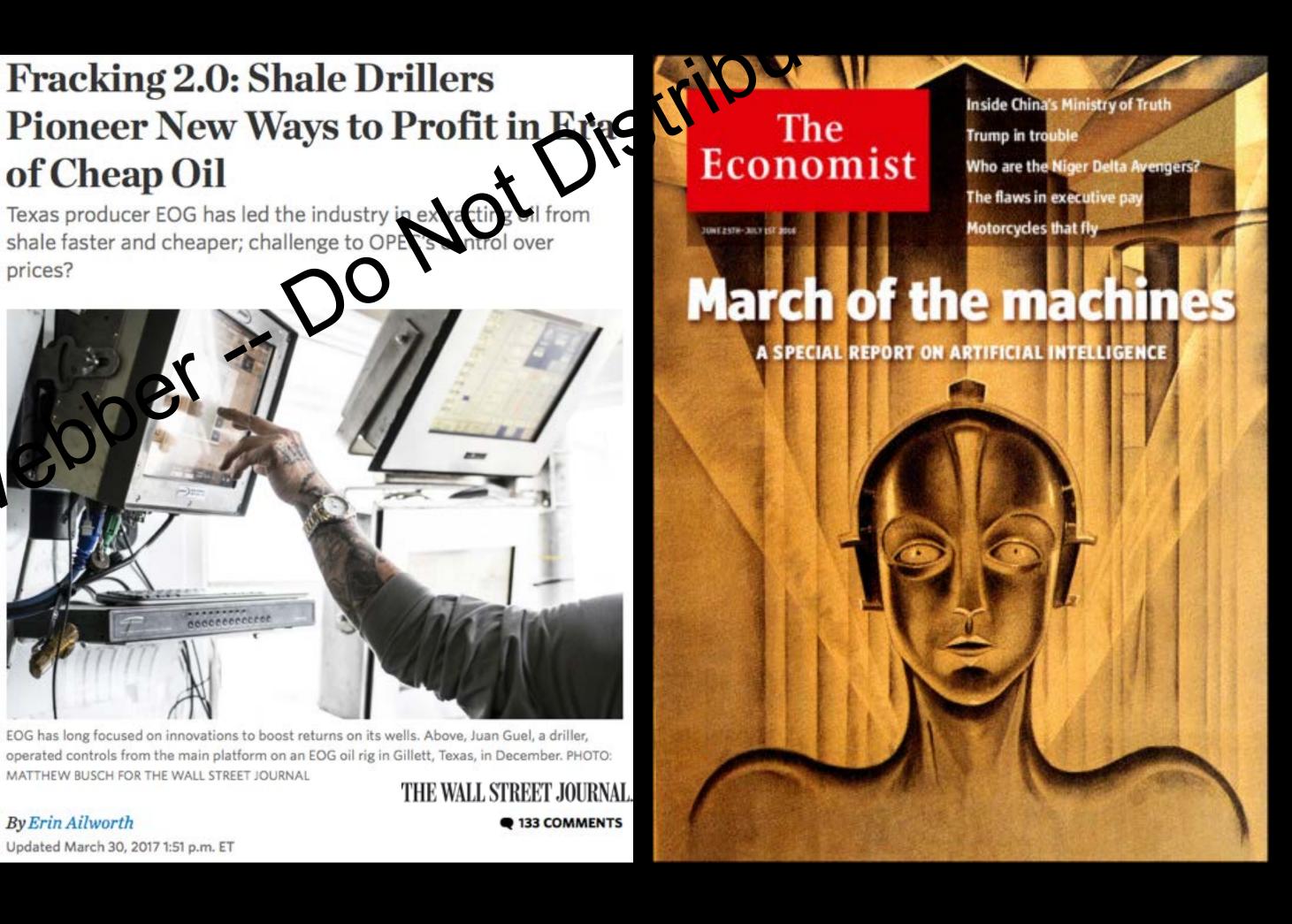
- Using data to reduce costs of O&G production
- Replacing men with machines: 150+ year-old tradition



Fracking 2.0: Shale Drillers

Texas producer EOG has led the industry in extracting

shale faster and cheaper; challenge to OPE





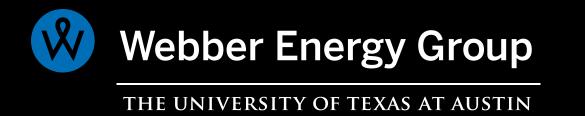
ONE HUNDRED YEAR STUDY ON ARTIFICIAL INTELLIGENCE | REPORT OF THE 2015 STUDY PANEL | SEPTEMBER 2016



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Smart Infrastructure Is An Important Economic, **Environmental and Performance Opportunity**

- Use IoT (ubiquitous sensors, analytics, smart algorithms, etc.) to extend life of existing infrastructure at much lower cost than rebuilding for \$1T
- Smart water mgmnt market: \$12B+/yr by 2021 (Technavio, Jan 2017)
- IoT in cities will have ~\$1T of value by 2025 (McKinsey Global Institute)
- IoT to reduce electricity/water loss/loaks in distribution systems could be worth as much as \$69B/year (McKinsey Global Institute)
- U.S. municipal drinking water consumption declined 5% this decade
 - -First time in 40+ years that water use at home has decreased (ASCE 2017)
 - -Installed costs amortized over fewer gallons, so we need tech to enable cost savings
- Water infrastructure can be used for demand response in power sector



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Smart Appliances Can Save Energy and Water And Stabilize the Grid

- Turn off heating element of dryer or water heater for 2 minutes when frequency sags to 59.95 Hz
- Leave motor running to avoid creases in clothes
- Adjust compressors for many fridges in coordinated fashion



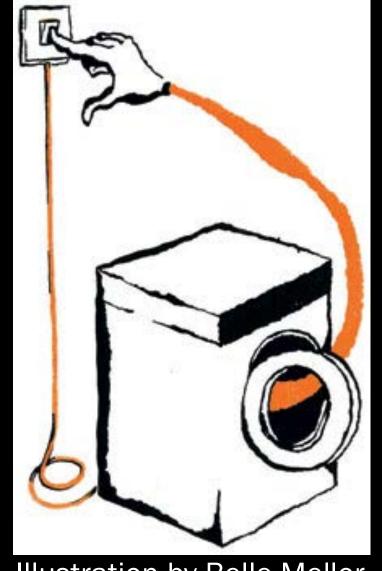
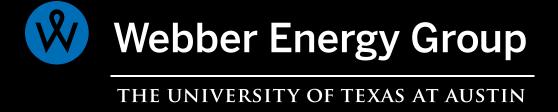


Illustration by Belle Mellor



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Use Energy In Water As a Thermal Storage Medium

Reduce peak demand, obviating need for tens of billions of dollars on power infrastructure





Contents lists available at Science Direct

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Modeling electric load and water consumption impacts from an integrated thermal energy and rainwater storage system for residential buildings in Texas

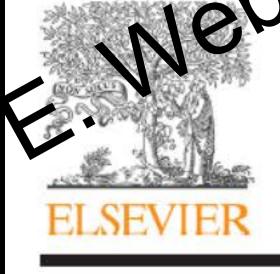
Charles R. Upshaw a,*, Joshua D. Rhodes a,b, Michael E. Webber a,b

Energy and Buildings 97 (2015) 21-32

Contents lists available at ScienceDirect

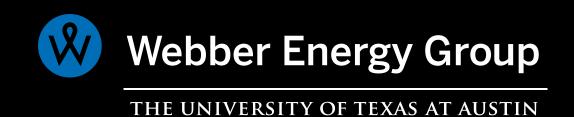
Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild



Modeling peak load reduction and energy consumption enabled by an integrated thermal energy and water storage system for residential air conditioning systems in Austin, Texas

Charles R. Upshaw^{a,*}, Joshua D. Rhodes^{a,b}, Michael E. Webber^{a,b}

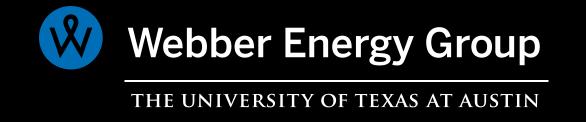


Integrating Renewables With Desalination Might Solve Several Problems at Once

Wind

Solar

Geothermal



Integrating Wind Power With Brackish Desalination Solves Several Problems Simultaneously

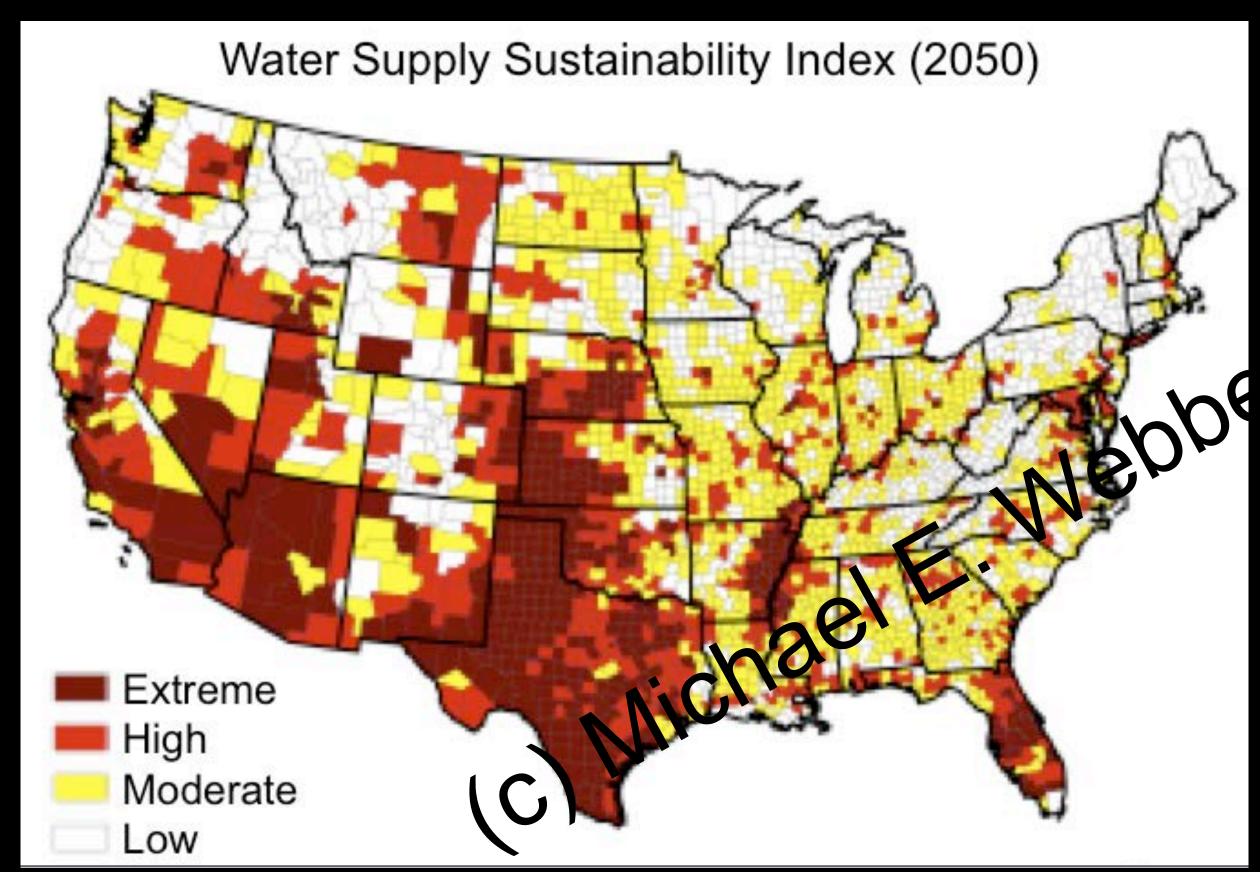
Article

Implementation of Brackish Groundwater Desalination Using Wind-Generated Electricity: A Case Study of the Energy-Water Nexus in Texas

Mary E. Clayton 1, Ashlynn S. Stillwell 2, and Michael E. Webber 1, **

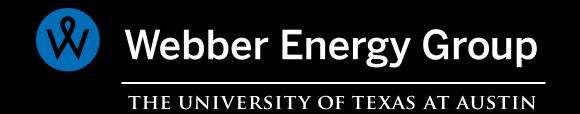


Water Problems, Brackish Groundwater, Sunshine, and Wind Resources Are Co-Located



Courtesy: Mary Clayton

- Use off-peak wind to power desalination of brackish groundwater
- Water treatment is cheaper than batteries
- Provide solutions to challenges of each technology
 - Desalination addresses intermittent, offpeak nature of wind power
 - Wind power addresses high energy requirements of desalination



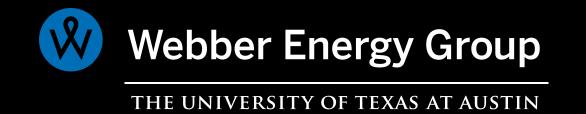
Where Does Solar-Aided Desalination Make Sense In the World?

- Water temperature and salinity are relatively low
- Solar insolation, population and water prices are high
- Some tropical and sub-tropical locations book very promising
 - Bay of Bengal, etc.

Where does solar-aided seawater desalination make sense? A method for identifying sustainable sites

Emily A. Grubert 1, 1, Ashlynn S. Stillwell a, 1, Michael E. Webber b

E.A. Grubert et al. / Desalination 339 (2014) 10–17



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Integrating Solar PV with Brackish Desalination Increases Energy and Water

Resources 2015, 4, 476-489; doi:10.3390/resources4030476



ISSN 2079-9276

www.mdpi.com/journal/resource

Article

The Energy-Water Nexus: Spatially-Resolved Analysis of the Potential for Desalinating Brackish Groundwater by Use of Solar Energy

**Resources 2015. 2, 227-276: 0

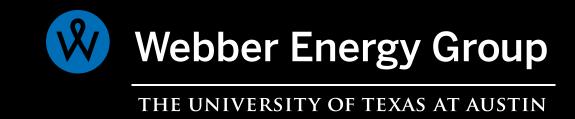
Jill B. Kjellsson 1,* and Michael E. Webber 2

Resources 2015, 2, 227-276; doi:10.3390/resources4020227



Article

The Energy-Water Nexus: An Analysis and Comparison of Various Configurations Integrating Desalination with Renewable Power



Gary M. Gold *, Michael E. Webber

Integrating Solar PV with Brackish Desalination Increases Energy and Water

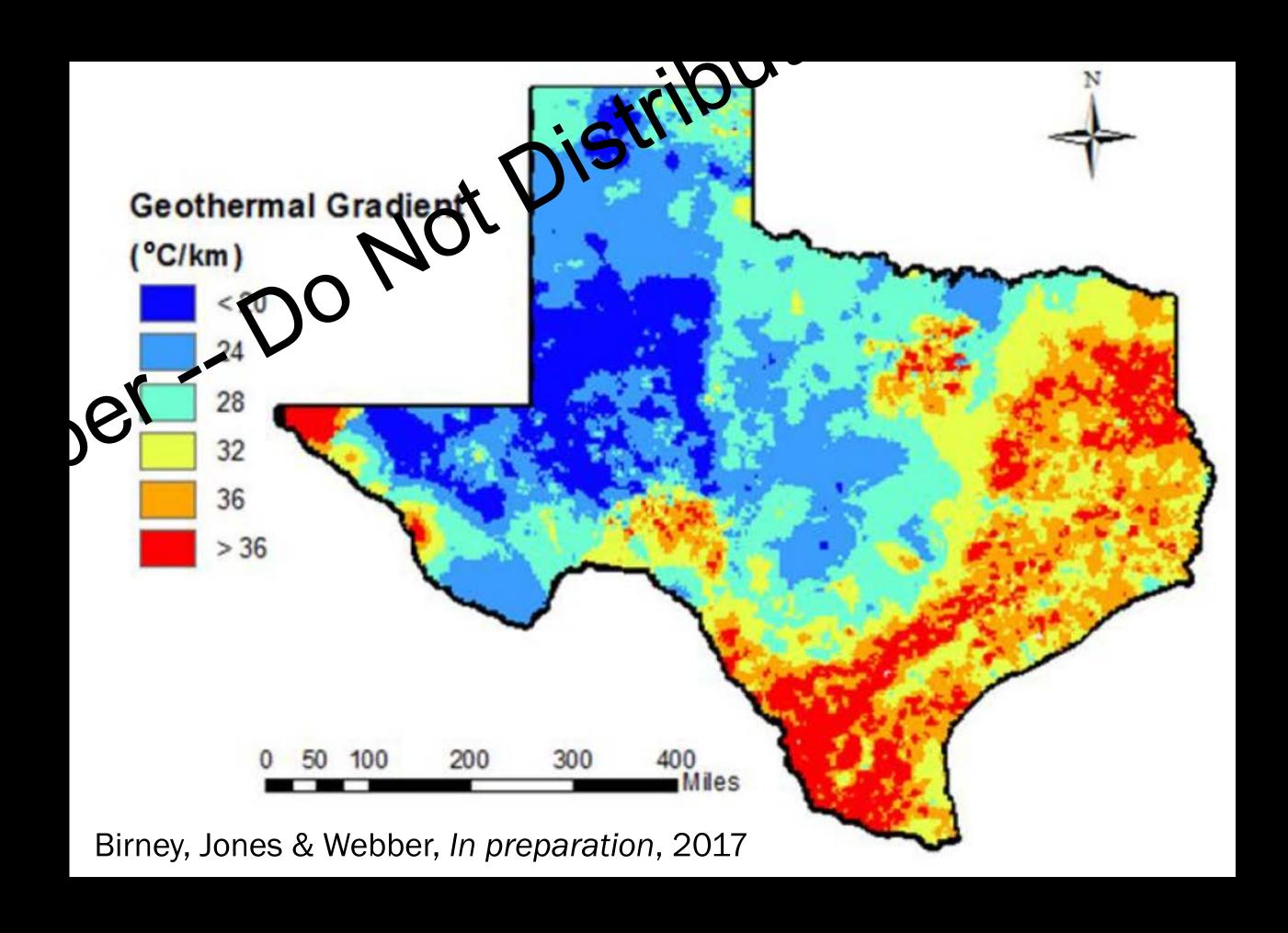
- Saline/brackish water for cooling solar PV systems
- Improves Solar PV performance
- Preheats water for higher throughput during treatment
 - -Example: El Paso, TX test systems

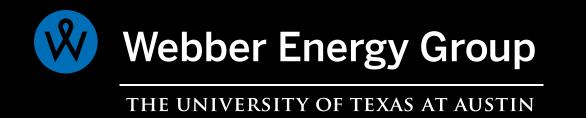


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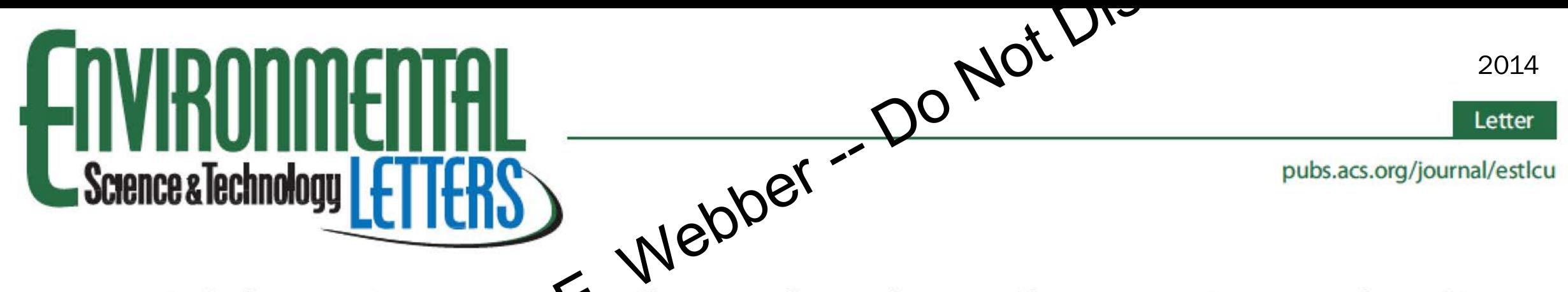
Some Sites Are Very Promising for Geothermal Powered Brackish Groundwater Desalination

- Energy requirements for MED depend on
 - -Depth
 - -Salinity
 - -Temperature
- In some geopressured zones, brackish desal could be self-sustaining





Flared Gas Can Be Used for On Site Treatment of Wastewater From Shale Production



Potential for Using Energy from Flared Gas for On-Site Hydraulic Fracturing Wastewater Treatment in Texas

Yael R. Glazer, Jill B. Kjellsson, Kelly T. Sanders, and Michael E. Webber*



Flared Gas Can Be Used for On Site Treatment of Wastewater From Shale Production



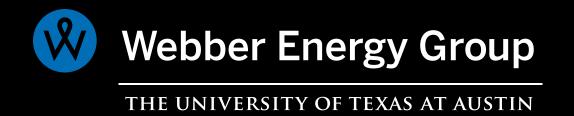


Converting two waste streams into a valuable commodity

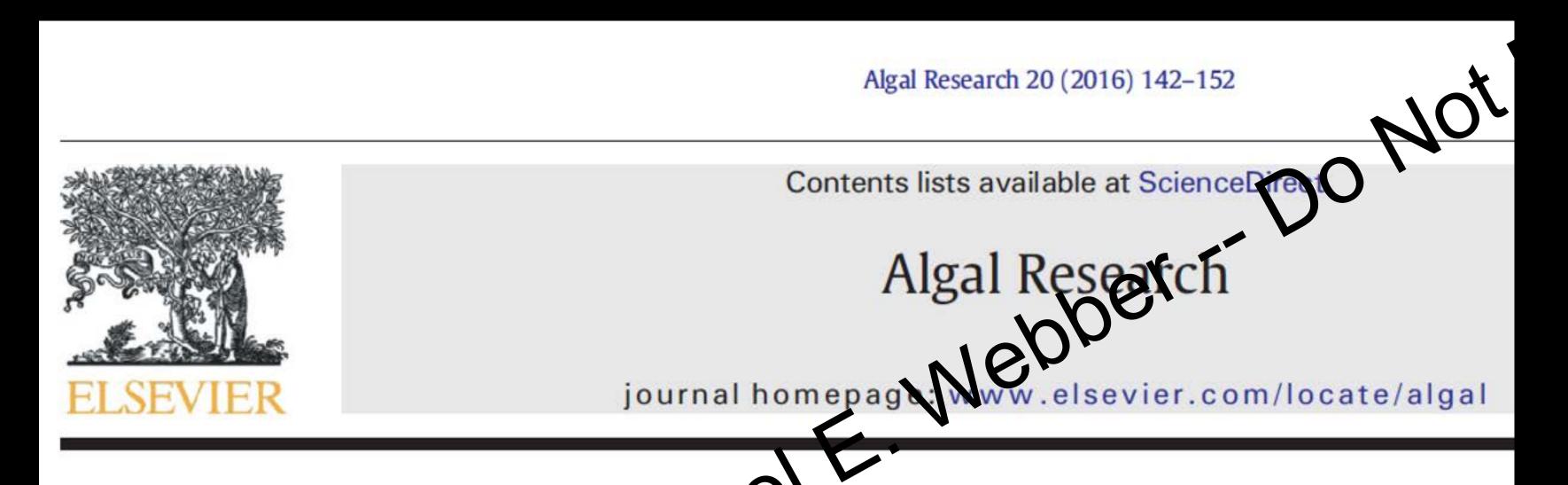
[Photo Credit: Jared Garrison]

Enough flaced gas in Texas to increase annual water supply by 1 to 2.4%

The Oil & Gas Industry Could Become the Oil, Gas, and Water Industry



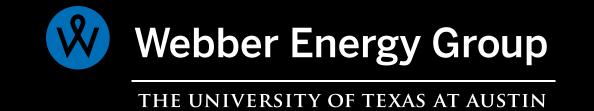
Flared Gas Can Be Also Be Used for Food Production



 Combined heat, power, and ammonia for algal protein production

Flare gas recovery for algal protein production

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We Need To Fix Our Markets



Water Prices Are Dysfunctional

Bottled water: \$6.98/gallon

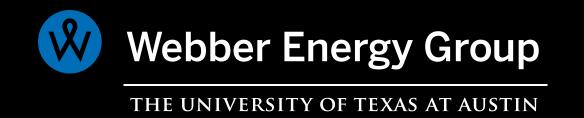


20 oz. bottle, 128 oz./gallon

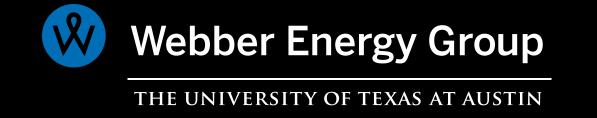


20 lbs. × 0.13 gallons/lb. = 2.6 gallons \$0.99 ÷ 2.6 gallons = \$0.38/gallon

Bag of ice: \$0.38/gallon



There is Justifiable Cause for a Healthy Dose of Realistic Pessimism That This Could Take a While



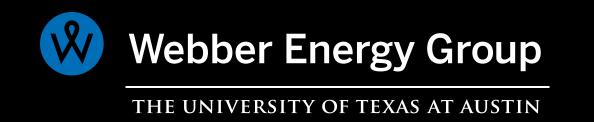
It Is Possible To Build Infrastructure In The Wrong Place and Pointed the Wrong Direction

- Building petroleum-fired power plants in the 1960s and early 1970s just in time for the oil crises
- Building LNG import terminals just in time to need export terminals
- Building a south-going pipeline from Canada vs. a north-going pipeline from Mexico?
- Building centralized water systems rather than distributed systems?



Infrastructure-building blunders can leave countries unprepared for unexpected challenges.

Michael E. Webber, Mechanical Engineering, July 2017



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