The Energy Water Nexus

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Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

There Are Good and Bad Tradeoffs At the Energy Water Nexus (Quantity)

- With sufficiently abundant, clean and affordable energy, our water problems are solved
  - Long-haul transfer, desalination, deep wells,…
- With sufficiently abundant, clean, and affordable water, our energy problems are solved
  - Biofuels, hydro,…
- Coupled infrastructures causes cascading vulnerabilities
  - Water constraints become energy constraints
  - Energy constraints become water constraints

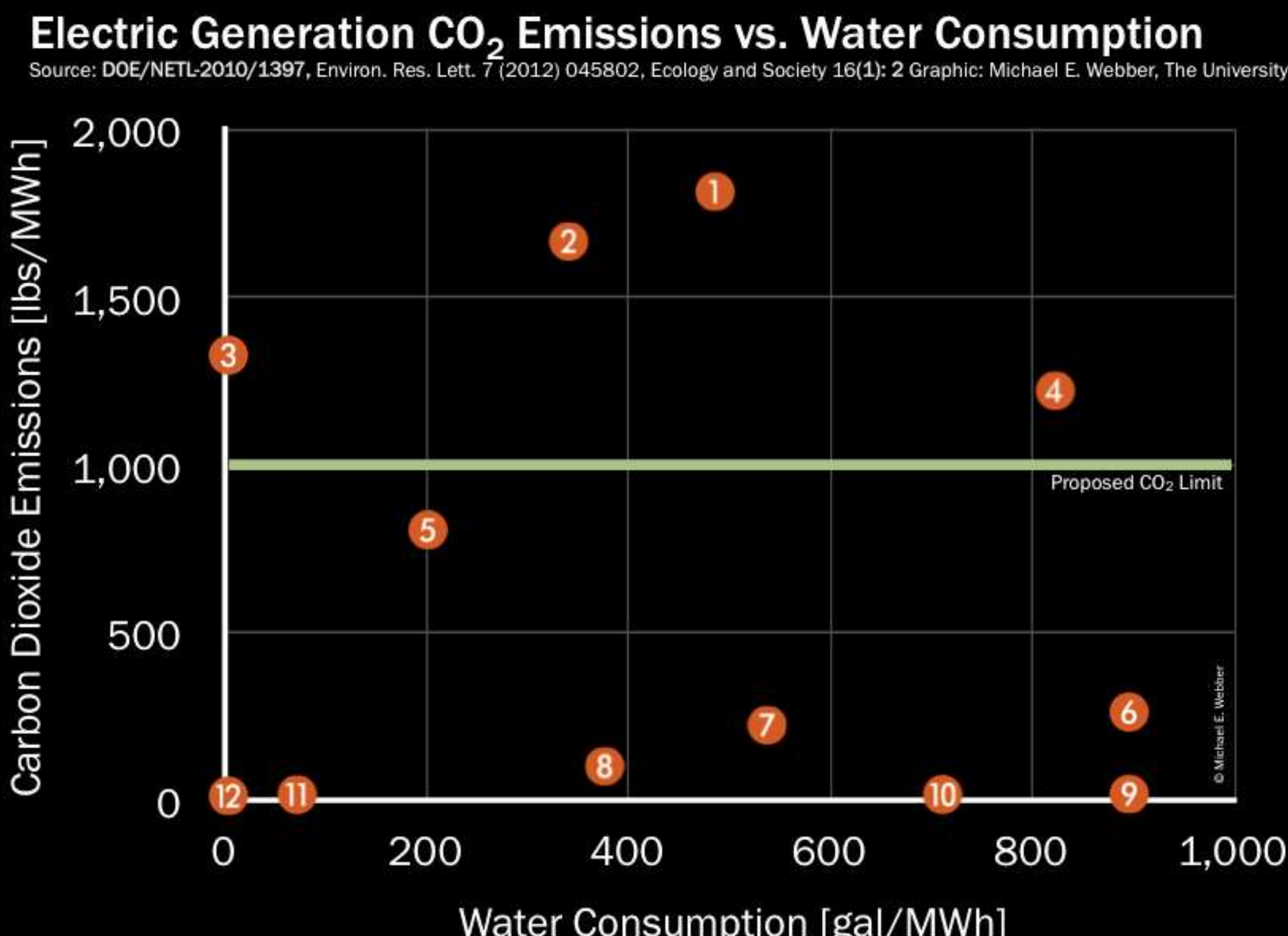
There Are Good and Bad Tradeoffs At the Energy Water Nexus (Quality)

- Energy affects water quality (good and bad)
  - Energy is used to treat (clean, move, heat,…)
  - Energy pollutes water (thermal, chemical,…)
- Water affects energy quality (good and bad)
  - Improved efficiency at power plants (thermoelectric, solar PV, …)
  - Improved recovery for oil and gas production
  - Degraded performance in heat waves

We Use Water for Energy

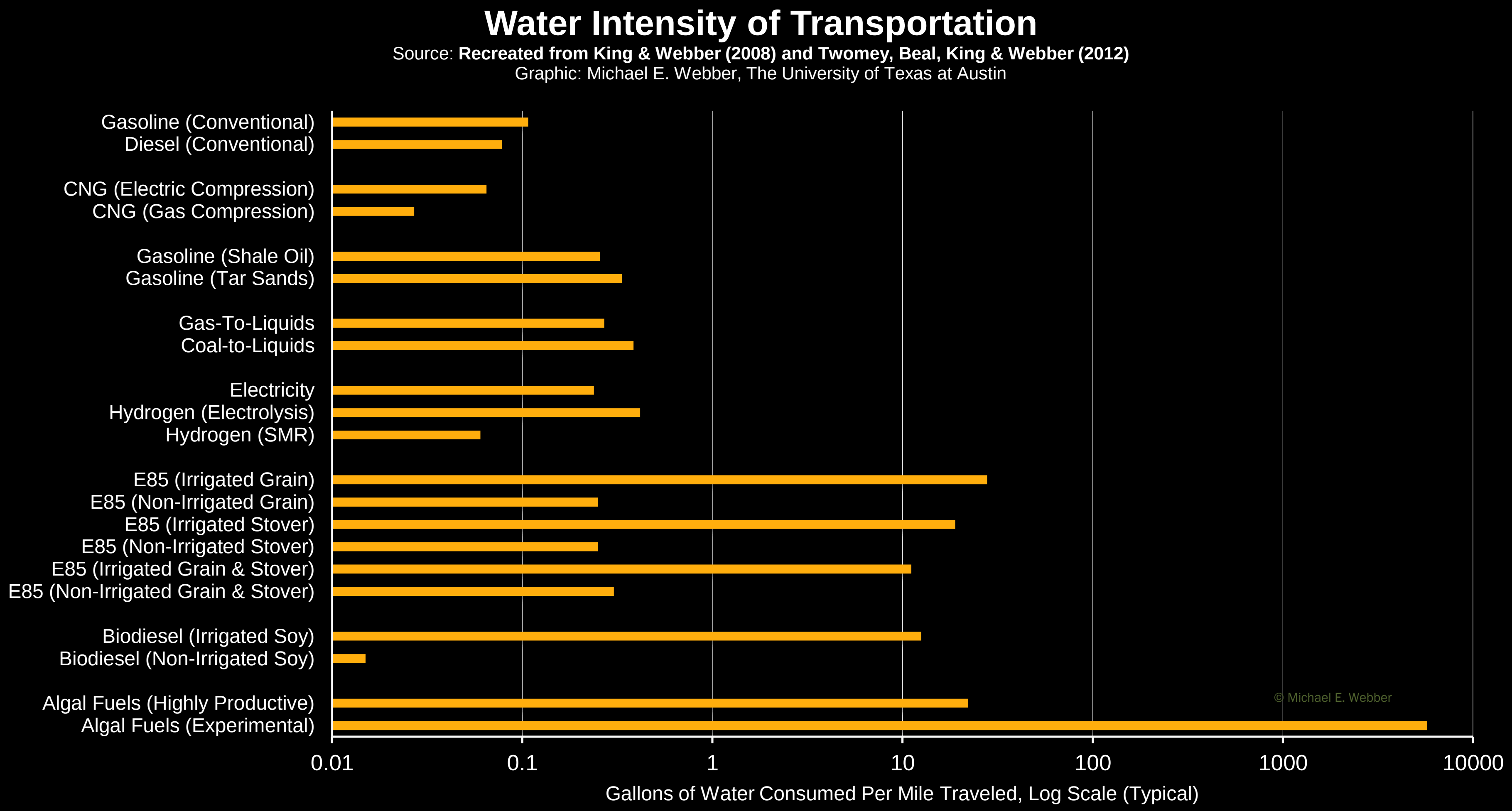
- We use water for the power sector
  - Driving hydroelectric turbines
  - Driving steam turbines
  - Cooling power plants
- We use water for fuels production
  - Growing biofuels
  - Extracting oil and gas
  - Mining coal and uranium
  - Refining/upgrading fuels
- We use water for transporting fuels

There Is Tension Between CO_2 and H_2O In The Power Sector



1	Coal
2	Coal, IGCC
3	Natural Gas Combustion Turbine
4	Natural Gas Steam Generator
5	Natural Gas Combined Cycle
6	Coal w/capture
7	Coal, IGCC w/capture
8	Natural Gas Combined Cycle w/ capture
9	Solar CSP
10	Nuclear (typ. Gen II)
11	Nuclear Small Modular Reactor
12	Solar PV, Wind

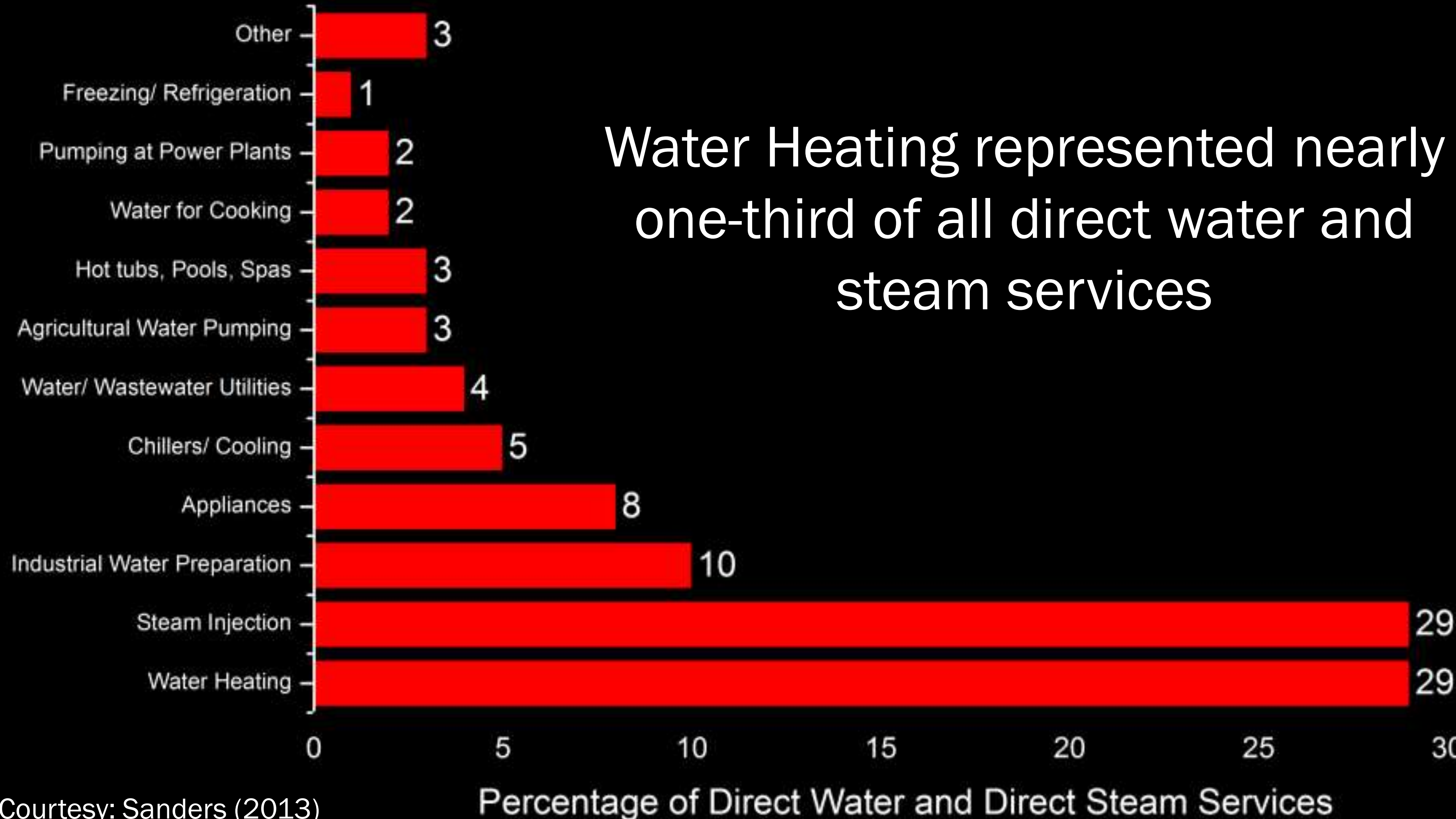
Water Intensity of Transportation



We Use Energy for Water

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

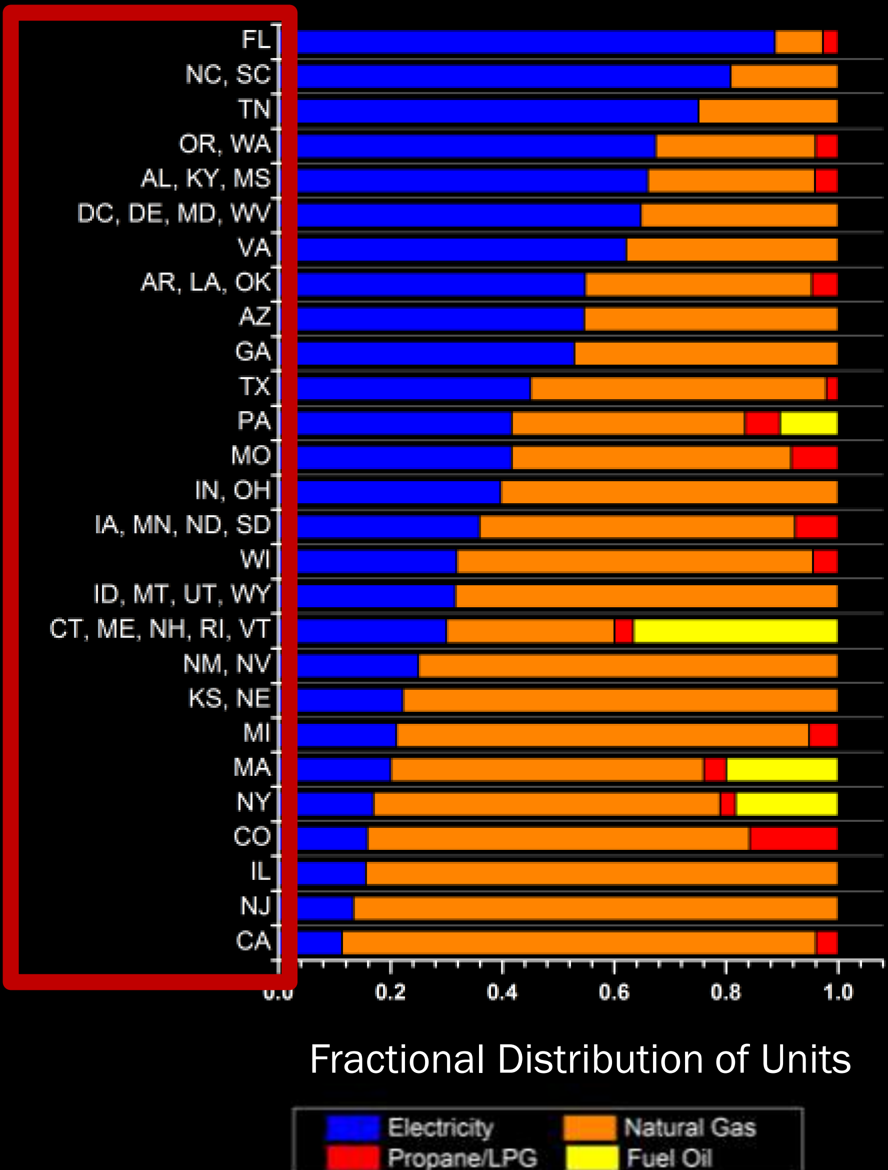
Water and Steam Are Responsible for >12% of National Energy Use



Water Heating represented nearly one-third of all direct water and steam services

Courtesy: Sanders (2013)

Water heating technologies vary geographically: electric and gas dominate



US Water Heating Unit Inventory in 2009:

- **Electric : 41%**
- **Natural gas : 52%**
- **Fuel oil: 4%**
- **LPG : 7%**
- **Solar: Trivial**

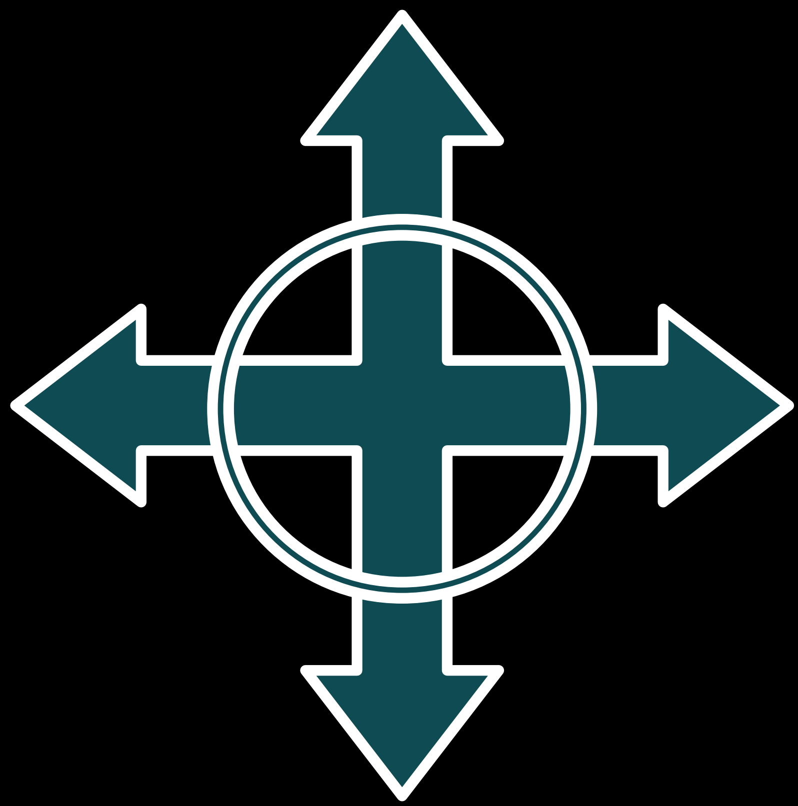
[Data: EIA RECS 2009]

Courtesy: Sanders (2013)

The Energy-Water Relationship Is Already Under Strain

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

Water Constraints Become Energy Constraints

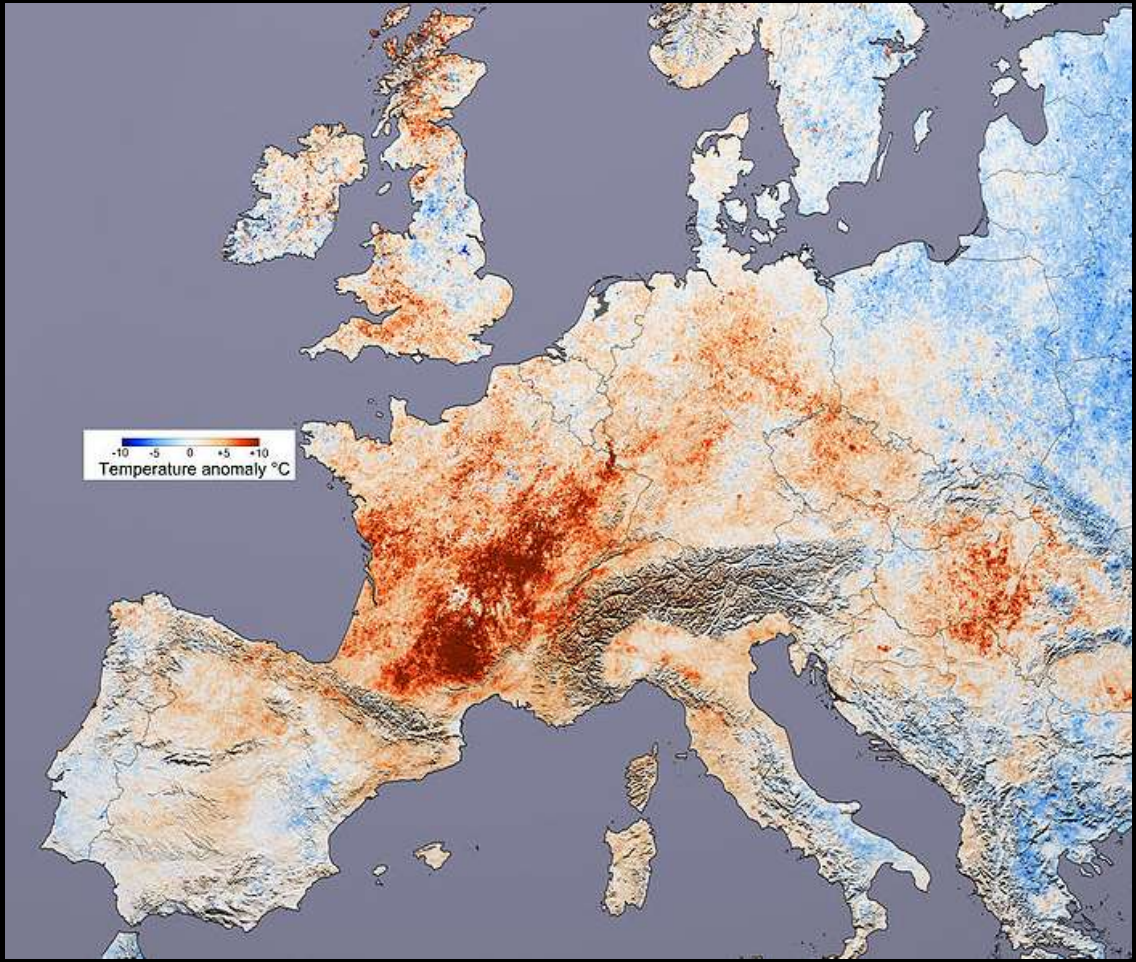


Heat Waves Can Strain The Power Sector

Source: NASA (2003)

Snapshot of the record heat wave in 2003

Nuclear power plants dialed back because of high water temperatures (less cooling capability) and rejection water temperature limits



Water Constraints Become Energy Constraints

- Freeze in Texas in February 2011 shut down two coal plants causing statewide rolling blackouts
- Cascading Failures
  - Freeze causes coal plants to stop
  - Gas power plants cannot come on
    - Power outage takes some gas compressors off line
    - Cold temperatures means demand for gas is high

Frozen Water Threatens the Niagara Falls Hydro Plant (Jan 2014)

The ice cutter William H. Lathan navigates through thick ice in the Niagara River. The cutter works constantly in cold weather to keep the water intakes for the Niagara Falls hydro-electric plants free of damaging ice.
Picture: REUTERS

Water Constraints Become Energy Constraints

- Droughts:
  - Nuclear power plants within days of shutting in SE 2008
  - TX power plants at risk of shutting down
  - Western Hydropower down in drought years
- Floods:
  - Nebraska nuclear power plant nearly shut down because of flooding of the Missouri River in June 2011
  - Caused silting behind dams in India in 2012

The 2012 Indian Blackout Affected 600 Million People and was Triggered Partly by Drought

The New York Times

2nd Day of Power Failures Cripples Wide Swath of India

Adnan Abidi/Reuters

Passengers waited Tuesday for train service to be restored in New Delhi. More Photos »

By JIM YARDLEY and GARDINER HARRIS

Published: July 31, 2012 | 429 Comments

1) Increased power demand from irrigation

2) Decreased power generation at dams

Drought Hurts the Ability to Ship Energy By Inland Waterways

The New York Times

After Drought, Reducing Water Flow Could Hurt Mississippi River Transport

Jeff Roberson/Associated Press

Barges on the Mississippi River in St. Louis on Friday. A plan approved by Congress for maintaining irrigation systems is likely to affect shipping in the region.

By JOHN SCHWARTZ
Published: November 26, 2012

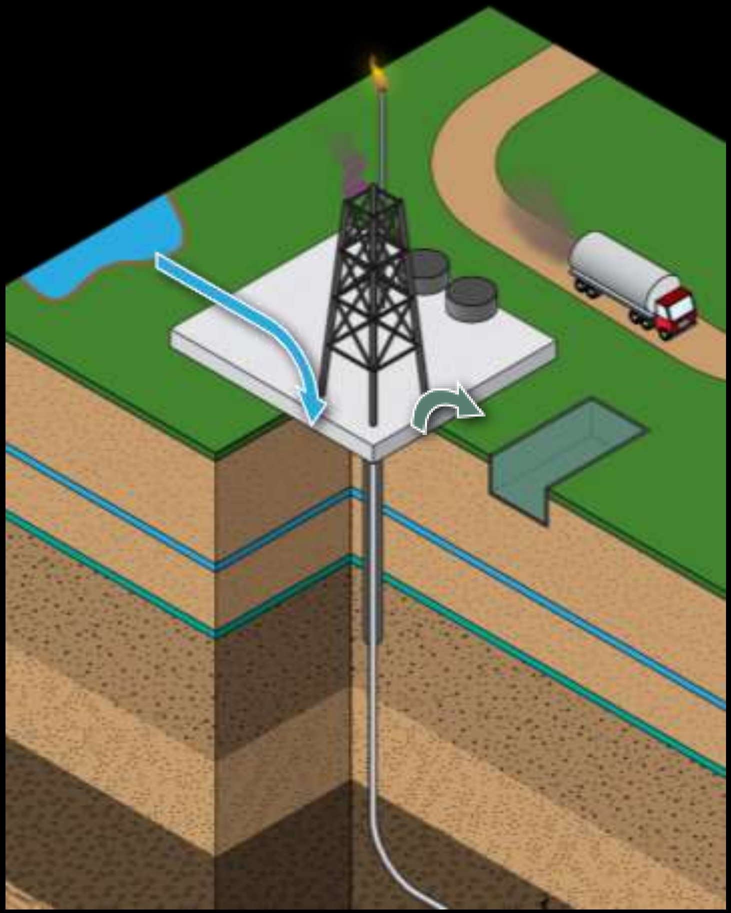
$7 billion of coal, petroleum products, fertilizer, and agriculture products could not ship in Jan and Feb 2013 because of low water

Water Use, Challenges, and Opportunities In Shale Production

Nationally, Oil & Gas Is Responsible for <5% of Water Withdrawals

- Overall, small part of water withdrawals
  - Oil and gas extraction: <1%
  - Industrial uses: <4%
    - Partly for refining and chemicals [Source: USGS]
- However, at local scale, water use for oil/gas can be large fraction of use
- Shale revolution puts pressure on watersheds for new production AND refining/chemicals

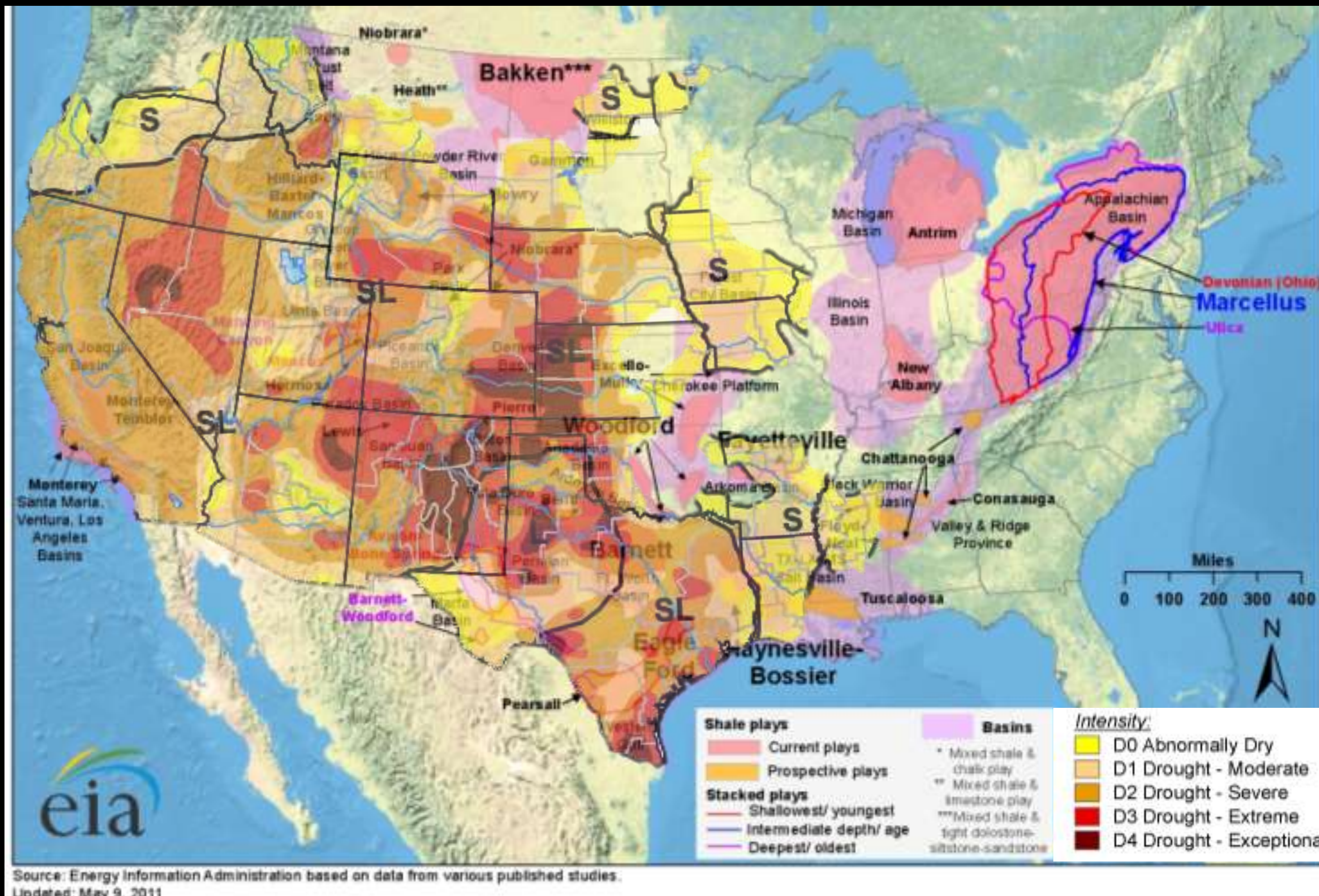
Drilling and Completion Requires Significant Volumes of Water



- It requires 2 to 9 million gallons of frac fluids per well
  - Proppants (sand): 0.5 M lbs
  - Injected at thousands of gpm
  - Chemical additives: 2%
    - Fractions grow as water use decreases
    - Liquids-rich shales use more acids/gels
- Concerns about induced seismicity and seepage

Source: Matt Mantell, Chesapeake Energy, Feb 2013, and DoE: “Modern Shale Gas Development in U.S.,” 2009

The U.S. shale basins are extensive and often overlap with areas of drought



Source: Drought Monitor August 6, 2013

Water Constraints Are Inhibiting Shale Production

- Texas
  - Grand Prairie: banned the use of municipal water for shale liquid and gas fracking
  - Ogallala Aquifer: restrictions on water use for fracking in the groundwater district
    - Source: Businessweek, October 2011
- New Mexico: Mora County banned fracking

New Mexico county first in nation to ban fracking to safeguard water

In acting to protect their water supply, the 5,000 residents of poor, conservative Mora County make it the first in the U.S. to ban fracking -- hydraulic fracturing for oil.

May 28, 2013 | By Julie Cart, Los Angeles Times

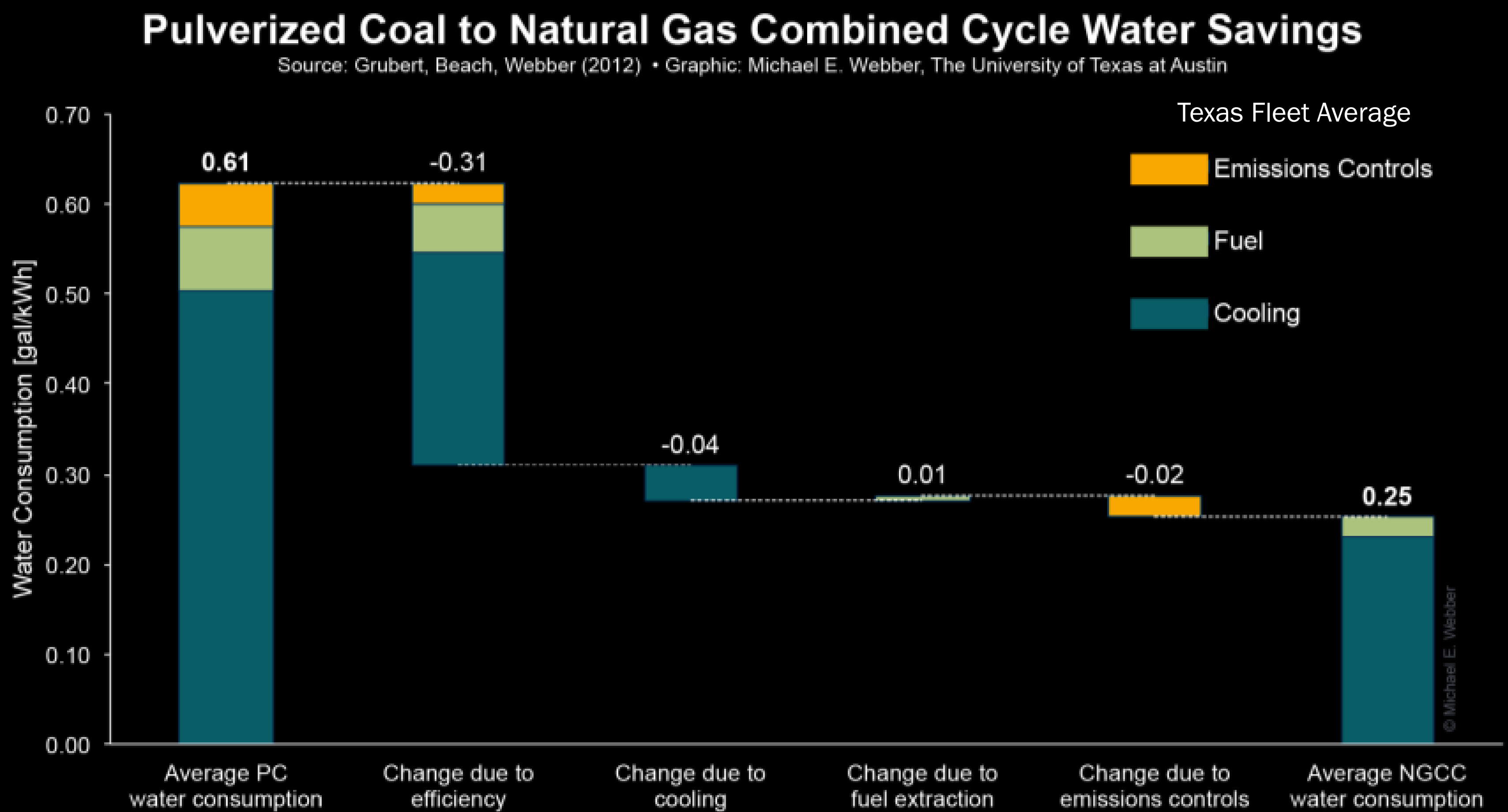
Yet, Overall, Shale Gas Has Relatively Low Water Consumption

- Volumetric Basis
  - Conventional oil: 1-5 gal/gal
  - Unconventional oil: 5-10 gal/gal
  - Irrigated Corn: 500-2000 gal/gal
  - Algae: 10,000-100,000 gal/gal

- Energetic Basis
  - Shale Gas consumes 1.25 gal/MMBTU
  - Corn Ethanol consumes >2,500 gal/MMBTU

[Source: various publications by Webber, et al.]

Despite Water Needs of Hydraulic Fracturing, Switching From Coal to NGCC Saves Water

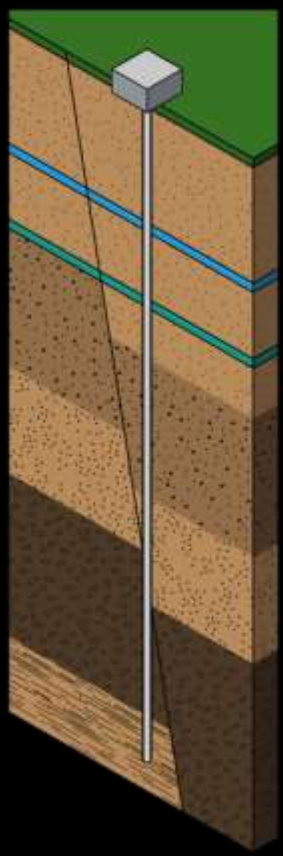


Hydraulic Fracturing in Shale Formations Produces Significant Volumes of Wastewater

- Volumes: 15% (Marcellus), 30% (EF), 300% (Barnett) [Source: Matt Mantell, Chesapeake Energy]

- Wastewater has three components:
  - Drilling muds
  - Flowback water
  - Produced water
- Often stored on-site in ponds/pits
- Wastewater can leak down from the pit to the groundwater
  - Pits should be lined to prevent leaks
  - Leaks have happened

Injection is One Method of Wastewater Disposal



- Some states allow wastewater injection to specified locations
  - TX does, OH does, PA does not
- Injecting at a fault can induce seismicity
- Reinjection is easier (and probably cleaner) than treatment
- Re-use is even cleaner (but not necessarily easier)
  - Some leases prohibit reuse

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

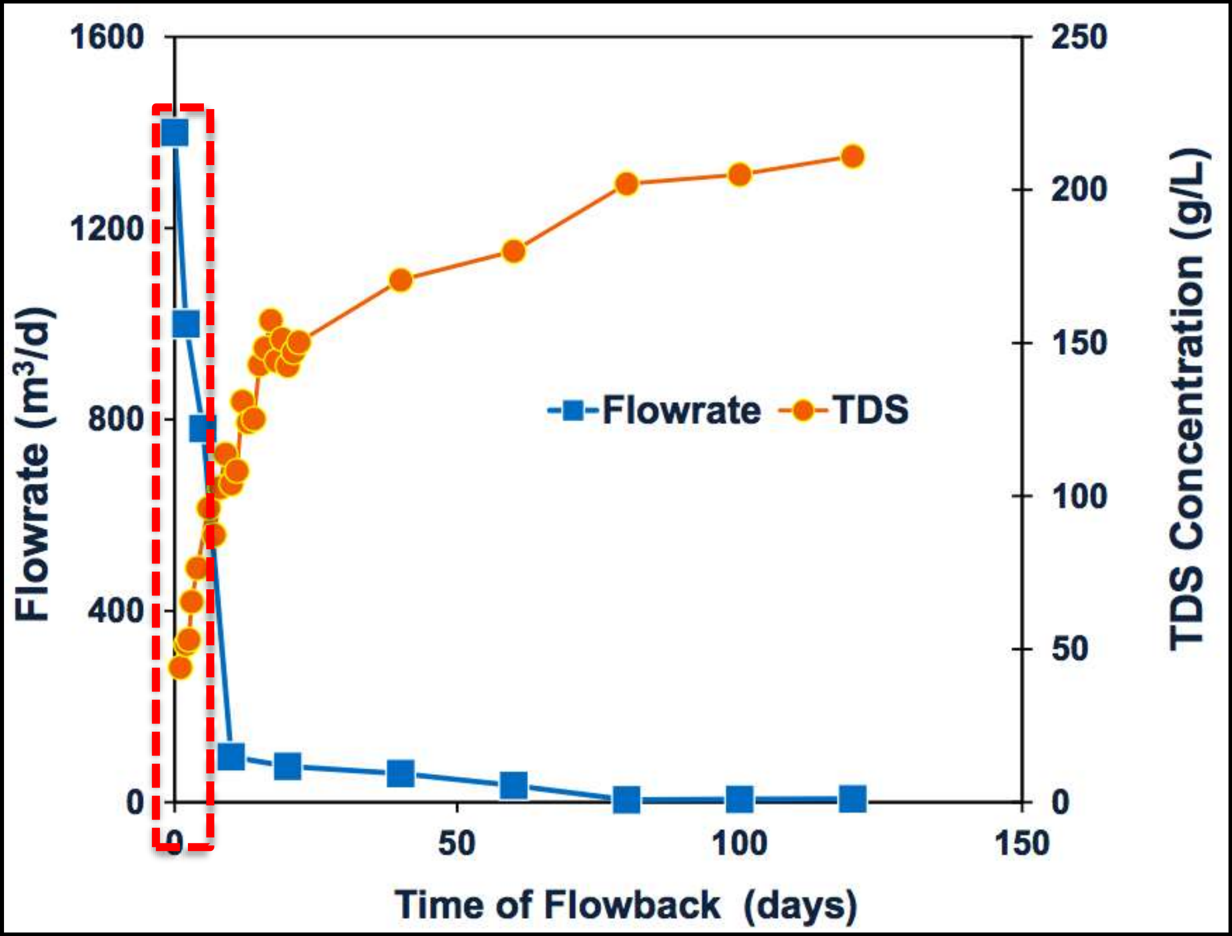
- Chesapeake, Chevron, ExxonMobil, etc., are actually water producers who happen to have very high value byproducts
- Daily liquids production in the USA:
  - Oil extraction: 7 MMBD
  - Wastewater injection: 47 MMBD
    - 2 billion gallons per day (~2% of daily consumption)
- On-site treatment would yield a lot of water

Solutions

Flared Gases Could Be Captured For On-Site Treatment of Wastewater

- Use flared gases for on-site thermal distillation
- Reduces trucks
- Increases water supply
- Reduces flares
  - Up to 1/3 of gas production is flared in N. Dakota

Flowback TDS increases while flowrate decreases with time



Well location: Washington County, PA (Marcellus Shale)

Plot courtesy of Dr. Kelvin Gregory, Carnegie Mellon University

There Are Some Catchy Slogans for Water Solutions

- Efficiency:
  - "more crop per drop"
    - Increasing agricultural yields per unit of water
- Water Re-use:
  - "showers to flowers"
    - Reusing wastewater for irrigation
  - "toilet to tap"
    - Turning wastewater into drinking water
    - International Space Station
    - Singapore's NewWater

Integrating Power Plants with Water Treatment & Desalination

- Waste heat from power plants
  - Increases throughput for membrane systems
  - Reduces energy for distillation systems
    - Example: Abu Dhabi's desalination plant
- Intermittent renewables: wind and solar PV

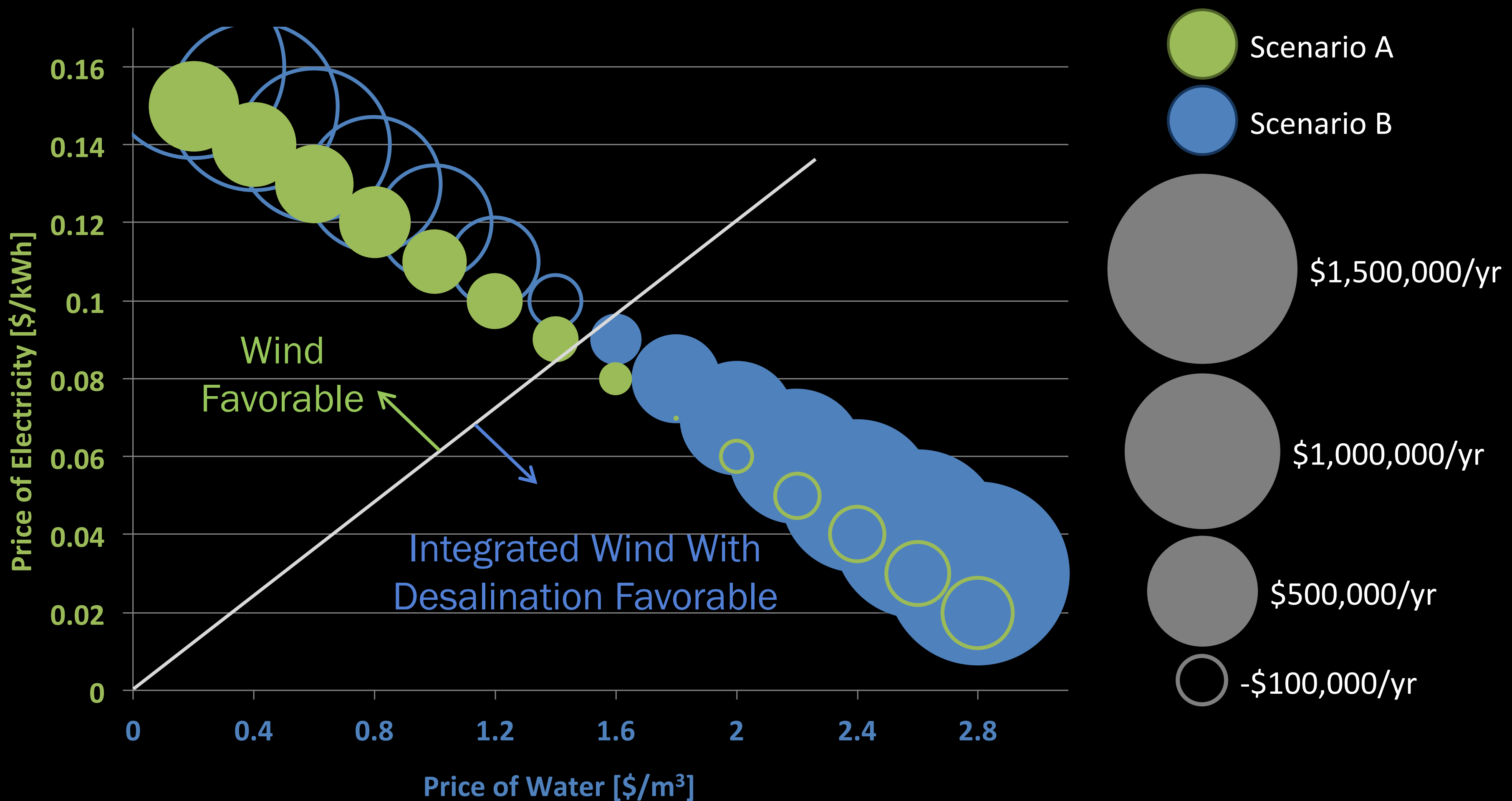
Integrating Wind Power With Brackish Desalination Solves Several Problems Simultaneously

- Transform low-value products (brackish groundwater and intermittent electricity) into a high-value product (treated drinking water)

- Abundant saline/brackish water in W. Texas
- Abundant wind and solar radiation in W. Texas
  - 1000+ hours of negative pricing in Texas b/c of extra wind
  - Solution: Match intermittent wind w/intermittent desalination

- Provide solutions to challenges of each technology
  - Desal addresses intermittent, off-peak nature of wind
  - Wind addresses high marginal energy of desalination

Integrated wind power with desalination presents greater profitability potential for a high water price and low electricity price



Integrating Solar PV with Desal 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

Using The Water Sector For Grid Management

- Demand reduction
  - Pumping/treating at night or off-peak
  - Installing variable-speed-drives (VSD) on pumping systems
- Reactive power management
  - Rise of solar power worsens power quality
  - Water/wastewater pumps are distributed and can be used to improve power quality

Clean Energy Commercialization at UT Austin

- **Clean Energy Incubator (CEI):** Part of Austin Technology Incubator, UT Austin
  - Energy startups raised $192M in investor capital since 2007
- **Types of Companies:**
  - *Omni Water Solutions*: on-site treatment of produced water from shale
  - *Yan Engines:* more efficient diesel engines
  - *nCarbon*: graphene technology for ultracapacitors for energy storage
- **IP:** current CEI companies have filed 13 patents
- **Successful exits:** Ideal Power Converters: $17M IPO in November 2013
- **Training Entrepreneurs:**
  - Large-scale internship program (1-2 dozen students annually)
  - Working with professors on campus to teach classes
- Sponsor: Texas SECO (Dub Taylor), Austin Energy, Industrial partners
- Next: Water Technology Incubator

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Flared gas energy could be harnessed to treat a significant amount of produced water

- In 2012, Texas flared 48 BCF of natural gas
  - Enough to treat ~1.6 billion barrels of produced water
- Our ongoing research focuses on establishing an analytical framework for assessing the feasibility of on-site treatment of produced water using distributed natural gas and includes a cost-benefit analysis