Quantifying Water Impacts of Buildings' Energy Usage

Doug Elliott & Jim Dirks

Pacific Northwest National Laboratory

Presentation to the Buildings Technology Research and Development (BTRD) Subcommittee

of the

National Science and Technology Council, Committee on Technology

May 28, 2009

(updated Sept. 25, 2009)

PNNL-SA-66601

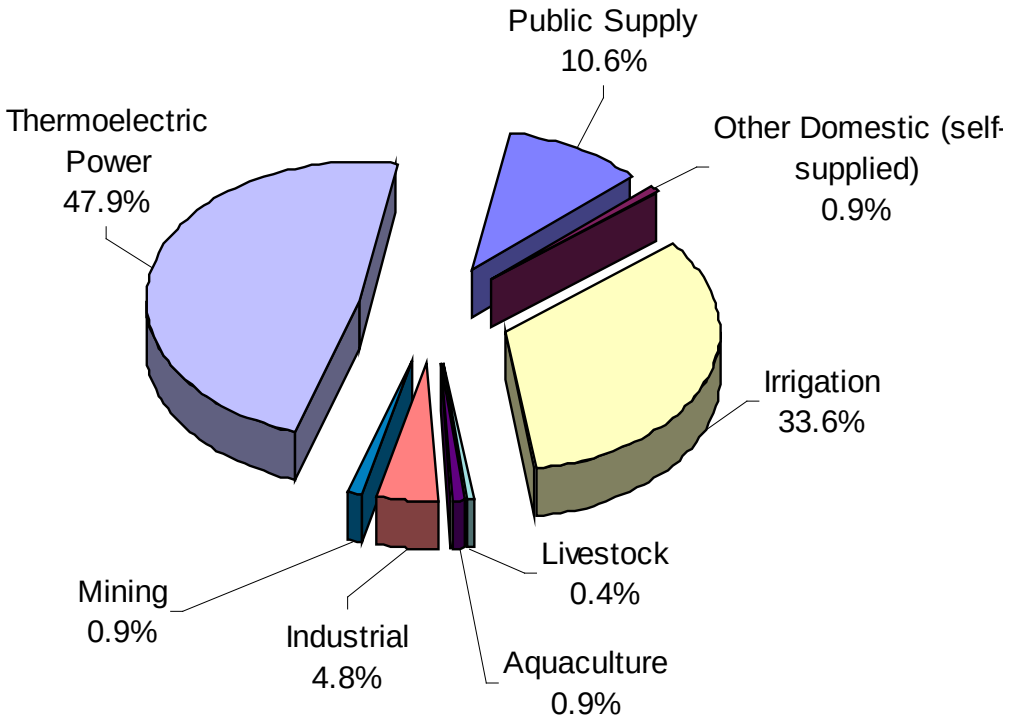
The issue – indirect water usage

- Most building energy use does not directly impact water.
- Yet, water impact of energy production is very large, via generation plant cooling requirements.
- “Thermoelectric-power withdrawals accounted for 48 percent of total water use, 39 percent of total freshwater withdrawals for all categories, and 52 percent of fresh surface-water withdrawals” in 2000.

Source: USGS.
http://ga.water.usgs.gov/edu/wupt.html

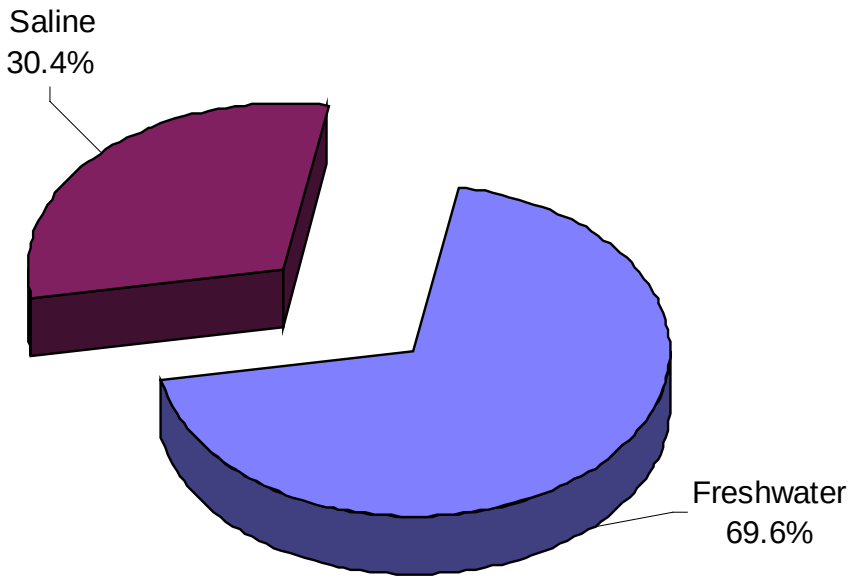
2000 total water withdrawal

Total: 148,920 Billion Gal./Year
Thermoelectric Power: 71,358 Billion Gal./Year



Data source: 2000 USGS Circular 1268.
http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf

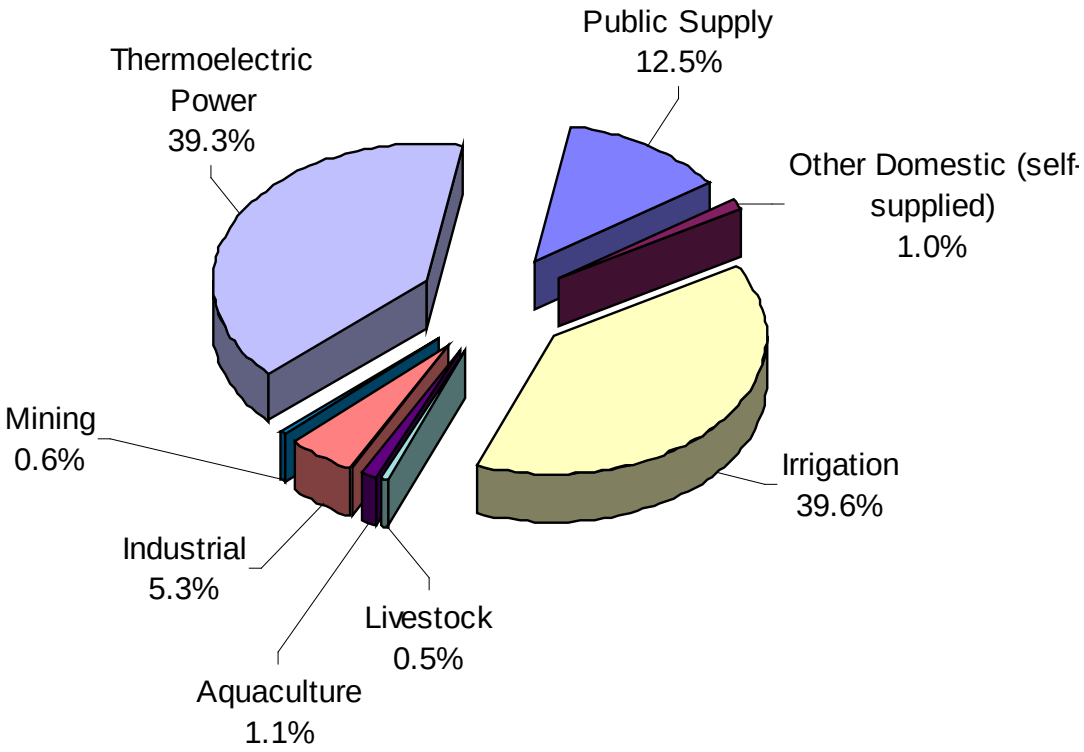
2000 thermoelectric power withdrawal breakout



Data source: 2000 USGS Circular 1268.
http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf

2000 freshwater withdrawal

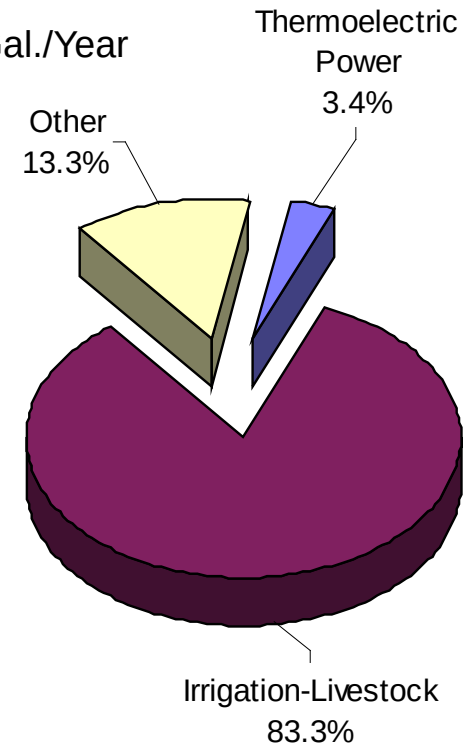
Total: 125,925 Billion Gal./Year
Thermoelectric Power: 49,640 Billion Gal./Year



Data source: 2000 USGS Circular 1268.
http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf

2000 freshwater consumption

Total: 36,896 Billion Gal./Year
Thermoelectric Power: 1,241 Billion Gal./Year



Data sources: 2000 USGS Circular 1268 and 1995 USGS Circular 1200.
http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf
http://water.usgs.gov/watuse/pdf1995/pdf/circular1200.pdf

But why does the Department of *Energy* care about *water*?

- Water withdrawal constraints may impact utility operations, and restrain energy production.
  - Drought
    - Several Southeast reactors threatened by drought in 2008.
    - Browns Ferry reactor shut down briefly in 2007.
  - Hydro. Water consumed upstream may not make it through turbines downstream.
  - New baseload plants, at least in some regions, could face difficulties in securing sufficient cooling water.
- In DOE's and society's interest to fully capture, understand, and convey program impacts, many of which are external and cannot easily be converted into dollar terms.
- Energy efficiency efforts can significantly reduce indirect water impacts of generation, while providing increased water consumptive capacity elsewhere.
  - A CFL in a porch light avoids the consumption of ~140 gallons of water over its lifetime.

The Building Energy Analysis and Modeling System (BEAMS)

- PNNL-developed and BTP-funded tool used to estimate impacts of buildings-related projects.
  - Lighting
  - Equipment
  - Envelope
  - Whole building
- Uses internal algorithms as well as inputs from the National Energy Modeling System (NEMS).
- Outputs
  - Energy savings
  - Required investment
  - External impacts: avoided carbon, CO, SO_x, NO_x, VOCs, PM10, and now H_2O withdrawal and consumption.

Enhancements to the estimation of external impacts in BEAMS

- Avoided indirect water withdrawal and consumption (tied to avoided electricity consumption).
- Mean or marginal analysis.
- “By plant” (base, intermediate, peaking) or “weighted” (aggregated across plant type) basis.
  - “By plant” method essentially a time-of-use approach, allowing specification of activity-specific avoided generation mixes.
  - “Weighted” analysis assumes efficiency activities do not shift generation plant dispatch. Generation is avoided at each plant type, using average plant-type mix.

The starting point: water coefficient development, by generation technology

Plant Technology	Mean Withdrawal Factor (Gal./kWh)	Mean Consumption Factor (Gal./kWh)
Coal Steam Turbine	11.664	0.299
Combined Cycle	0.925	0.048
Combustion Turbine	0.004	0.004
Import	0	0
Nuclear	15.691	0.456
Oil Steam Turbine	14.871	0.11
Renewable	0	0

Sources: DOE/NETL-400/2008/1339 and PNNL internally-developed estimates.
http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/2008_Water_Needs_Analysis-Final_10-2-2008.pdf

Water coefficient development, by generation plant type and year

2010

Plant Type	Marginal Withdrawal Factor (Gal./kWh)	Marginal Consumption Factor (Gal./kWh)
Baseload	11.585	0.309
Intermediate	3.411	0.104
Peaking	0.004	0.004
Weighted	9.391	0.254

2030

Plant Type	Marginal Withdrawal Factor (Gal./kWh)	Marginal Consumption Factor (Gal./kWh)
Baseload	11.361	0.304
Intermediate	3.313	0.101
Peaking	0.004	0.004
Weighted	9.204	0.249

Sources: PNNL internally-developed estimates, employing NETL inputs.

Note: Only two selected years of the annual data are displayed here for illustration.
Factors decline slightly over time due to increasing new-plant efficiencies.
Weighted factors utilize average plant-type mix (75.2% baseload, 20.0% intermediate, 4.8% peaking).
Factors are applied to site electricity savings.

Results (weighted): water withdrawal and consumption avoided due to BTP activities

Actual BEAMS output (Billion Gal./Year)

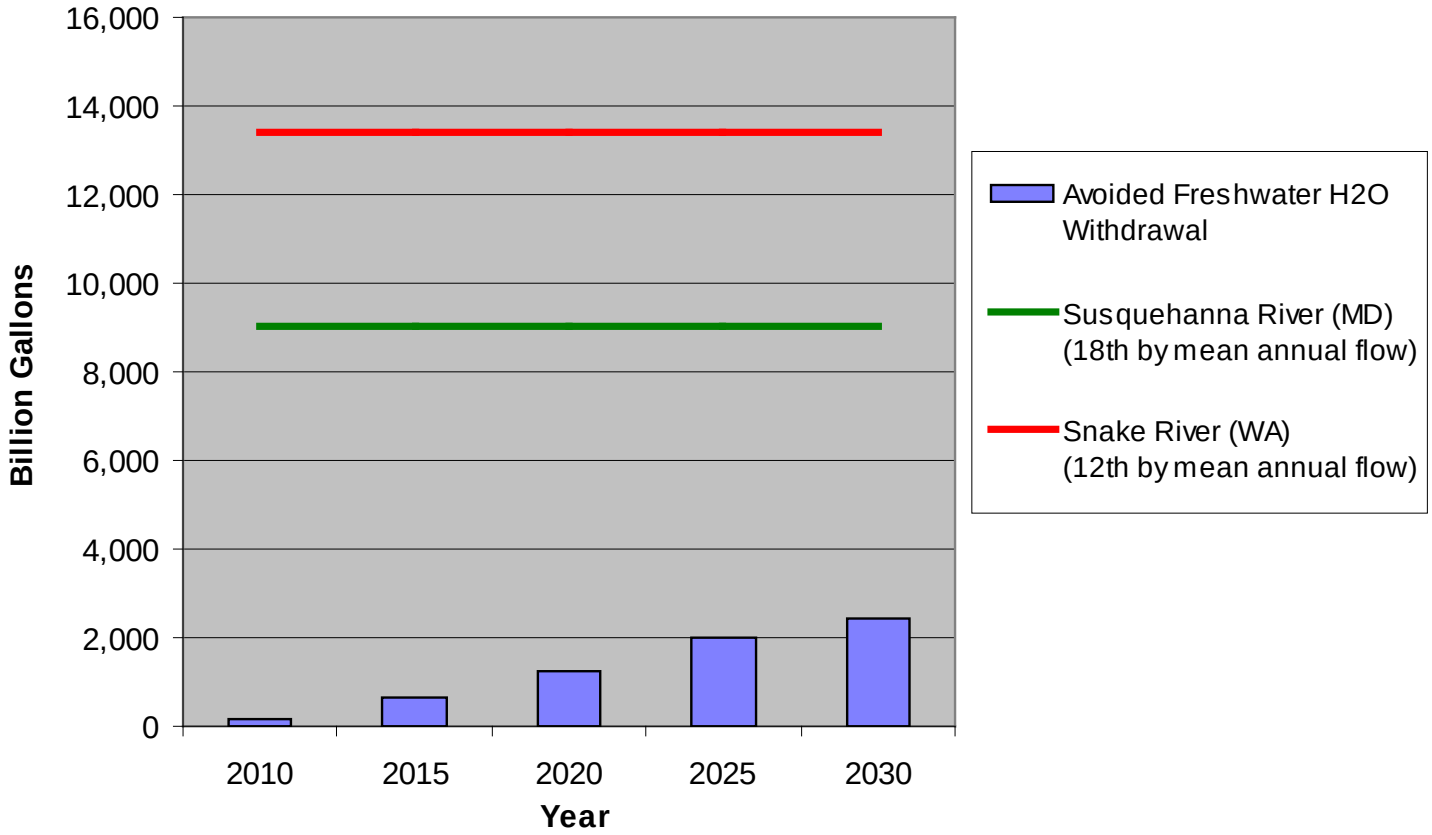
	2010	2015	2020	2025	2030
Avoided Total H2O Withdrawal	232	925	1,804	2,872	3,493
Avoided Total H2O Consumption	6	25	49	78	94

Using only freshwater portion of BEAMS output (Billion Gal./Year)

	2010	2015	2020	2025	2030
Avoided Freshwater H2O Withdrawal	161	644	1,255	1,998	2,430
Avoided Freshwater H2O Consumption	4	17	34	54	66

Sources: PNNL BEAMS model outputs and USGS Circular 1268.
http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf

But how much is a billion gallons of withdrawal?



Sources: BEAMS outputs; USGS, Largest Rivers in the United States. http://pubs.usgs.gov/of/1987/ofr87-242/

And for some perspective on avoided consumption…

- U.S. per capita annual domestic use in 2000: 33,600 gallons.
- Avoided freshwater consumption indicated by BEAMS outputs, in terms of persons offset:

Persons offset

2010	2015	2020	2025	2030
129,415	517,521	1,009,088	1,606,170	1,953,689

Sources: BEAMS outputs, World Bank, and 2000 US Census.
http://www.census.gov/main/www/cen2000.html
http://www.newton.dep.anl.gov/askasci/gen01/gen01629.htm

Alternative methods of acquiring equivalent consumptive capacity

- Household-level retrofits:
  - Replace older toilets with 1.6 gallon/flush toilets.
  - Replace older top-loading clothes washers with current Energy Star clothes washers.

Number of retrofit households necessary to yield equivalent consumptive capacity

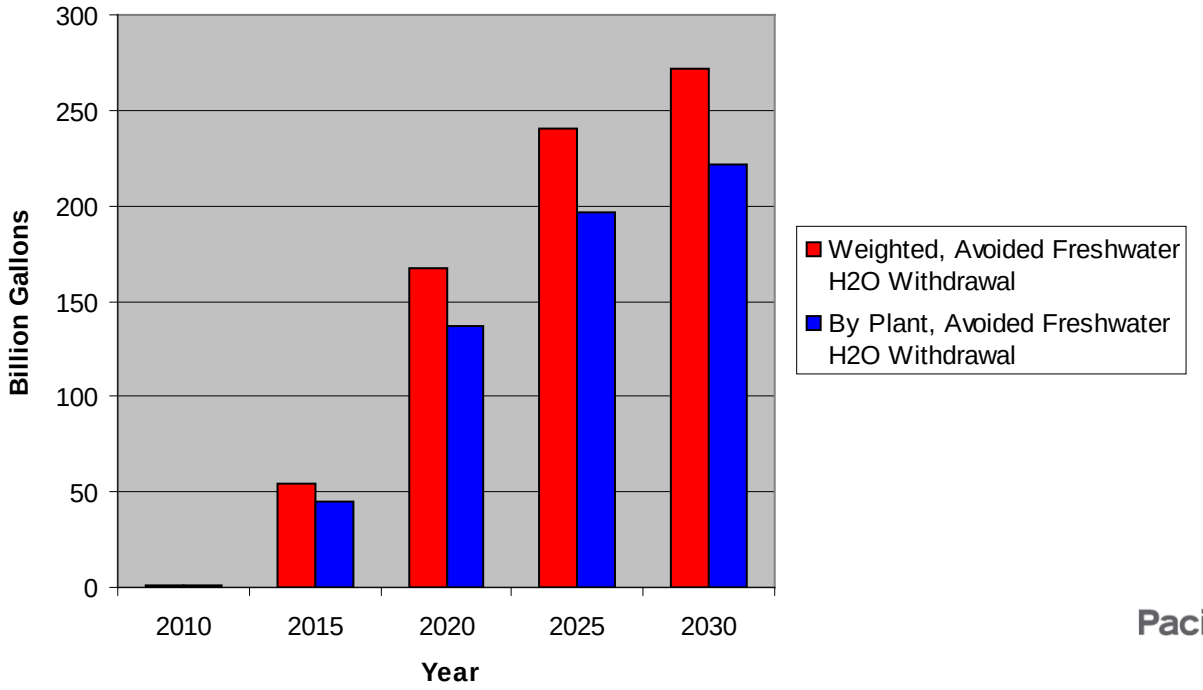
	2010	2015	2020	2025	2030
Households: 1.6 GPF Toilets	425,104	1,699,964	3,314,676	5,275,982	6,417,522
Households: Energy Star Clothes Washers	505,368	2,020,934	3,940,521	6,272,141	7,629,216

- 2030: would require at least $950 million toward toilets.

Sources: BEAMS outputs, PNNL Save Water and Energy Education Program (SWEEP), and Energy Star criteria.
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-13538.pdf
http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

“By plant” analysis example

- Avoided-generation plant mixes
  - By plant: 55.7% baseload, 35.7% intermediate, 8.6% peaking.
  - Weighted: 75.2% baseload, 20.0% intermediate, 4.8% peaking.
- In this example, “by plant” analysis yields less avoidance of water withdrawal, due to less avoided generation at water-intensive baseload plants.



Conclusions

- Water and energy are intertwined, not only at the point of consumption (in some instances), but also at the point of generation (nearly always).
- Efficiency programs can provide significant reductions in indirect water withdrawal and consumption. To the extent this is unrecognized, we may be undervaluing energy efficiency.
- Analysis of efficiency impacts on generation plant dispatch is important not only for utility operation, but also for more accurate quantification of water and emissions impacts.

Conclusions (cont.)

- By 2030, BTP efficiency activities will reduce annual freshwater withdrawal and consumption by an estimated 2.43 trillion gallons and 66 billion gallons, respectively.