Quantifying Indirect Water Impacts of Buildings' Energy Usage

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A LOOK AT

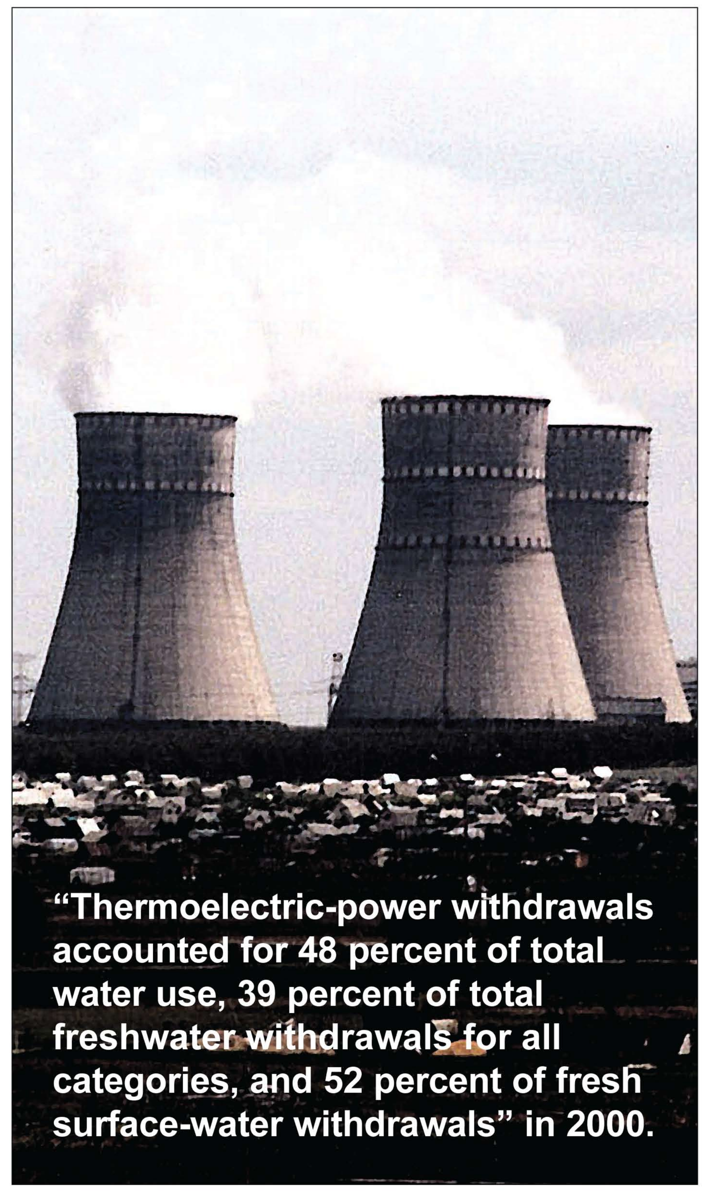
NATIONAL WATER SAVINGS

Provided by the Building Technologies Program (BTP)

BACKGROUND

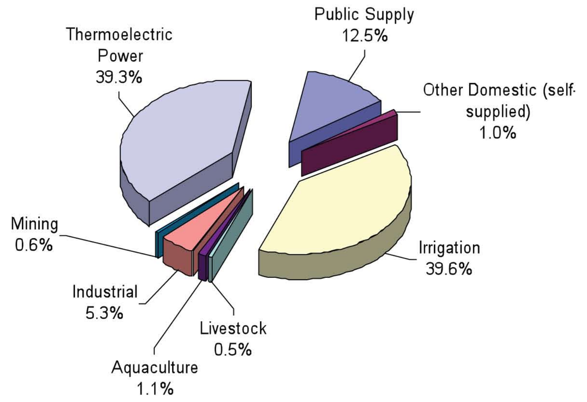
The issue: indirect water usage

- Most building energy use does not directly impact water.
- Yet, water impact of energy production is very large, via generation plant cooling requirements.



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

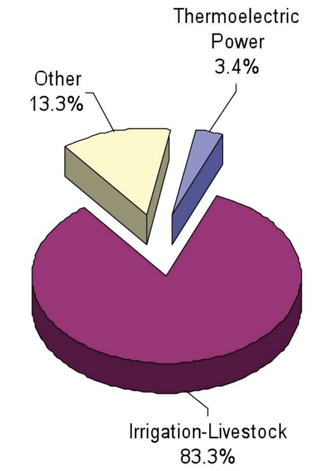
2000 FRESHWATER WITHDRAWAL



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

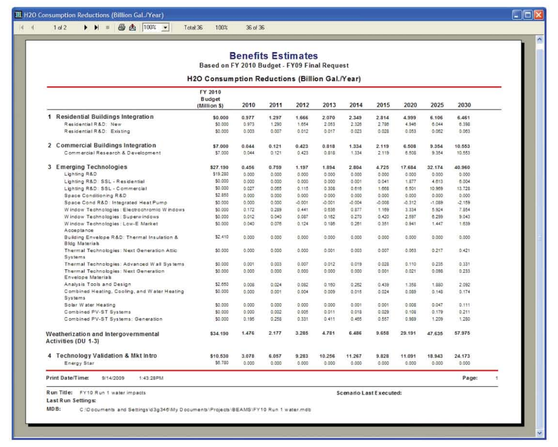
Why does the Department of Energy care about water?

A CFL in a porch light avoids the consumption of ~140 gallons of water over its lifetime.

- 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.

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.



TECHNICAL APPROACH

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

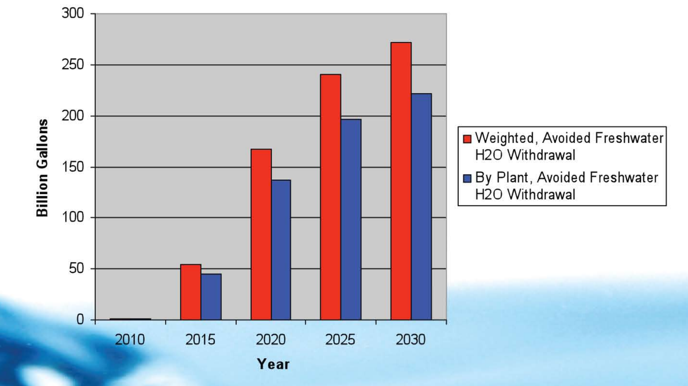
Sources: PNNL internally-developed estimates, employing NETL inputs.

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

"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.



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

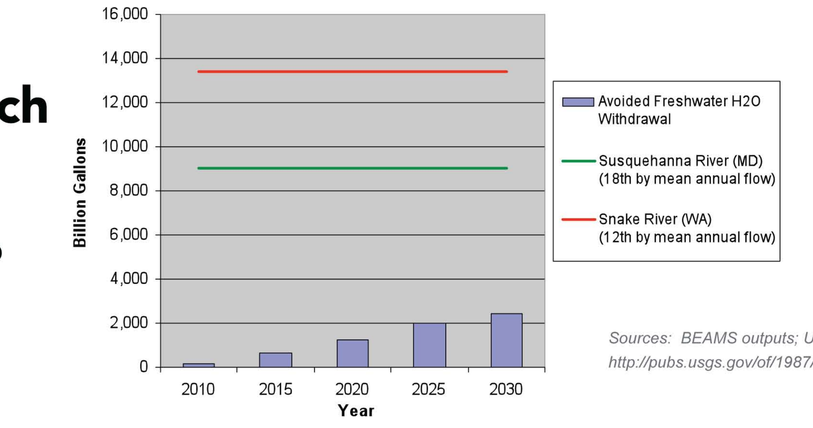
Using only freshwater portion of BEAMS output (Billion Gal./Year)

	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

RESULTS

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.

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

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

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/PNNL-13538.pdf
http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

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

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U.S. DEPARTMENT OF ENERGY

BUILDING TECHNOLOGIES PROGRAM (BTP)

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