USDN Urban Water Learning Project

Exploring the Energy-Water Nexus in Urban Water Systems

Draft 1

March 31, 2014

Key Insights

Current State of the Field

- Awareness:
  - There is heightened awareness that energy and water systems should be managed together
  - Awareness is first stage of action
- Convening / Probing the System:
  - Next stage is to collaborate for a better blend of management practices

Primary Observations

- **Energy needs will increasingly become a problem for water systems** as they face cost issues, carbon reduction pressures, and source reliability concerns.
- **Maximizing energy efficiency is a 'whole system' challenge** (demand, management, technology, etc.), but typically these systems are fragmented and not collaborative.
- **Technology is particularly important** to maximize energy conservation and production (i.e., small-scale generation of hydropower) and minimize regulatory action (i.e. thermoelectric cooling systems gaining more EPA attention).

Research Question

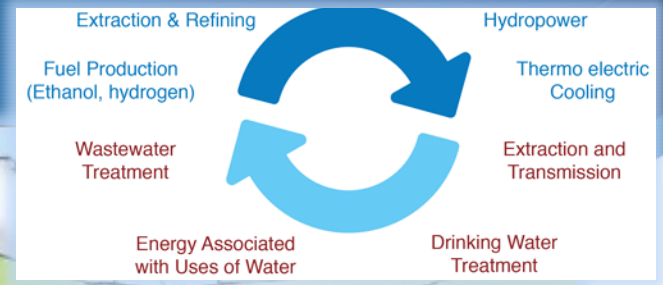
What is the 'state of the art' in managing:

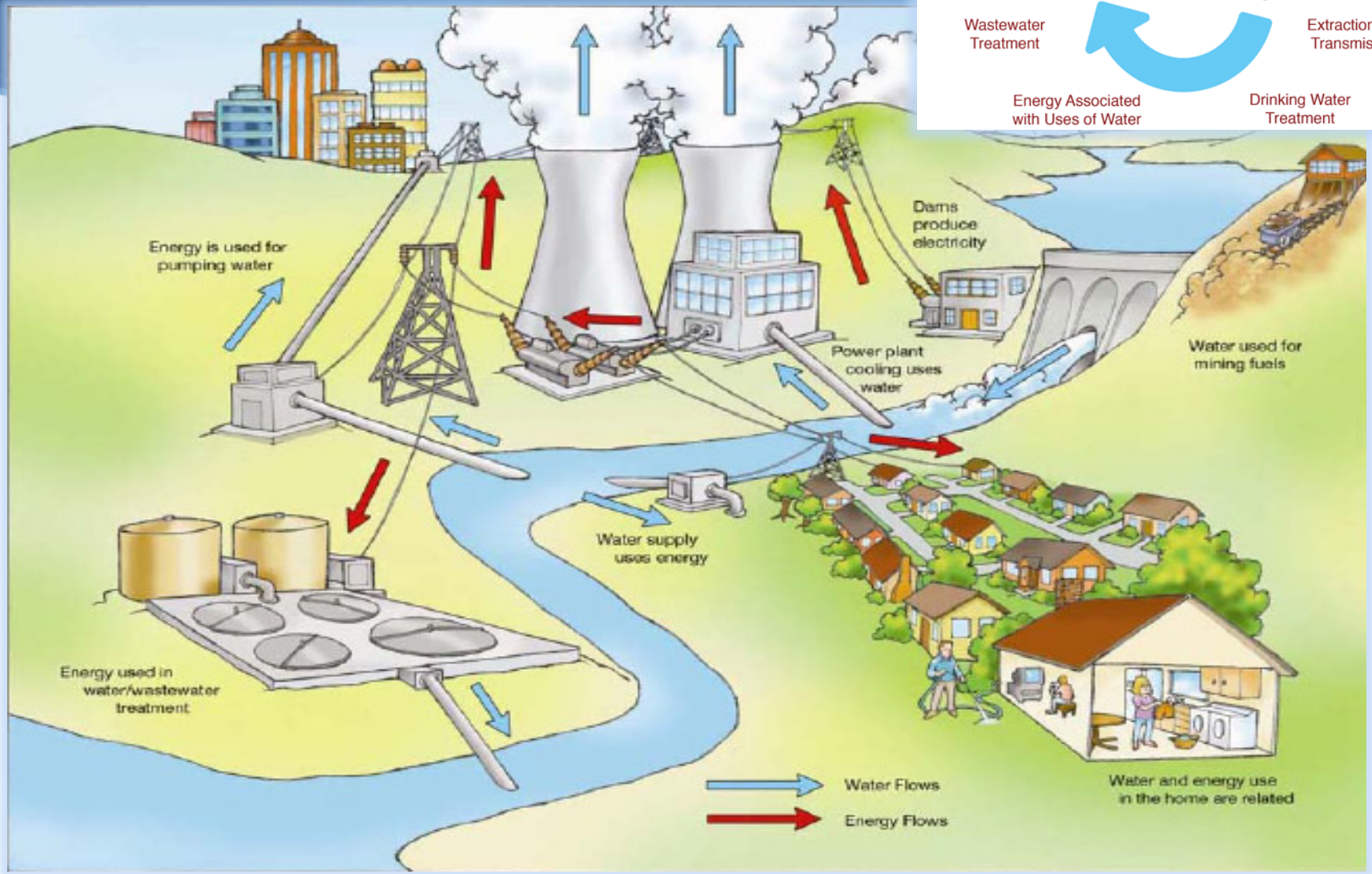
- Consumption
- Production

of energy in water utilities?

- **Energy Consumption in Water Systems**:
  - Transport from Source to Tap
  - Treatment of source and grey water
  - Water heating and cooling by the consumer
- **Energy Production in Water Systems:**
  - Utilizing downward flows
  - Using water for energy production (nuclear, hydro, geothermal)

DOE Energy Water Nexus Refresher





Energy Water Nexus Process and Progress to Date

- *Identify topic and sub-questions (Done)*
- *Conduct initial research (Done)*
- *Produce first draft of findings (Done)*
- **Review findings with advisors - identify additional questions & resources (We Are Here)**
- Revise report & review with advisors
- Complete report for dissemination to advisors & others

NOTE TO ADVISORY BOARD:

- **As you review the information:**
  - What's new and interesting?
  - What further questions does it raise?
  - **Is this information you want to share with your city's water people?**

Framework for the Energy Water Nexus:
section by section

Section 1 **Energy Needs in Water Systems**	• **Slides 7-14**
Section 2 **Collaborating for Energy Efficiency in Water Systems**	• **Slides 15-24**
Section 3 **The Importance of Technology in Operations**	• **Slides 25-31**
Appendix	• **Slides 32-39**

Section 1

Energy Needs in Water Systems

Emerging Energy Water Issues

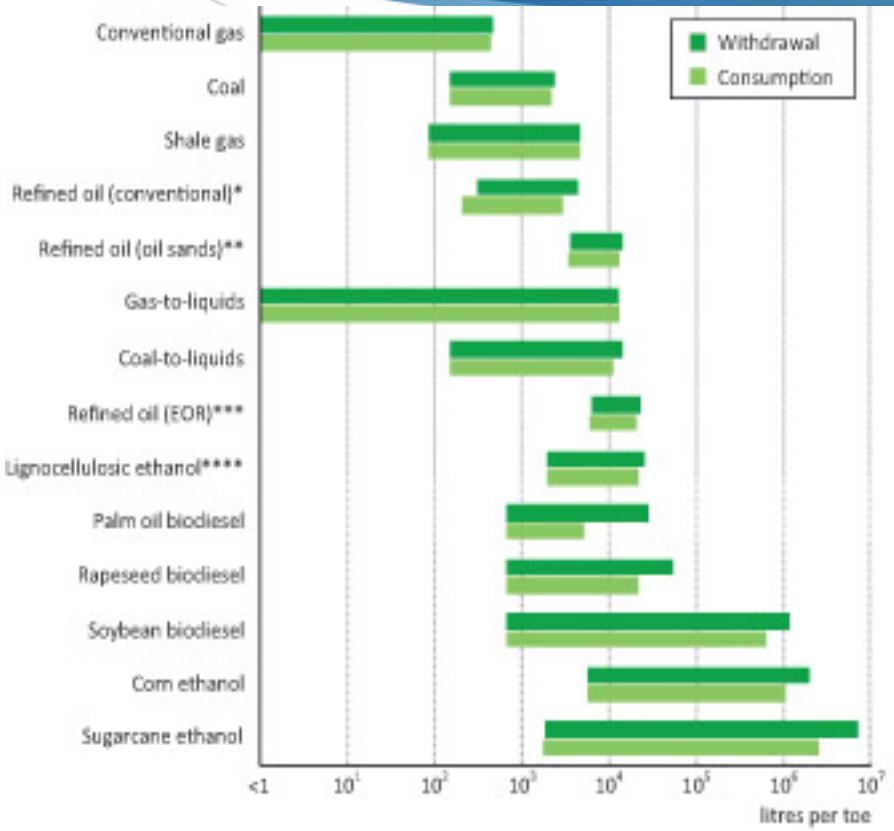
- Reports from leading business organizations have recognized the water-energy nexus as the next area of challenge and opportunity for the business community:
- World Economic Forum: "*translating global water worries into local solutions will not only require increasing awareness of the water challenge but also a better understanding within the energy industry of the complex relationship between water and energy*"
- World Business Council for Sustainable Development: *"[Businesses will have to] adequately address the nexus of water, energy and food; and the effective management and maintenance of biodiversity, ecosystems and ecosystem services"*

- **Emerging Impact: Rise of Alternative Fuels (DOE)**
  - First-generation biofuels consume 20 times as much water for every mile traveled compared to gas
  - Every mile of all-electric driving actually consumes about three times more water than a mile driven with gas
  - Pulverized coal plants ("Clean Coal") fitted with carbon capture equipment use twice as much water for thermal cooling as conventional coal. For gasification coal plants, water demand rises about 14% with the addition of carbon capture

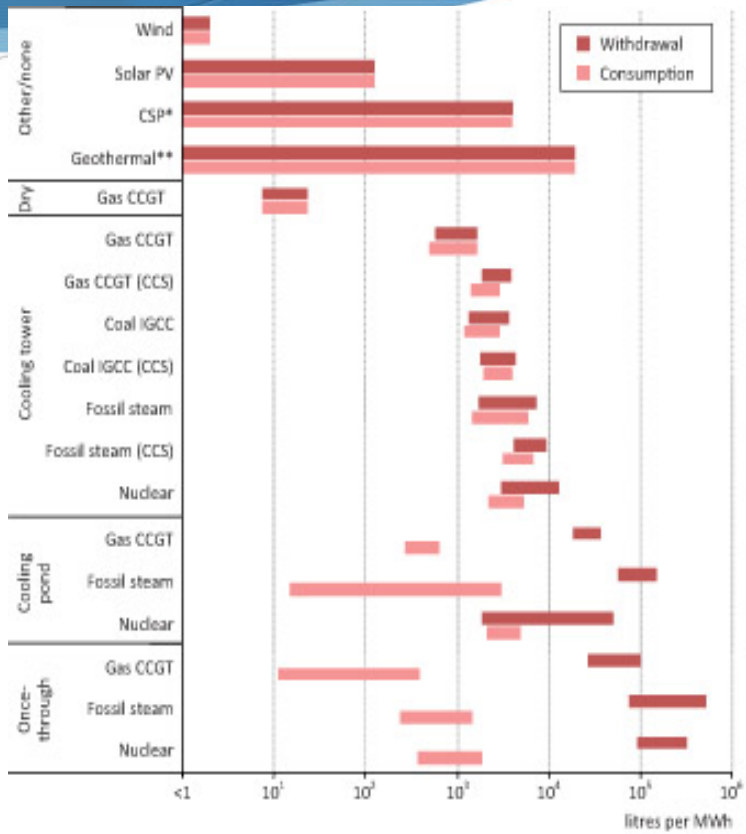
- **Emerging Impact: Rise of the Middle Class**
  - Some estimates say that by 2020 the world's middle class will grow to 52 % of global population, up from 30%
  - All told, in the next 12 years, the middle class will grow by as many as 1.8 billion, putting added strain on water supply

Water Requirements by Energy Source

Primary Energy



Electricity Generation



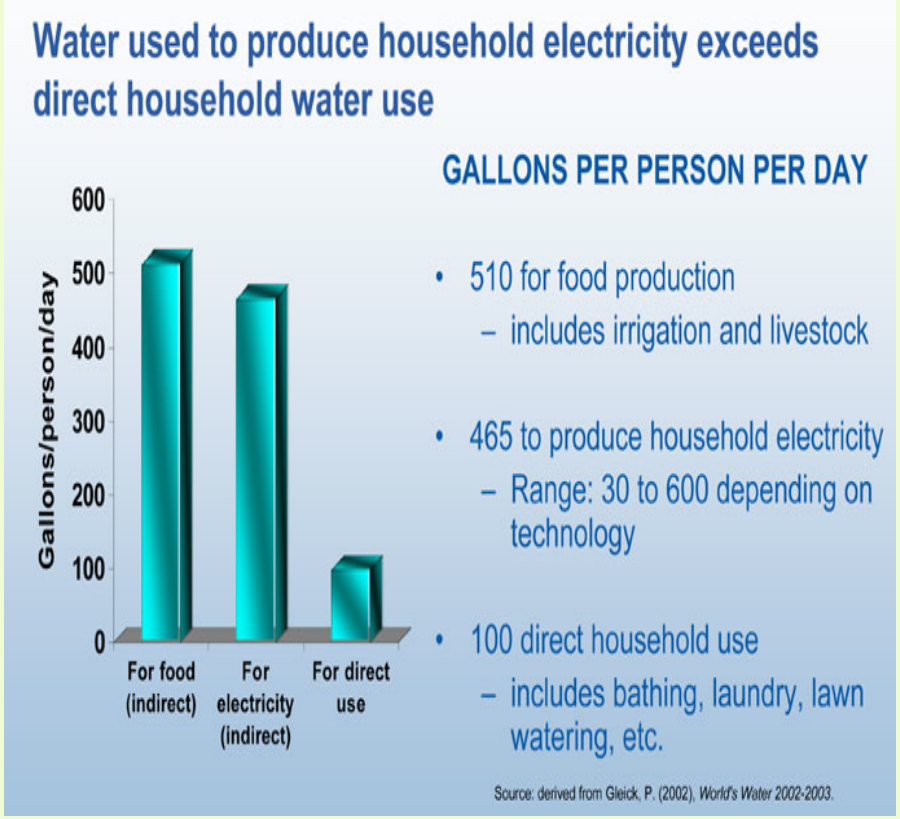
http://www.worldenergyoutlook.org/resources/water-energynexus/

How Consumer Behaviors Drive Energy and Water Costs

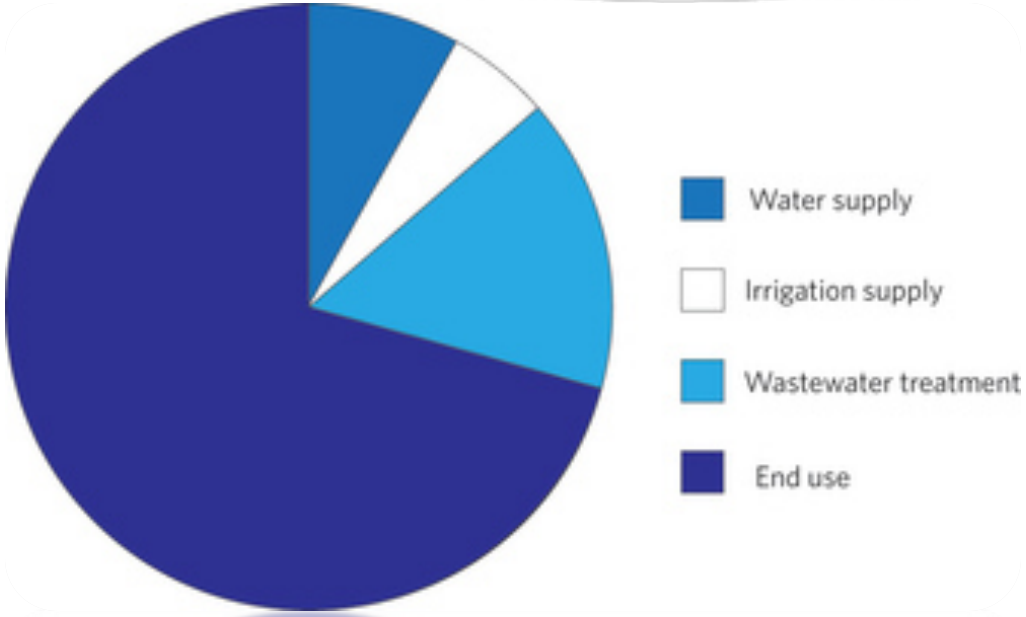
More Energy for End Use

- **Consumer Behavior:** according to DOE, **end use of water** (i.e., washing clothes, taking showers**) consumes more energy that any other part of the urban water conveyance and treatment cycle.**
- **Conservation:** Energy efficiency initiatives offer opportunities for delivering significant water savings, and water efficiency initiatives offer opportunities for delivering significant energy savings.
- **Residential Behaviors:** Residential water use is less than residential energy use. EPA's WaterSense program emphasizes "saving water saves energy", making the point that use of both is linked by cost.
- **Estimated Savings:** In the commercial and industrial sectors, there is a **15-30% potential water savings through energy efficiency** - without reducing water services (Congressional Research Service, Energy Water Nexus Report, Aug. 2013).

More Water for Energy



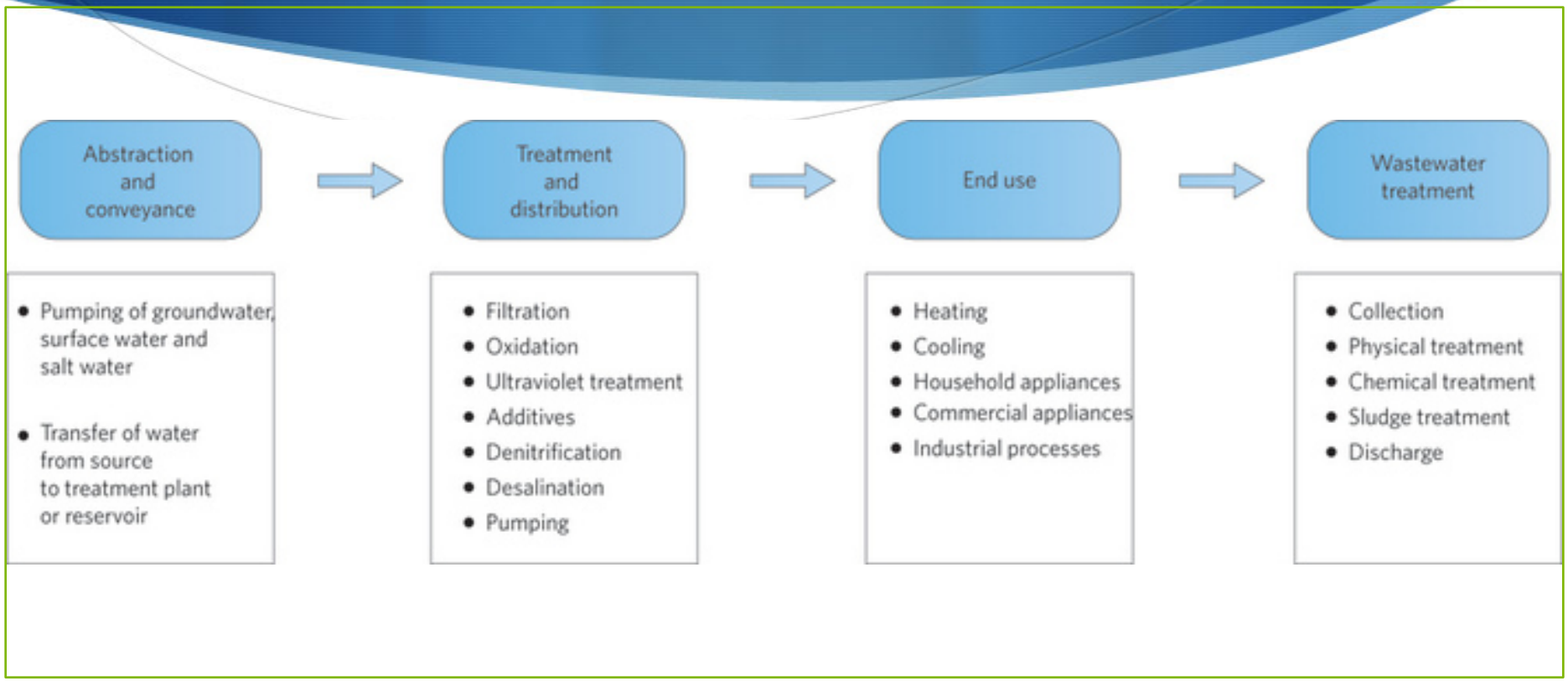
GHG Emissions In the Water Sector



- Some recent studies have highlighted the importance of GHG emissions from energy use in the water sector.
- They show that water-related energy use in the US accounts for between 5 and 8% of total GHG emissions
- In regions with very high freshwater withdrawals, most of the water is used for irrigation and the energy used in its extraction / transport is considerable.

[14] Rothausen, S., Declan Conway. "Greenhouse-gas emissions from energy use in the water sector", *Nature Climate Change,* July 2011. http://www.nature.com/nclimate/journal/v1/n4/abs/nclimate1147.html (Figures)

A Model of Energy Consuming Water Processes



[14] Rothausen, S., Declan Conway. "Greenhouse-gas emissions from energy use in the water sector", *Nature Climate Change,* July 2011. http://www.nature.com/nclimate/journal/v1/n4/abs/nclimate1147.html (Figures)

Energy Needs in Water Systems

Key drivers of energy consumption in water systems

- **Climate:** conditions by region (hot, dry, wet, cold) and climate change variability increasingly impact the water system energy consumption
- **Population Growth and Consumer Behavior:** as the middle class grows, end use of water (energy intensive uses like washing clothes / taking showers) consumes more energy that any other part of the urban water conveyance and treatment cycle
- **Fuel Types Utilized**: increasing use of alternate fuels / renewable energy has a larger water footprint than fossil fuel only, so there's a new balance to find

Changing the Conversation to include both systems

- Integrated decision making based on **good data is increasingly important as competition for water resources grow and energy costs increase**, but water system data is poor.
- Including energy considerations in water management decisions can lead to **significant energy, water, and cost savings.**
- Continued moves toward **energy efficiency in water systems** gains overall system resiliency in the face of climate change.

Sample Ways Water and Energy are Linked: Energy Consumption

Process Category	Process Goal	Physical Process	System Type	System Scale
Source to Tap	Clean water for consumption	Pump, convey, treat, and deliver water	Water supply, Water pipe delivery infrastructure	Regional distributors to local utilities
Water Recycling	Treat water for reuse	Collect, treat, and discharge wastewater	Wastewater Infrastructure	Regional distributors to local utilities
Water Comfort	Hot water on demand with as little energy as possible	Water Heating (preferably heated on demand, not stored heated)	Individual buildings (heat pumps, water heaters)	Industrial, Commercial, Residential

Sample Ways Water and Energy are Linked: Energy Reduction

Process Category	Process Goal	Physical Process	System Type	System Scale
Cooling	Meet urban demand during drought / heat waves	Planned storage capacity to meet short term conditions	Hydropower / small pump storage	Regional distributors to local utilities
Hydroelectric	Power generation from spilling	Produce energy from release	Hydropower / small pump storage	Regional distributors to local utilities
Nuclear	Maintain plant operations with existing water supply	Produce energy with proper cooling	Nuclear power plants	Regional distributors to local utilities
Geothermal	Goundwater for heating / cooling	Produce energy for heating / cooling	Buildings or Districts	Industrial, Commercial, District, Residential
Inter-regional Transmission	Capture Energy from transport of water downhill	Produce energy from release	Water Supply, Water Pipe Infrastructure	Regional distributors to local utilities

Water / Energy in Utility Operations – by the numbers (1)

Supply (Sources: EPA, DOE, and Congressional Reports)

- **Amount: There are ~200,000 drinking water treatment systems in the U.S.**, of which ~52,000 are community water systems that serve 25 or more year-round residents. Most U.S. drinking water is provided by large community water systems. ~ 85% of the U.S. is supplied by about 5% of the systems; the remaining 95% (small systems) serve 3,300 people or less. (Congress Report).
- **Ownership: Public agencies own and operate most community water systems** (some are privately operated). Smaller utilities use more electricity and pay more per unit of water produced than medium and large utilities, due to economies of scale.
- **Water Consumption: More than 400 billion gallons of water is withdrawn daily** from surface and ground water sources of freshwater and saline-water to supply domestic uses, agriculture (including irrigation), industry, mining, and thermoelectric power (DOE report). In 2005, Thermoelectric-power withdrawals accounted for 49 % of total water use, 41 % of total freshwater withdrawals for all categories, and 53 % of fresh surface-water withdrawals (USGS).
- **Energy Consumption: Community drinking water and publicly owned wastewater systems use 75 billion kWh per year**—as much as the pulp and paper and petroleum industries combined, or enough electricity to power 6.75 million homes (EPA). Groundwater supply from public sources requires 1,824 kilowatt-hours (kWh) per million gallons, about 30% more electricity than surface water supply, due to higher raw water pumping requirements for groundwater systems. (MI report).

Water / Energy in Utility Operations – by the numbers (2)

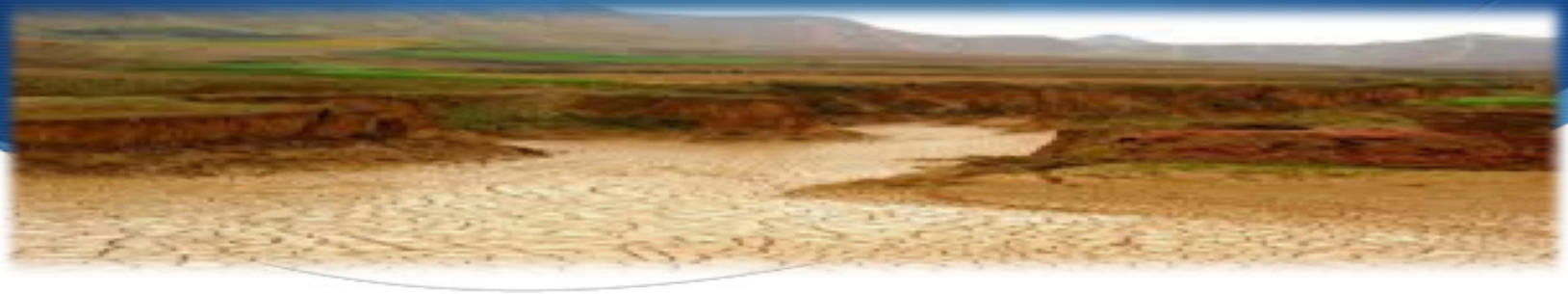
Treatment and Transport

- **Amount/ Ownership: There are ~ 15,000 U.S. wastewater treatment plants**. Most are publicly owned, and they serve more than 75% of the U.S. population. Nearly 70% of facilities are small, serving only 10% of the U.S. population. Approximately 22% are large (with flow greater than 1 million gallons per day) and serve over 85% of the population. Wastewater aeration, pumping, and solids processing account for most of the electricity used in wastewater treatment.
- **Costs by Percent: Electricity use accounts for ~80% of municipal water processing and distribution costs** (used by motors for pumping). Energy consumption by water utilities can comprise 30-40% of a municipality's total energy bill (Congress Report). 4% of total U.S. electricity use goes towards moving and treating water.
- **Costs in Dollars: Utilities spend ~ 4 billion per year on electricity collectively**. Energy is the second highest budget item for municipal water utilities (after labor costs).

Section 2

Collaborating for Energy Efficiency in Water Systems

Energy / Water Policy Findings



Action Items

- Prioritizing water conservation funding
- Enforcing existing conservation requirements
- Requiring water measurement
- Promoting conservation through conservation pricing
- Offering conservation incentives
- Implementing measures to ensure conservation savings

Reasons Why

- Both water and energy policymakers should give water conservation higher priority because:
  - **End use is where it's at:** Policy actions that affect water end uses of water may have much larger energy implications than policy actions that affect water sources
  - **Conservation is still the low hanging fruit**: has much greater potential, and stronger energy- related economic and environmental benefits, than has been recognized to date
  - **Conservation impacts environmental (air) quality, saves money, and allows for resiliency – even if water isn't scarce, saving energy saves water**

Rising Energy Demand and Policy Trade Offs

Water use and Wastewater are one of Many Energy Policy Factors

- To help meet increasing energy demand, domestic energy production is rising (along with its associated water usage)
- Increase in water use associated with energy development is driven by:
  - Rising energy demand
  - Increased development of domestic energy
  - Shifts to water-intense energy sources and technologies
  - Generation source (some energy producers use significant water):
    - Cool thermoelectric power plants
    - Grow feedstock for biofuels
    - Extract oil and natural gas

Other Energy Concerns that Compete with Water Considerations

For some Utility or Governmental decision makers, there are more significant drivers of priorities in energy policies:

- Low-cost reliable energy
- Energy independence and security
- Climate change mitigation
- Public health / public opinion
- Job creation
- Political priorities / Administrations

Political Landscape / System Jurisdictions

Sample Barriers to Integrated Planning

- **System Isolation (many different "owners")**
  - *Planning, funding, regulation, and standard setting for water and energy systems are managed separately*
- **Political Boundaries**
  - *Watershed and grid boundaries have their own scope that is beyond city / county limits*
- **Different Methods of Collecting and Storing Data:**
  - *Makes energy and water system integration difficult*
- **Lack of Performance Metrics / Indicators / Targets**
  - *Lack of ability to judge performance systematically, benchmark, or look at energy and water systems*
- **Uncoordinated Reporting**
  - *Separate management and reporting of water and energy performance, no "big picture" perspective or conversation*

Sample Best Practice (Cities and Utilities)

- **System Integration (Many owners with the same conversation)**
  - *Collaboration at all levels of government, especially between city (i.e., policy setting through building codes) and utilities (i.e., operations and rate setting)*
- **Utilizing Planning Tools**
  - *Using geographic information and hydro / grid model scenario outputs to better inform decision makers of reach and impact (especially useful in adaptation planning)*
- **Coordinated Data**
  - *Understanding what information is needed to consider both systems effectively*
- **Performance Metrics / Indicators / Targets**
  - *Simultaneously considering water and energy and involving all impacted sectors in determining targets (which will differ by region)*
- **Coordinated Messaging to Change the Conversation**
  - *Reporting is transparent and used to evaluate efficiency of both water and energy systems; the conversation framing is in terms of sustainability and resiliency*

Regulations and Responses Typical of Both Systems

Attributes of Energy and Water Systems that can be Regulated

- Quality
- Supply
- Monopolistic Systems
- Transport Methods
- Rate Setting
- Monitoring and Measurement (sensor) Systems

Responses of Energy and Water Systems to Regulation

- Increased treatment
- Increased efficiencies
- Competition Introduced
- Restructuring of Systems
- Decoupling of rates & consumption
- Disclosure

Energy Water Policy Across Regions

Best Practice, No Borders

- **Examples of Reoccurring Themes:**
  - Top Down Leadership
  - Integrated Planning
  - Measurement/Data Gathering/Metrics
  - Performance Evaluation
  - System Upgrades
  - Disclosure

Regional Variations

- **Examples of Regional Items:**
  - Climate Change
  - Water Supply Sensitivities
  - Watershed Planning
  - Integrated Systems Planning
  - State Support/Programs
  - State/Regional Regulations
  - Comparison Sensitivities

Energy Water Issues by Region

Challenge Group	Challenges	Energy Water Impacts
Drought	• Reduced Groundwater Recharge • Lower Lake and Reservoir Levels • Changes in Seasonal Runoff and Loss of Snowpack	• Transport needs increase / energy needs rise • Nuclear and hydro generation reduced • Collapsing infrastructure due to reduced flows
Water Quality Degradation	• Low Flow Conditions and Altered Water Quality • Saltwater Intrusion into Aquifers • Altered Surface Water Quality	• Transport needs increase • Nuclear and hydro generation reduced • Treatment costs increase / energy needs rise
Floods	• High Flow Events and Flooding • Flooding from Coastal Storm Surges	• Transport infrastructure stressed, threatened • Increased flows in pipe means increased treatment / more energy to process
Ecosystem Changes	• Loss of Coastal Landforms / Wetlands • Increased Fire Risk and Altered • Vegetation	• Infrastructure systems threatened • Transport threatened • Energy needs difficult to project • Fuel supplies jeopardized
Service Demand and Use	• Volume and Temperature Challenges • Changes in Agricultural Water Demand • Changes in Energy Sector Needs and Energy Needs of Utilities	• Infrastructure inappropriately sized • Demand under or over estimated • Demand exceeding supply / grid reliability

Factoring Water and Energy into City policies / decisions

Why it Matters to Local Government

- Social and economic progress depends on access to water and energy
- As energy demands and costs grow, conflict over water increases. Competition for water among municipalities, farmers, industrial and power suppliers is already evident in a range of locations, notably in the West and Southwest United States
- As new energy policies emerge, water needs to be added to the mix. Energy decisions are a series of tradeoffs between water, security, cost, and carbon

Current Local Government Best Practice

- **Adaptation Planning:** integrated planning that looks at water and energy in the same lens
- **Energy Audits and Performance Contracting:** Payback period financing for system upgrades that can include sensors to improve interactive system management
- **Pairing Energy and Water with a local sustainability issue that resonates (food supply / waste stream, etc.):** some communities gain traction when energy and water are paired with another issue

Changing the Conversation: Tucson

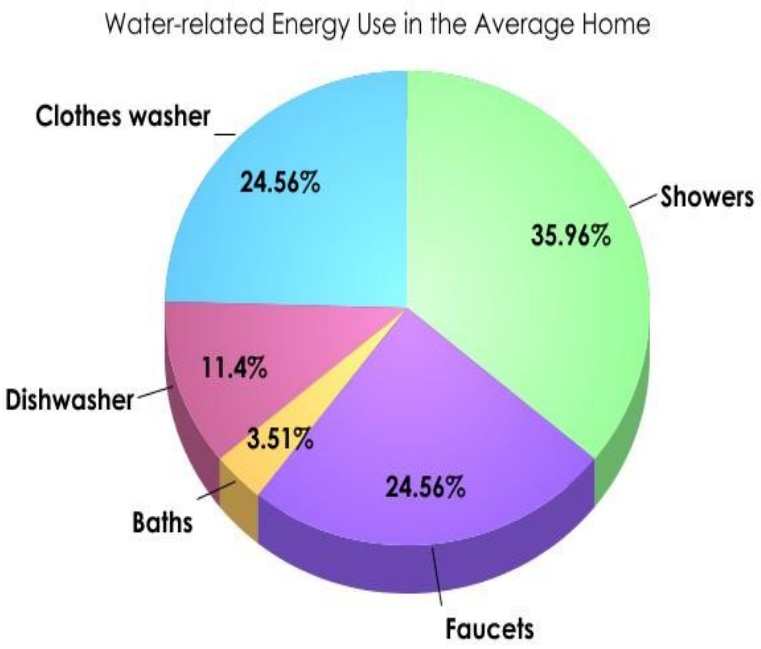
- Leslie Ethen noted **energy capture is the key component of how Tucson talks about its water system** because the Colorado River is prohibited from recharge delivery (i.e., they have to pump over a small mountain range into the city)
- There's embedded energy just for transport. Is there a way to recapture some energy on the way down the mountain? Technology opportunities?
- Water audits / upgrades are often based on energy consumption
- Tucson Electric power is the main supplier (primarily coal based, with natural gas growing and some renewable energy in the portfolio)
- The Ina Road Water Pollution Control Facility achieved an annual savings of $1.26M from installing a cogeneration system (EPA data)
- Tucson requires proposed commercial development to get 50 percent of its water on site (rain collection)
- There may be a renewable energy requirement in 2050 at the State level

Consumer Behavior: Education is Still Key

- Energy and water use consumption factors
  - Short-term dynamics: daily habits and patterns
  - Long-term dynamics: migration/population growth

Bottom Line:

Keep up the energy efficiency and water conservation push



Source: Western Resource Advocates

Section 3

The Importance of Technology in Operations

Programmatic Approaches

- **As populations grow / environmental requirements become more stringent, demand for electricity at drinking water and wastewater utility plants is expected to grow by approximately 20%**
- **As electricity rates increase, energy conservation /efficiency are of increasing importance to many utilities. By some estimates, potential energy savings by drinking water and wastewater utilities are in the range of 15-30% per year**

- Opportunities for efficiency exist in several categories
  - **Optimizing system processes:**
    - Modifying pumping and aeration operations, and implementing monitoring / controls
    - It's estimated that drinking water facilities can achieve energy savings of 5-15% through adjustable speed drives and high- efficiency motors, and 10-20% through monitoring systems
  - **Upgrading and right-sizing equipment**
    - Plants and pipes can be oversized (to accommodate future peak load); pumps and other equipment used beyond expected life and operate well below optimal efficiency
    - Energy is embedded through pipe systems, since leaking drinking water pipes require more energy to deliver water
    - Leaky sewer lines allow groundwater to infiltrate and increase the flow of water into the wastewater treatment plant
    - Projects to address water loss and improve end-use efficiency can be promoted as both water and energy saving investments
  - **Improved energy management**: there is a need to develop better ways to measure and report energy use
  - **Energy Generation in water**
    - Some water utilities are reducing energy costs by recovering energy from municipal waste and using the resulting biogas to generate electricity, heat the plant, and in some cases sell electricity back to the grid

Planning for Water System Energy Improvements

Use Technical Tools

- **Planning:** Geographic Information Systems (GIS) and dynamic modeling of water and energy systems together (overlays) can inform the planning process for system upgrades and find areas of potential power loss or generation
- **Implementation:** system upgrades should include advanced materials /sensors based on model results– so the system isn't just a maintenance item, it's proactively performing

Use Policy Tools

- **Top Down Leadership:** Place responsibility for water-related issues at the Board / Executive Committee / Administration level
- **Integrated Planning:** Integrate water consumption into overall climate and energy risk assessments
- **Implement:** Develop specific action items with measurable outcomes
- **Forecast:** Identify linkages and tradeoffs in management of water and energy
- **Grow Economically**: Identify water-related business opportunities
- **Report:** Be transparent about the energy and water relationship as well as the tradeoffs made managing them together

Today's Operations / Technologies

Consumption Reduction

- Equipment and Collection System Upgrades
  - Install variable-frequency drives (adjusts based on power delivered)
  - Upgrade to energy efficient motors and motor systems
  - Heating, cooling, ventilation, and lighting system upgrades
- Operating Strategies
  - Managing electrical load
  - Bio solids management
  - Regular training and maintenance
  - Inflow and Infiltration Control

Emerging Production

- Cogeneration / Combined Heat and Power
  - Cogeneration using landfill gas
- In Conduit Hydro-Power
  - Small-scale hydro, including utilizing downward flows in pipes
- Wind, Solar, or Biodiesel use
- Produce biogas through anaerobic digestion of organics (fats, grease)
- Small-scale pump storage (for release during peak loads)
- Small modular nuclear reactors (research phase, attractive due to less footprint and ease of going on / off line)

Case Studies: Utility Best Practices

- **Benchmarking Energy Use**
  - **The New York State Energy Research and Development Authority** has done extensive work to help water utilities benchmark their energy use and support a range of initiatives through its Focus on Municipal Water and Wastewater Treatment program.
  - It developed a best practices handbook for the water and wastewater sectors, including methods to track performance and assess program effectiveness (see Resources)

- **Implementing Energy Efficiency**
  - **The California Energy Commission** has been active on energy management issues.
  - It has reported on case studies of water facilities throughout the state that implemented energy efficiency measures, including resulting energy and cost savings.
  - In 2006, the California Public Utilities Commission (CPUC) directed the state's largest electric utilities to
    - Partner with water agencies
    - Undertake water conservation and efficiency programs, and
    - Measure the results

- **Energy Generation**
  - **D.C. Water, the wastewater utility in Washington, D.C.**, is constructing a project to convert residuals that remain after wastewater is treated into fuel for combined heat and power operations at the facility.
    - The utility estimates that when the project is completed, it will save $10 million per year on electricity (powering one-third of the treatment plant) and another $10 million annually in solid waste management.
  - **The Gloversville-Johnstown, NY Joint Wastewater Treatment Facilities** began accepting dairy whey in 2003 as a fuel for its own energy through a combined heat and power process.
    - Reduced electrical costs save the utility about $500,000 per year, and accepting the dairy wastes results in additional revenue of $750,000 annually.
  - **Calera Creek Water Recycling Plant in Pacifica, California** plants are using other sources of renewable energy:
    - Solar panels provide 10-15% of the plant's energy needs and save an estimated $100,000 per year.
    - Savings are contingent upon recouping capital investment costs.

Barriers to Energy Action in Water Utilities

- **Cost**
  - Utilities have limited resources
  - Capital and operations budgets are constrained, while the up-front costs of installing more energy-efficient equipment can be prohibitive
  - Some funding sources to finance projects do exist (e.g., private sector, municipal bonds), but may not be suitable / known to water utility officials
  - Federal and state funding for energy efficiency projects is spotty and limited
- **Risk Aversion**
  - Municipalities that own and operate water utilities generally are risk-averse, reluctant to change practices, and hesitant to implement new technologies.
  - Tendency is to wait until equipment fails rather than be pro-active
- **Incomplete Information**
  - Facility operators who could advocate for energy efficiency often are disconnected from those in the utility who pay the electricity bill.
  - Most water and wastewater facilities were built decades ago when electricity costs were low enough to be of little concern
  - Facilities and equipment were designed to run continuously, without regard for wasted energy.
  - Water utilities can pass on energy costs to customers, so there is little incentive to investigate energy efficiencies
  - Utility managers may not understand how energy is used at a plant and how to reduce or control, energy costs

City and Utility Resources

- **Tools for Initial Planning Phase and Determining Baseline Energy Use in Utilities:**
  - ACEEE Local Technical Assistance Toolkit: Energy Efficiency in Water and Wastewater Facilities: http://www.aceee.org/files/pdf/toolkit/Local_Toolkit_Water.pdf
  - New York State: Payback, checklists, benchmarking: http://www.nyserda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Commercial-and-Industrial/Sectors/Municipal-Water-and-Wastewater/MWWT-Tools-and-Materials.aspx
  - EPA Energy Star for Water and Wastewater Treatment Plants: http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager

- **Tools for Cutting Energy Costs and Use in Utilities:**
  - California Energy Commission: http://www.energy.ca.gov/process/water/index.html
  - EPA Energy Guide for Water Utilities: http://www.epa.gov/owm/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf
  - EPA Energy Guide for Wastewater: http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf
  - DOE: http://www.nrel.gov/docs/legosti/old/7974.pdf

- **Sample Programs / Educational Tool that Combine Water and Energy Considerations:**
  - Lexington Green: http://www.lexingtonky.gov/index.aspx?page=2323
  - Water Footprint Calculator: http://www.waterfootprint.org/?page=files/home

- **Organizations that research best practices for energy conservation and benchmarking:**
  - Water Environment Research Foundation
  - Water Research Foundation
  - American Council for an Energy-Efficient Economy

Sources

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- U.S. EPA, "Energy Efficiency in Water and Wastewater Facilities: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs"
- Water, Energy and Climate Change: A Contribution from the Business Community. World Business Council for Sustainable Development. 2009
- Water Environment Federation: Energy and Water, Access Water Knowledge Center – The Energy Roadmap: A Water and Wastewater Utility Guide to More Sustainable Energy Management

Appendix

Energy Water Nexus

Utility Resilience: examples

- **Sonoma County Water Goals:**
- Carbon Free Water
  - Water conservation
  - System efficiency
  - Develop/procure renewable energy
  - Projects of Regional Benefit

- **Santa Clara Valley Water District Goals:**
- Achieve carbon neutrality by 2020 by:
  - Establishing an internal carbon offset method for emission reduction including:
  - Crediting emission reductions from water conservation programs, habitat restoration or enhancements
  - Adding renewable energy production
  - Contributing to countywide emission reduction efforts.

- **Seattle Public Utilities Goals:**
  - Enhance knowledge by engaging the science
  - Assess impacts and vulnerabilities ,
  - Establish collaborative partnerships
  - Strengthen institutions and people,
  - Mainstream adaptation into decision-making
  - Develop portfolios of approaches
  - Quantify and reduce our emissions

- **Resources on Carbon Neutral Water Systems:**
  - EPA- *Energy Efficiency in Water and Wastewater Facilities: A Guide to Developing and Implementing Greenhouse Gas Reduction*
  - Water Environment Federation: Energy and Water, Access Water Knowledge Center – *The Energy Roadmap: A Water and Wastewater Utility Guide to More Sustainable Energy Management*

Budgeting for Resilience

- Water and wastewater **utilities are tied together by cost and billing**, and capital resources and ratepayer resources are constrained.
  - **Wet weather extremes**: programs require expensive re-sizing to manage higher flows, it may reduce influent challenges for water utilities, but will still have an impact on the water supply side of the business through this financial connection.
  - **Dry weather extremes:** discharge permits and waste load allocations are quite often grounded in the low flows documented in the historic hydrologic record.
- **For utilities, financing infrastructure upgrades on their own is challenging**, due to:
  - Limitations on their capital expenditure imposed by regulators
  - Their own revenue-raising models

- **Cities are a system of interacting systems**
  - One single stakeholder rarely stands out as having sufficient motivation to organize the required collaboration on their own.
- **The question of who pays for physical resilience improvements depends on whether the resilience benefits go to the private property owner or the community**
  - What is the impact of resilience investment on disadvantaged communities and how can social equity be achieved / maintained

Utility Energy Generation: Services and Retail Prices

2012 Total Electric Industry- Sales By Sector	U.S. Totals (Thousand Megawatthours)	Average Retail Price (cents/kWh) 1,000 kWh = 1 MWh
Residential	1,374,515	11.88
Commercial	1,327,101	10.09
Industrial	985,714	6.67
Transportation	7,320	10.21
Total	3,694,650	9.84

Data from forms EIA-861- schedules 4A, 4B, 4D, EIA-861S and EIA-861U)