Campus Water Sustainability and the Energy-Water Nexus

Presented by

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Affiliated Engineers

Session Description

Campus engineers, architects and planners are increasingly concerned about the quality, price and availability of water to support campus needs. This session will explore sustainability of campus water needs including how to project water rates, their impact on design choices and best water use conserving practices in infrastructure design. The session will help understand the energy:water nexus effect based on calculating the true value of water and energy conservation measures in existing buildings leading to reduced operating costs related to both resources.

Agenda

- Introduction
- Water Rates, Quality and Availability
- Water and Energy
- Tools and Techniques

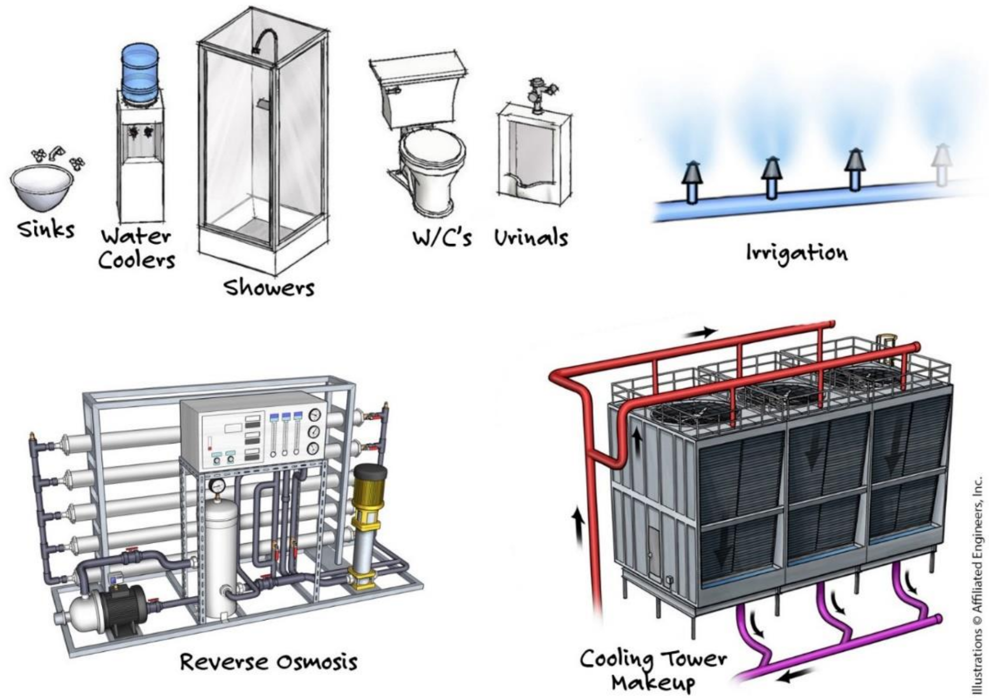
The Planners

From 1,000 to 42,000 students with endowments from $.27B to $24B

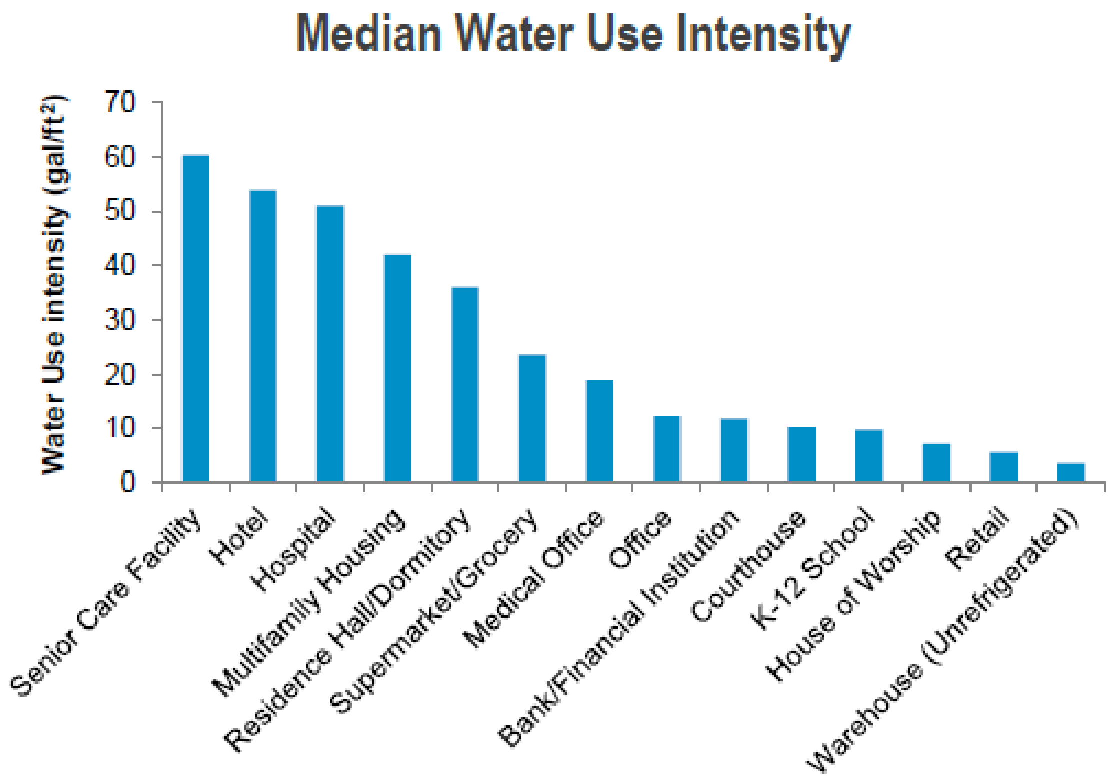
- Agnes Scott College
- Centennial College
- Emory University
- George Washington University
- Smith College
- Stanford University
- University of British Columbia
- University of California (10 of 13 campuses)
- Yale University

Campus Water Conservation Practices

- Appliances
- Car wash
- Domestic
- Education
- Kitchen and dining
- Landscape and Irrigation
- Laundry
- Leak detection
- Metering
- Mechanical equipment
- Rainwater reuse



Understanding Water Use: First Generation



Understanding Water Use: Typical Approach

CLASSIFICATION	WATER USE INTENSITY (Gallons / Sq. Ft. / Year)	TOTAL ANNUAL WATER CONSUMPTION (Gallons)	TOTAL SQ. FT.	NUMBER OF BUILDINGS
Parking Garage	0.3	428,229	1,640,852	4
Medium Office	12.5	18,981,702	1,516,567	38
Small Assembly	12.5	1,071,579	85,480	4
Small Commercial	12.7	3,490,221	275,899	40
College/University	13.3	6,268,309	470,770	5
Arts	13.9	6,398,751	460,641	7
Large Office	15.6	124,473,203	7,981,183	21
Large Office w/ mixed use	18.4	178,124,147	9,689,889	11
Residence Hall/ Dormitory	28.5	11,647,893	409,182	5
Multifamily	36.4	16,364,381	449,177	6
Hotel	41.0	83,761,196	2,043,011	7
Restaurant	134.5	6,935,913	51,566	15
TOTAL		**449,564,908**	**24,942,813**	**163**

Table 1: Pittsburgh 2030 District: Downtown Water Baseline Details

Understanding Water Use: Preferred Approach

Water Use

- Direct – 40%
- Heating and Cooling – 53%
- Irrigation – 7%

Direct Water use by Building Type (gallons/gsf)

- Academic/Admin – 17
- Residential – 27
- Lab – 25
- Library/Museum – 9

Agenda

Introduction

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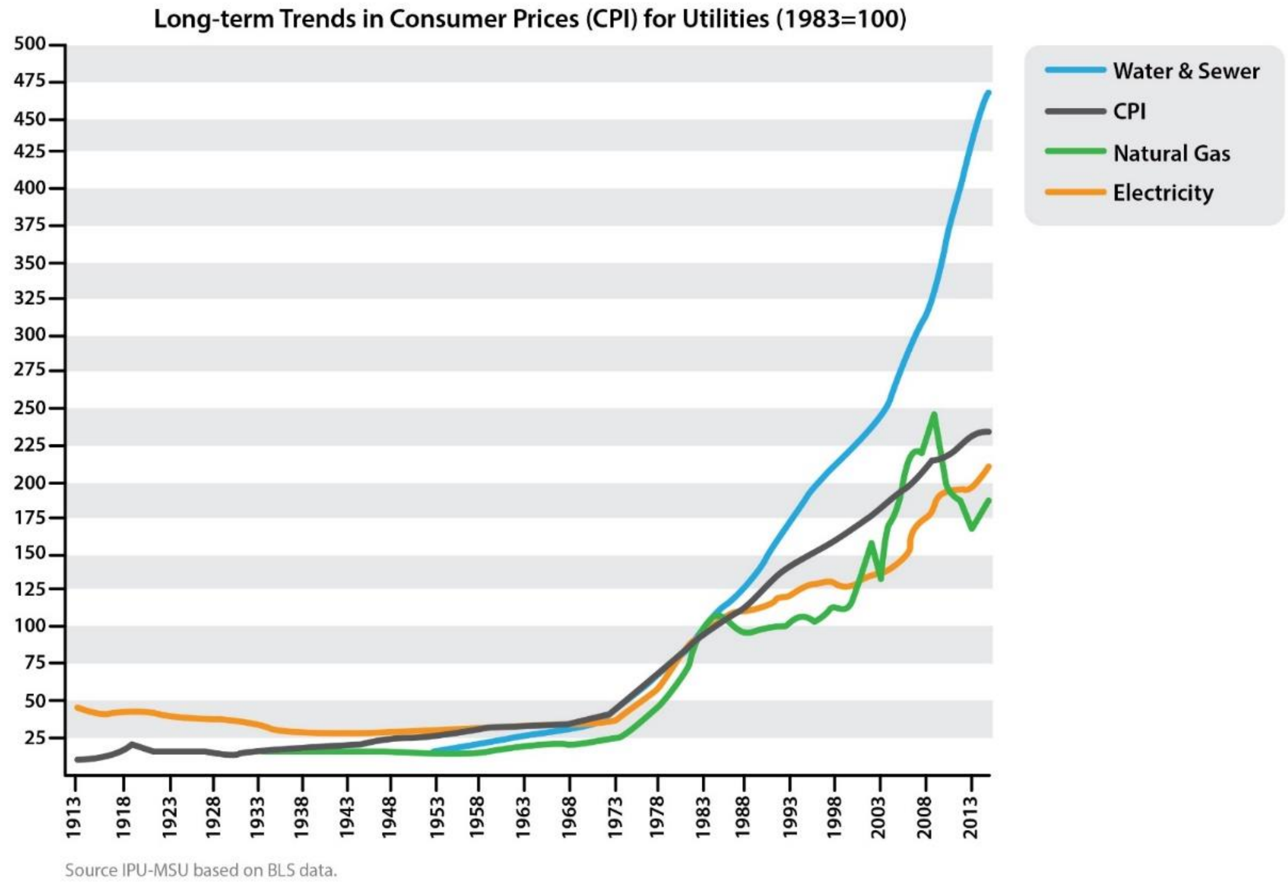
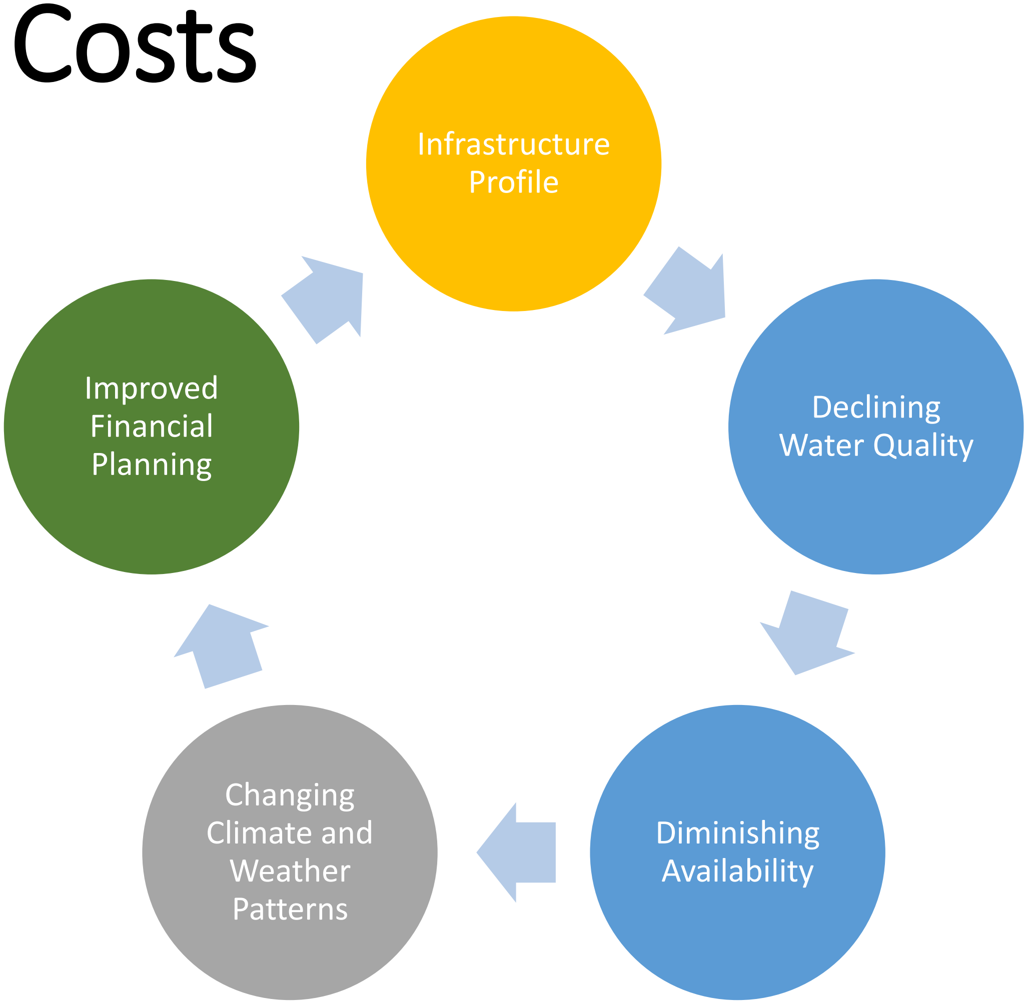
Water and Energy

Tools and Techniques

Water Costs Matter



Why Rising Costs



The Geography of Water Rates

(2015/16 combined water and sewer usage rates, per 1,000 gallons)

Atlanta	$29.21	Pittsburgh	$13.94	Tucson	$8.90
Seattle	$25.90	New York	$13.18	Minneapolis	$8.80
Boulder	$24.45	Wash, D.C.	$12.61	Phoenix	$821
Cambridge	$21.30	Anchorage	$12.25	Evanston	$8.18
San Francisco	$18.77	Berkeley	$11.62	Nashville	$7.84
Boston	$18.47	Gainesville, FL	$10.89	Chicago	$7.64
Portland, OR	$18.26	El Paso	$9.69	Pullman	$7.58
Oberlin	$18..06	Naperville	$9.24	Charlottesville	$6.72
Palo Alto	$15.64	East Lansing	$9.17	Tempe	$5.52
Austin	$15.46	Hanover	$9.16	Madison	$5.31

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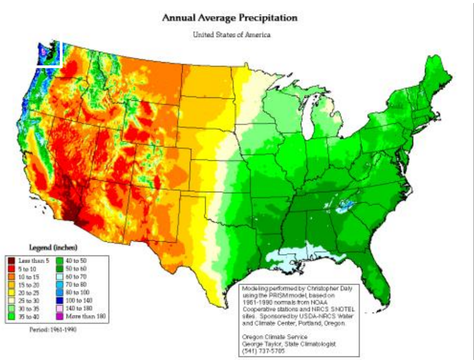

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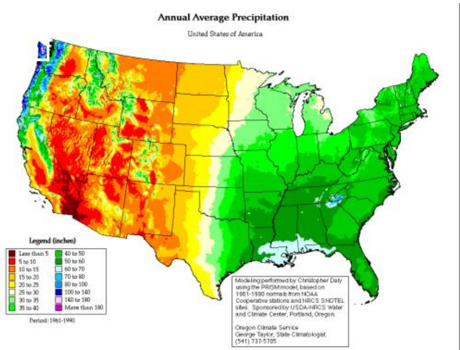

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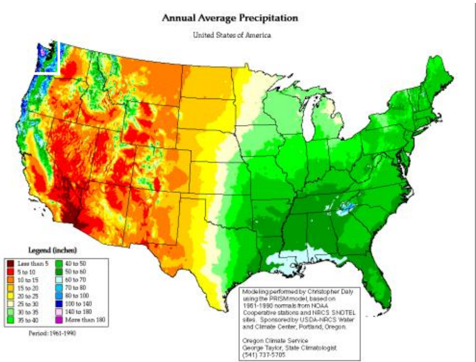

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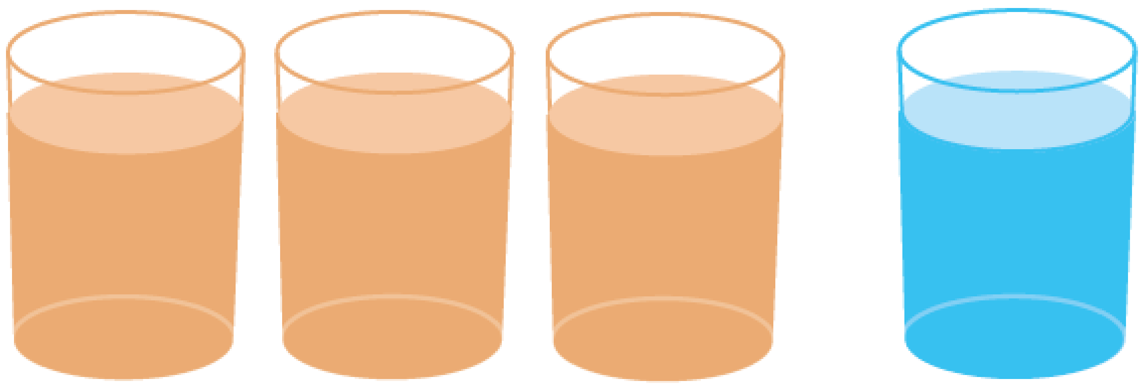
Water Rates, Quality and Availability

Water and Energy

Tools and Techniques

THE ENERGY:WATER NEXUS



U.S. power plants use three times as much fresh water daily – **143** billion gallons – as is used for public water supplies.

The Energy Footprint of Water Use

Natural Gas
35 gal/kWh[1]

Coal
36 gal/kWh1

Nuclear
44 gal/kWh1

Hydroelectric
65 gal/kWh2

Volumes represent high end of consumption
[1]Source: Macknick et al. 2011
[2]Source: UNESCO-IHE 2011

The Energy Footprint of Water Use

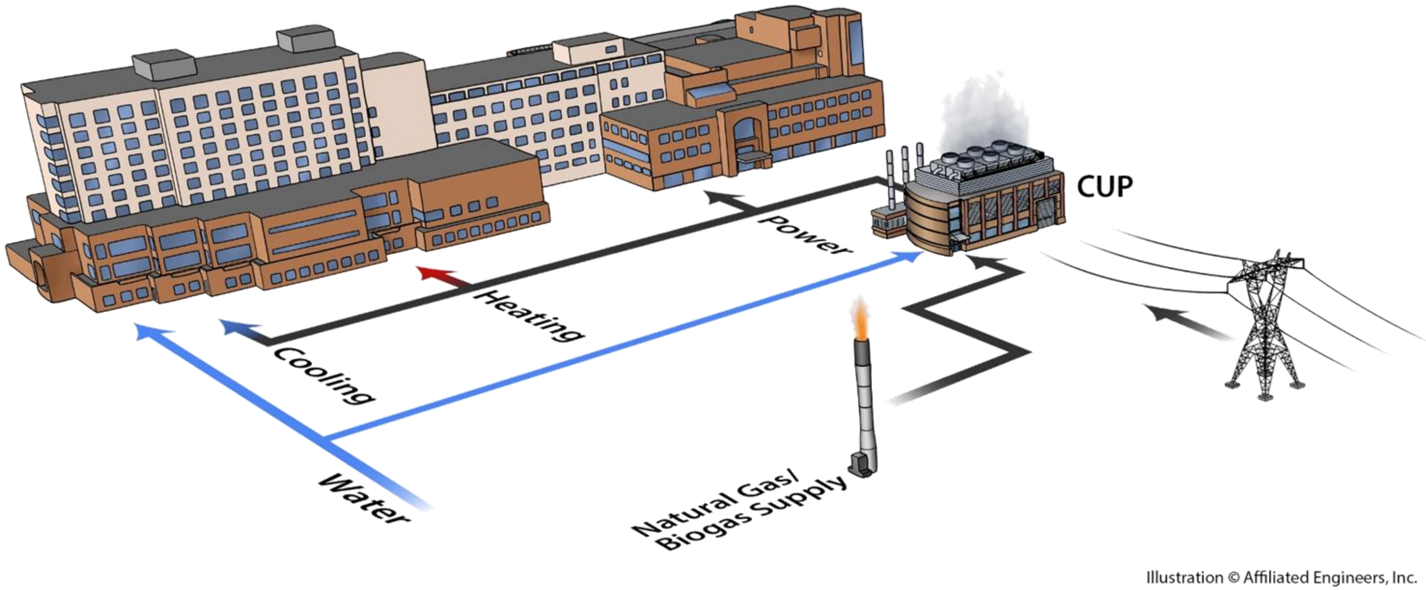
On-Campus

22,672,000 gallons

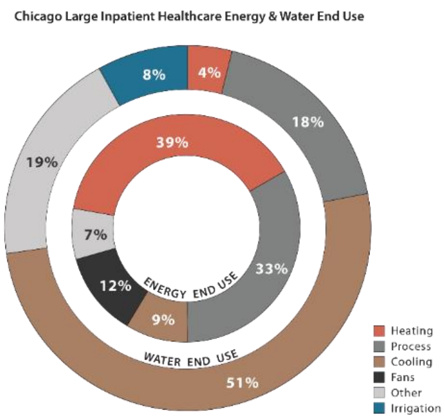
Embodied and On-Campus

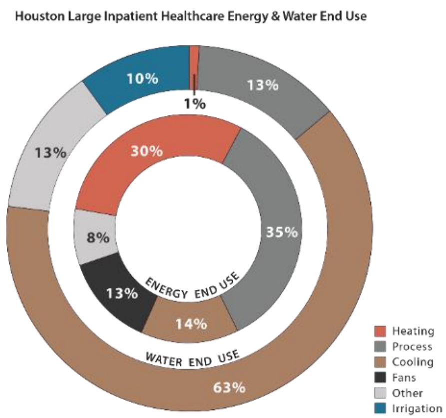
3,000,000,000 gallons

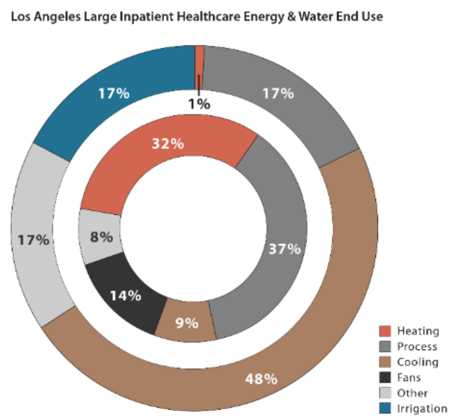
The Energy Footprint of Water Use

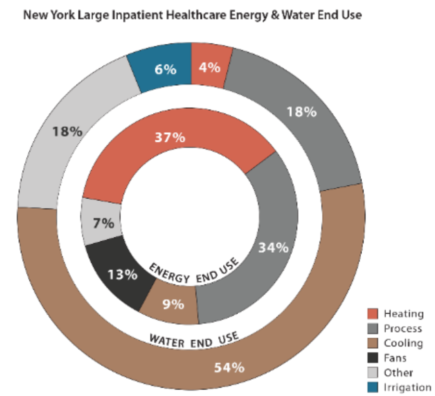


Building Energy: Water Relationship

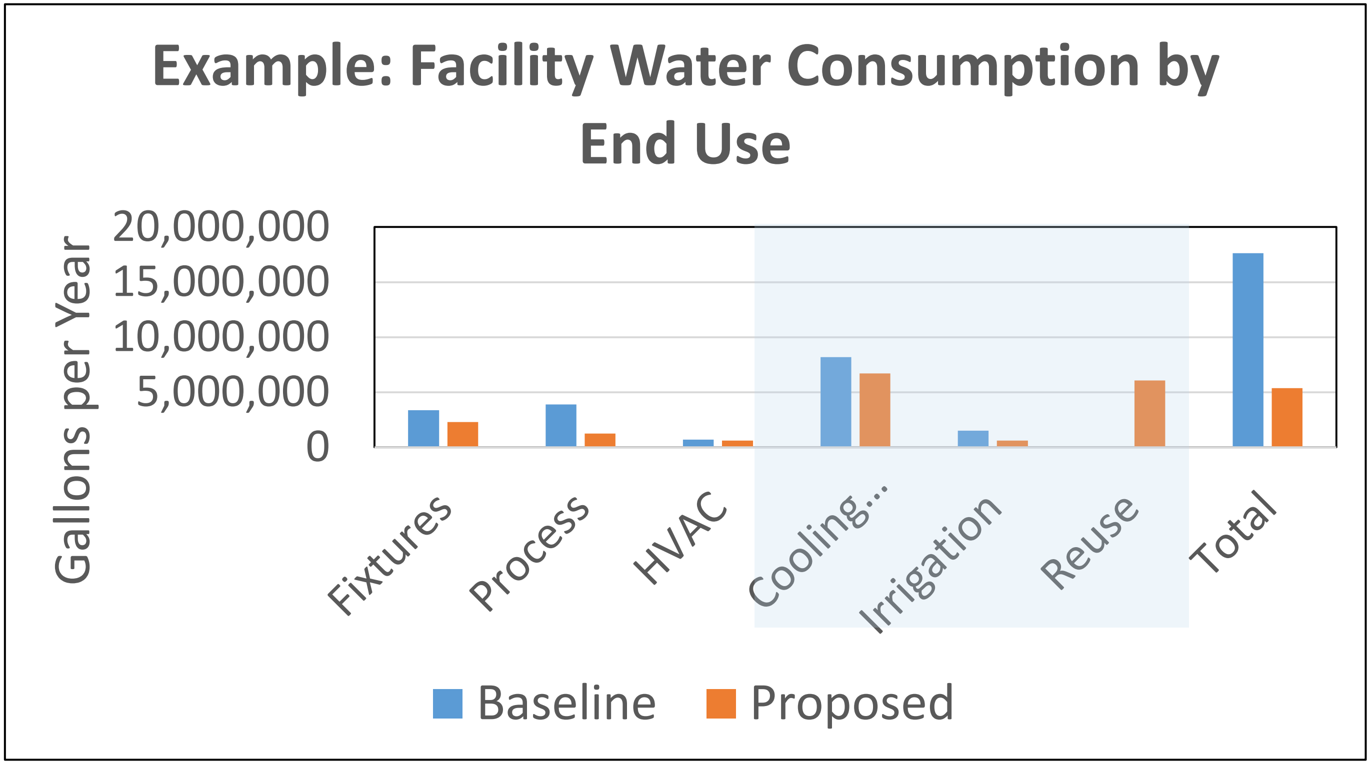




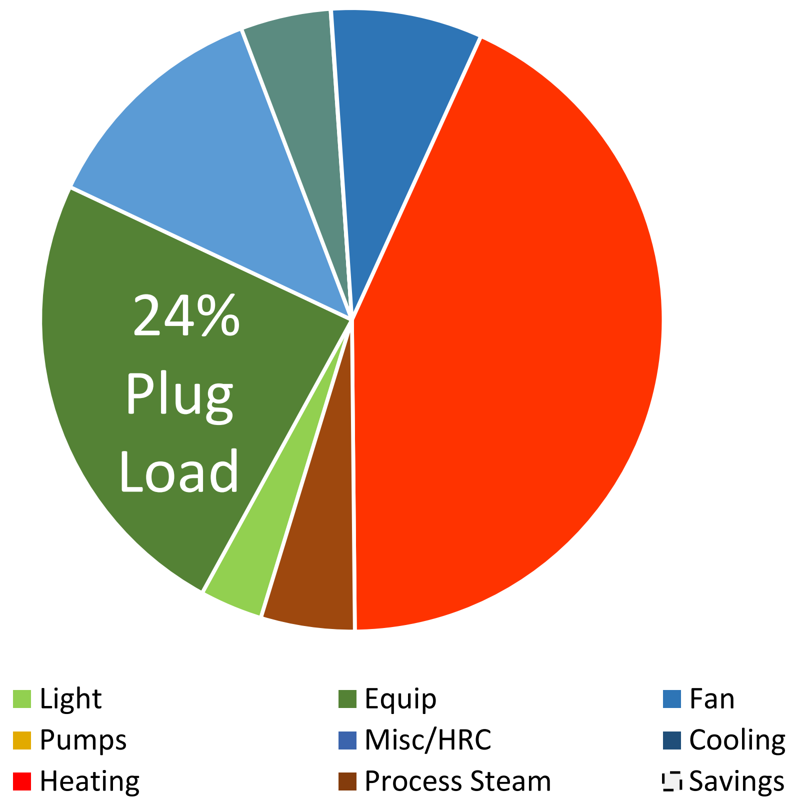




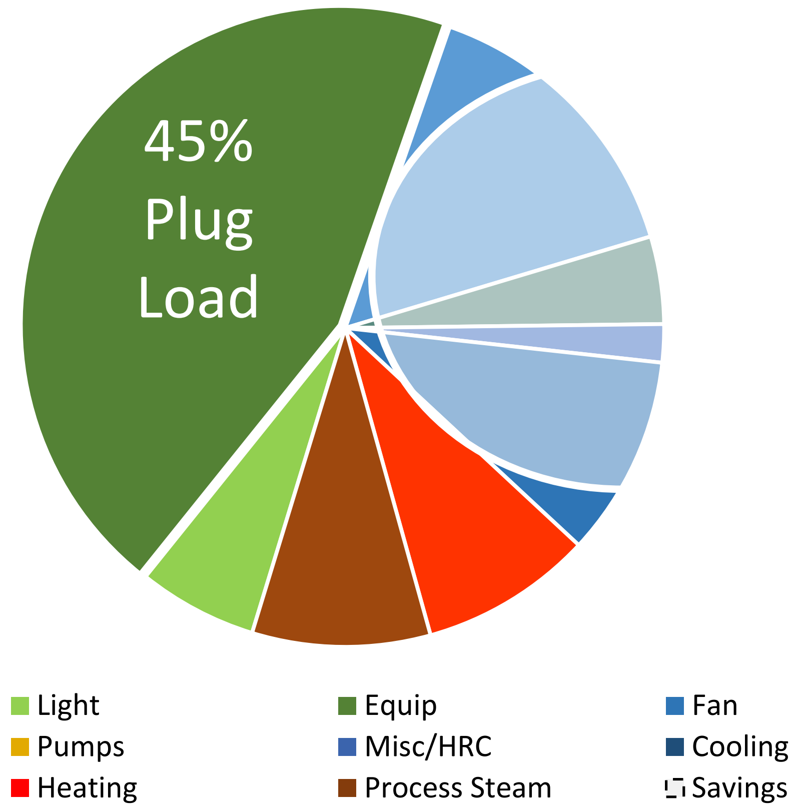
Water Hierarchy Results: Building Scale



Equipment Plug Load, 2005



Equipment Plug Load, 2015



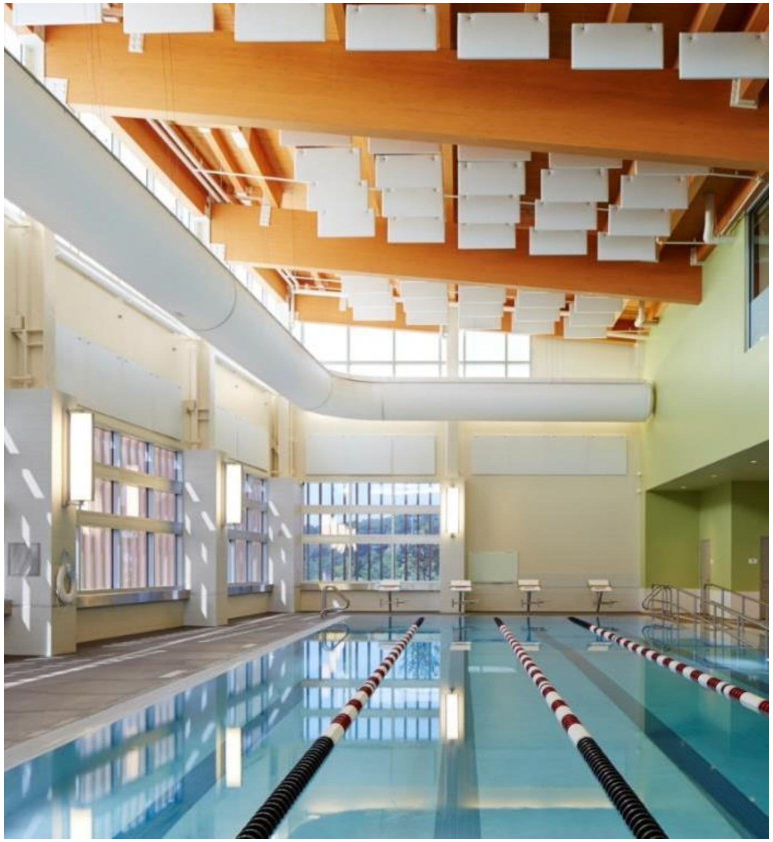
5% - 30% Indirect impact on energy demand

…and, up to 15% of total building water use

Energy in Water Conservation Measures

Energy savings leveraged by pool cover

- Reduces air moisture
  - air handling unit efficiency gain of ~24,000 kWh/yr ($3,500/yr)
- Reduces makeup water demand and steam needed for heat
  - efficiency gain of ~3,000 therms/yr ($2,100/yr)



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Tools and Techniques

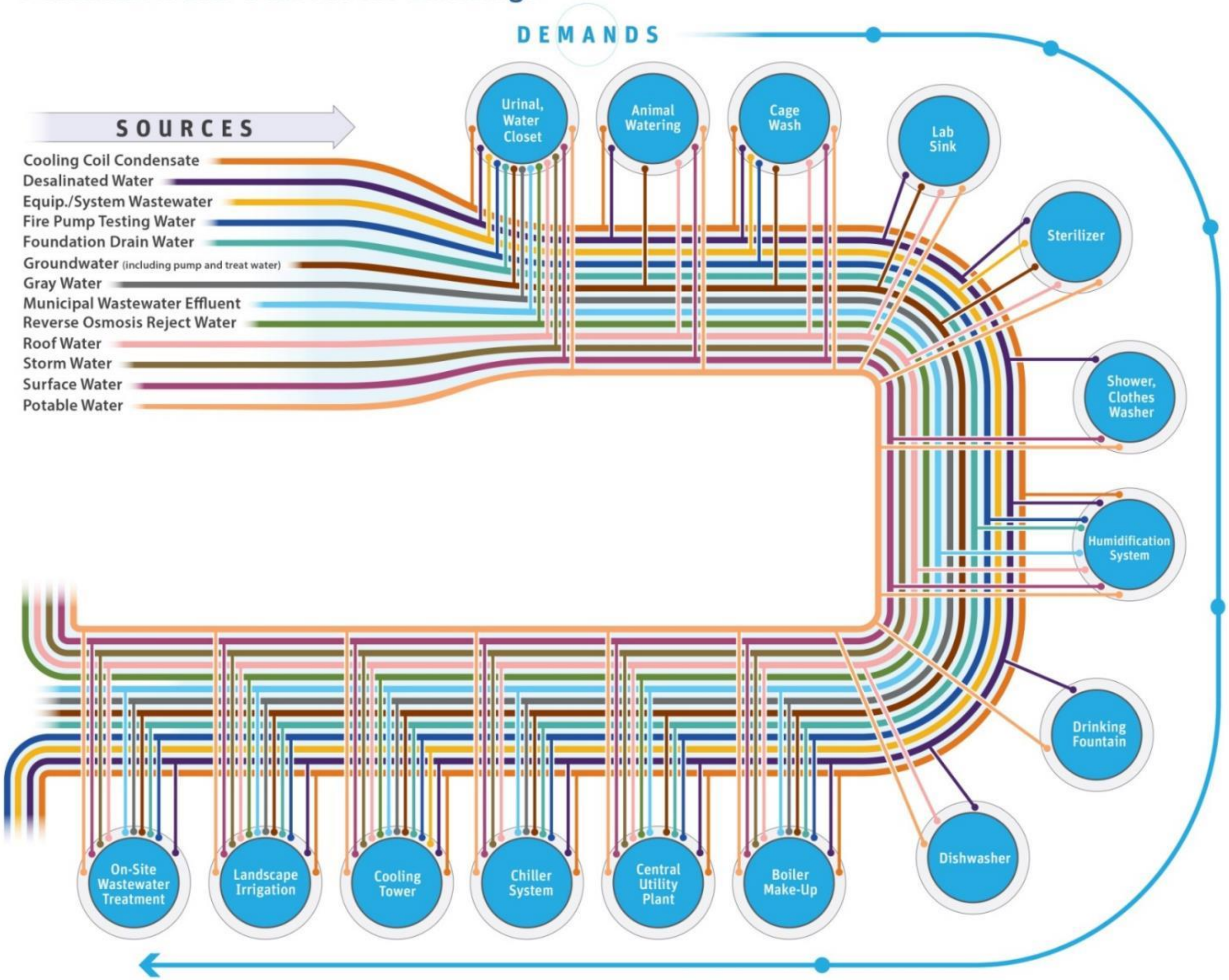
Rethink

Reduce

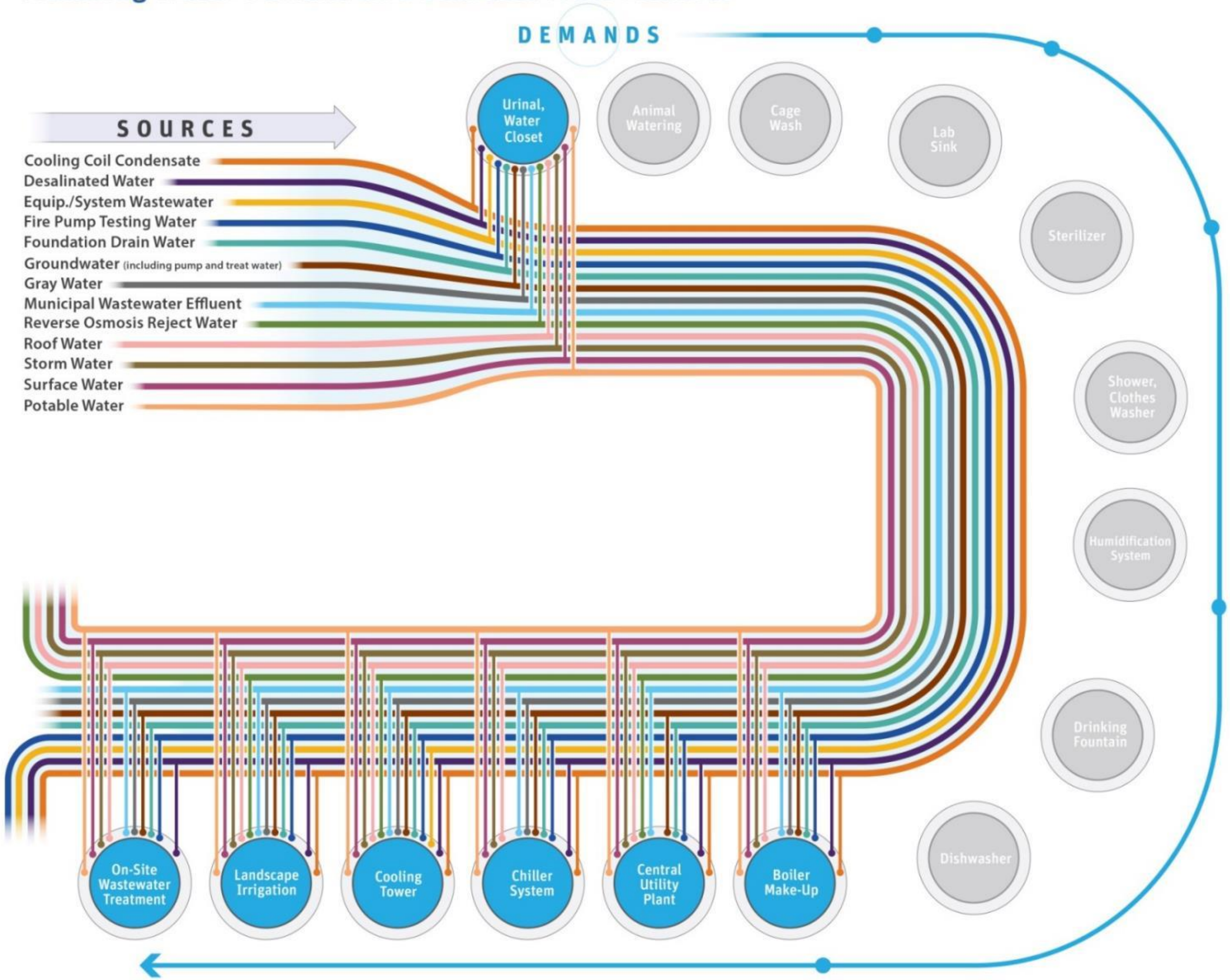
Reuse

Recycle

Potential Water Sources for Buildings



Matching Water Demand and Sources: Most Flexible



Water Hierarchy Results: Campus Scale

UNC Chapel Hill Utilities

- Reclaimed cooling coil condensate
- Groundwater recovery
- Reclaimed water from city
- Highly efficient chiller plant
- Ponds

Water Hierarchy Results: Campus Scale

Duke University Utilities

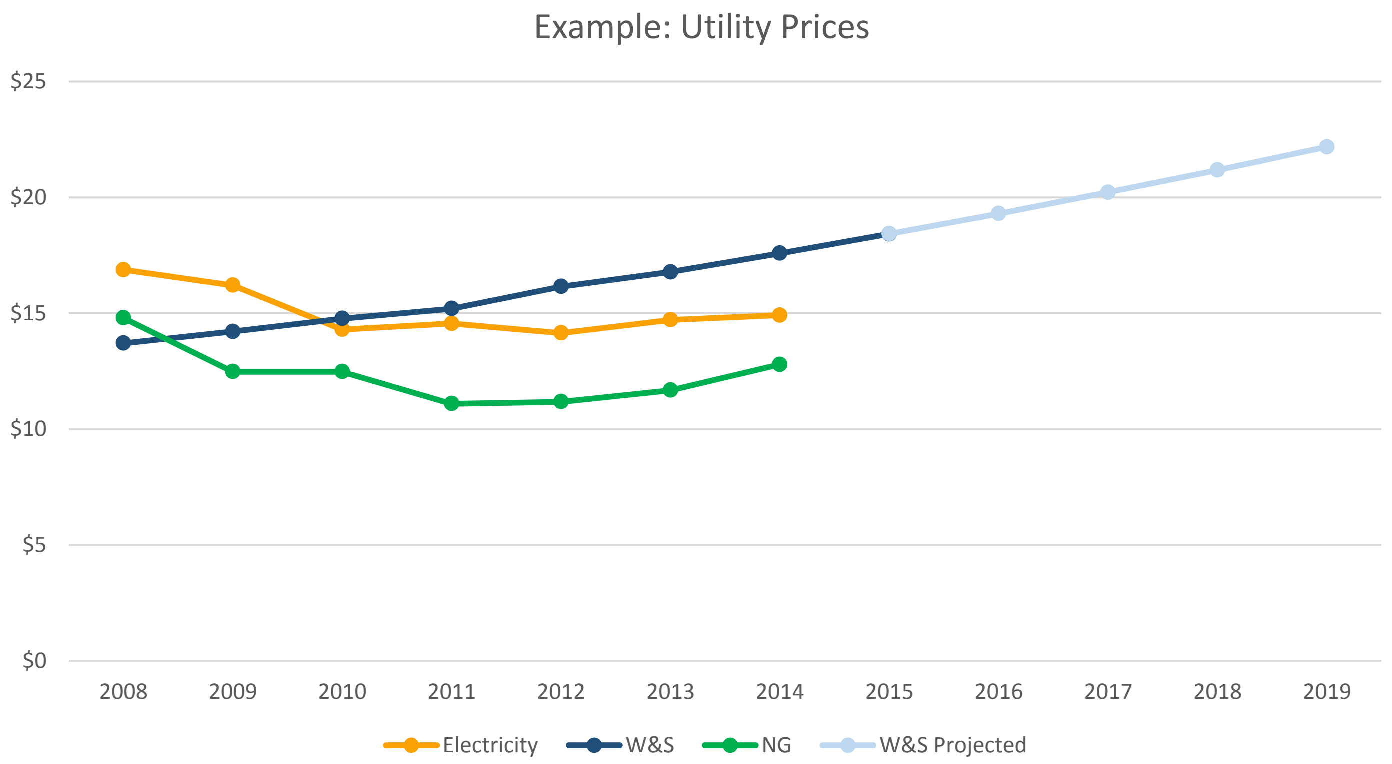
- Reclaimed cooling coil condensate
- Rainwater capture from roofs
- Blowdown recovery
- Ponds

Water Hierarchy Results: Campus Scale

Stanford University Utilities

- Stanford Energy Systems Innovations conversion from steam to hot water with building energy demand management investments reduces campus potable water demand by 15%
- Non-potable sources for irrigation
- Advanced metering infrastructure system

Anticipate Rate Changes



Anticipate Rate Changes

Drivers

- Responsible water management
- Full cost accounting
  - Cost increases trigger conservation activity, drive new rate structuring
- Deferred investments
  - Obvious problems
  - Well-documented problems - consent decree to compel investments
- Complex and/or uncertain water rights

Anticipate Rate Changes

Ecova's analysis

- 2008 to 2012 survey of commercial clients
- 27% water/sewer **rate** increase

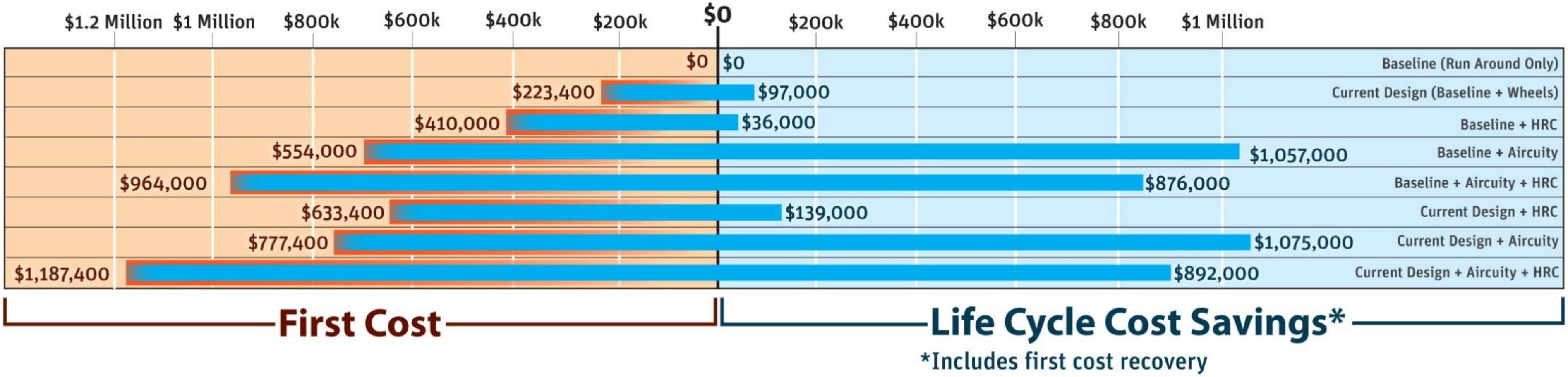
Black & Veatch's analysis and projection

- 2001 to 2013
- 6.4% per annum water **cost** increase
- 6.8% per annum sewer **cost** increase
- Predicts 5% to 15% **cost** increase "every few years"

Fitch Ratings' projection

- 5% per annum **rate** increase

Test Water and Energy



The Geography of Water Rates

500 Miles apart…

- Seattle, Washington - $22.98/1,000 gal (water and sewer, 2015)
- Nampa, Idaho - $3.85/1,000 gal (water and sewer, 2015)

Test Water and Energy

Example: Selecting the Best Chiller Plant

- Water-Cooled Chiller Plant
  - (3x) 500 ton Daikin WSC centrifugal chiller
  - NPLV kW/ton=0.375 , NPLV COP=9.3
  - Marley NC 8400 Cooling Towers
  - Annual total water-cooled plant COP=7

- Air-Cooled Chiller Plant
  - (4x) 350 ton Daikin PATHFINDER screw chiller
  - IPLV EER=19.2 , IPLV COP=5.6

Test Water and Energy: Energy Analysis

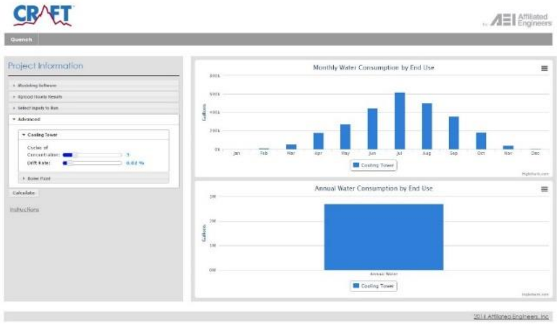
- Whole building shoebox model
- Custom chiller performance curves

ENERGY	**Air-Cooled [Total]**	**Water-Cooled [Total]**	Water-Cooled [Chiller]	Water-Cooled [Tower]	Water-Cooled [Pump]	Units
Nampa, ID	**778,953**	**570,238**	454,244	10,072	105,922	[kWh]
Seattle, WA	**689,488**	**504,745**	402,073	8,915	93,757	[kWh]

- Water-cooled chiller 40% more efficient than total air-cooled chiller
- Total water-cooled plant 25% more efficient than total air-cooled machine
- Water-cooled plant benefits from annual average ccondensor water supply of 67°F

Test Water and Energy: Water Analysis

WATER	Air-Cooled	Water-Cooled	Units
Nampa, ID	0	2,696,936	[gallons]
Seattle, WA	0	2,387,185	[gallons]



Test Water and Energy: Electricity Rates

Nampa, ID →

Virtual Rate = 0.061 [$/kWh]

SECONDARY SERVICE	Summer	Non-summer
Service Charge, per month	$39.00	$39.00
Basic Charge, per kW of Basic Load Capacity	$0.92	$0.92
Demand Charge, per kW of Billing Demand	$5.94	$4.25
On-Peak Demand Charge, per kW of On-Peak Billing Demand	$1.02	n/a
Energy Charge, per kWh		
On-Peak	6.3883¢	n/a
Mid-Peak	5.0580¢	4.7044¢
Off-Peak	4.4890¢	4.1795¢

← Seattle, WA

Virtual Rate = 0.064 [$/kWh]

ENERGY CHARGES:
Peak: Energy used between six (6:00) a.m. and ten (10:00) p.m., Monday through Saturday, excluding major holidays,* at 6.90¢ per kWh Off-peak: Energy used at all times other than the peak period at 4.63¢ per kWh
DEMAND CHARGES:
Peak: All kW of maximum demand between six (6:00) a.m. and ten (10:00) p.m., Monday through Saturday, excluding major holidays,* at $1.52 per kW Off-peak: All kW of maximum demand in excess of peak maximum demand, at all times other than the peak period, at $0.24 per kW
Minimum Charge: $16.77 per meter per day
Discounts: Transformer losses: 1756 + 0.53285 x kW + 0.00002 x kW^2+ 0.00527 x kWh Transformer investment: $0.24 per kW of monthly maximum demand

Test Water and Energy: Water Rates

Nampa

- $0.77/1,000gal [water]
- $3.08/1,000gal [sewer]
- $3.85/1,000gal [combined]

Seattle

- $7.27/1,000gal [water]
- $15.71/1,000gal [sewer]
- $22.98/1,000gal [combined]

Test Water and Energy: Financial Analysis

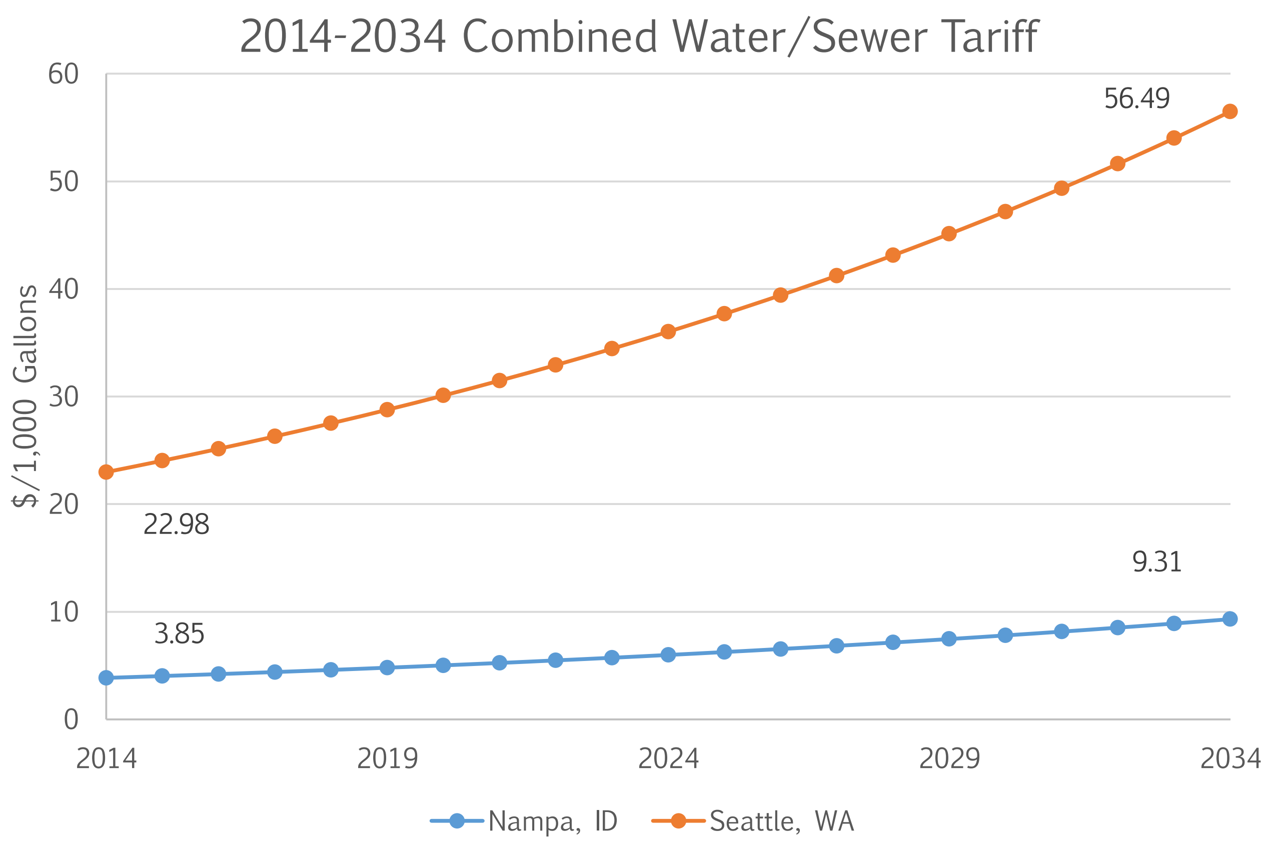
Escalation Rates:

- Electricity Escalation Rate = 2.18%
- Water/Sewer Escalation Rate (Seattle, WA) = 4.6%
- Water Escalation Rate (Nampa, ID) = 3.7%
- Sewer Escalation Rate (Nampa, ID) = 4.7%

Economic Assumptions:

- 20 year lifecycle
- Water-cooled plant incremental cost = $97,467
- Discount Rate = 4.1%

Test Water and Energy: Financial Analysis



Test Water and Energy: Financial Analysis

Nampa (Year 0)

Air-cooled, elec = 47,438 [$]

Water-cooled, elec = 34,727 [$]
Water-cooled, water = 2,080 [$]
Water-cooled, total utility = 36,808 [$]

Water-cooled, elec $ = 26.8% less than air

Water-cooled, total $ = 22.4% less than air

Nampa (Year 20)

Air-cooled, elec = 73,055 [$]

Water-cooled, elec = 53,480 [$]
Water-cooled, water = 4,302 [$]
Water-cooled, total utility = 57,783 [$]

Water-cooled, elec $ = 26.8% less than air

Water-cooled, total $ = 20.9% less than air

Test Water and Energy: Financial Analysis

Seattle (Year 0)

Air-cooled, elec = 44,403 [$]

Water-cooled, elec = 32,506 [$]
Water-cooled, water = 18,943 [$]
Water-cooled, total utility = 51,449 [$]

Water-cooled, elec $ = 26.7% less than air

Water-cooled, total $= 15.9% MORE than air

Seattle (Year 20)

Air-cooled, elec = 68,381 [$]

Water-cooled, elec = 50,059 [$]
Water-cooled, water = 46,568 [$]
Water-cooled, total utility = 96,627 [$]

Water-cooled, elec $ = 26.7% less than air

Water-cooled, total $ = 41.3% MORE than air

Test Water and Energy: NPV

- Nampa

  NPV of water-cooled plant = $112,867 *(excluding water costs)*

  NPV of water-cooled plant = $72,900 *(including water costs)*

- Seattle

  NPV of water-cooled plant = $99,409 *(excluding water costs)*

  NPV of water-cooled plant = $-299,156 *(including water costs)*

**NPV > 0 indicates water-cooled option is economically viable*

Test Water and Energy: Life-Cycle Cost

- Nampa

  LCC of air-cooled plant = $2,626,530 *(including water costs)*
  LCC of water-cooled plant = **$2,580,796** *(including water costs)* -$45,734 [-1.7%]

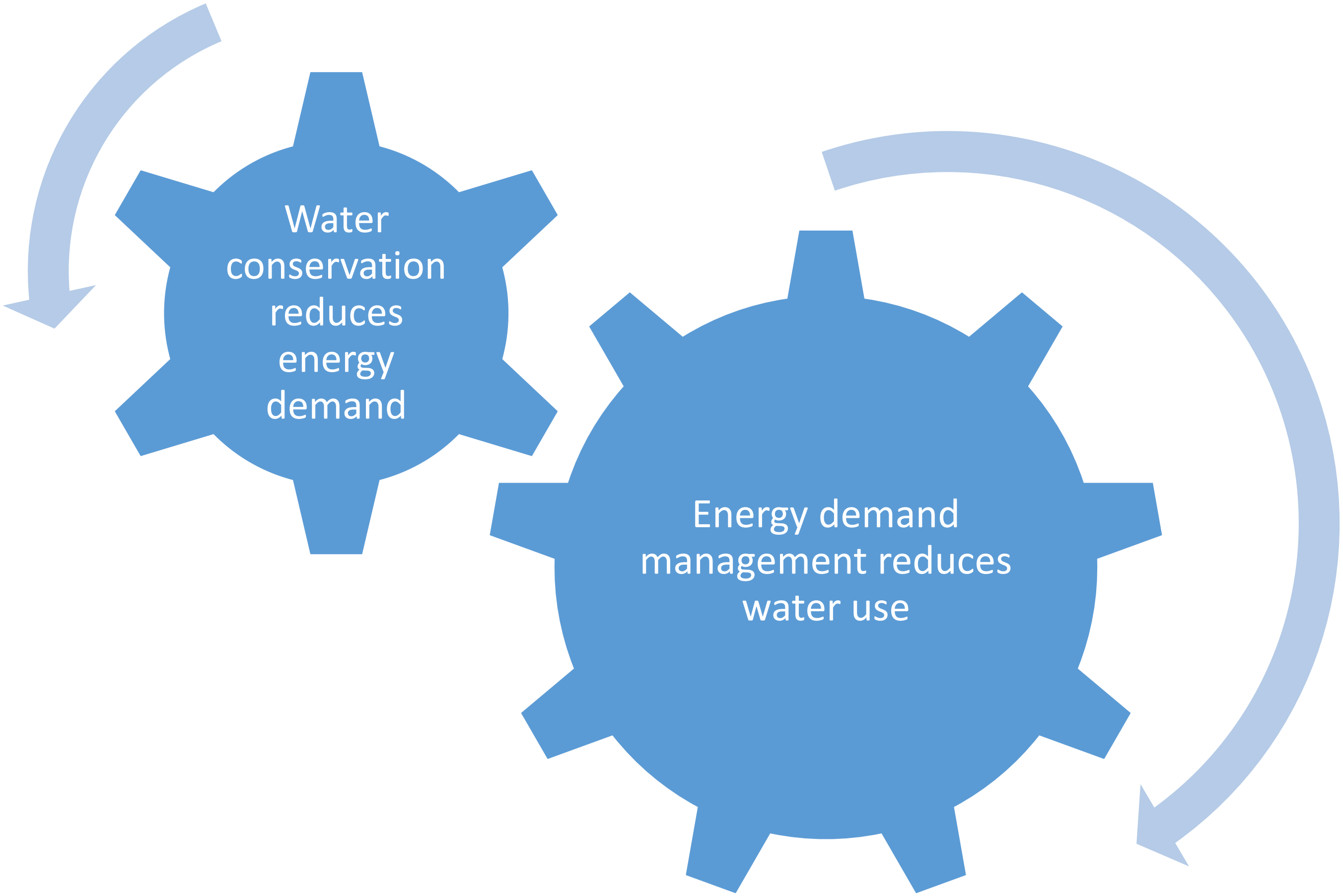
  LCC of air-cooled plant = $2,626,530 *(excluding water costs)*
  LCC of water-cooled plant = **$2,552,773** *(excluding water costs)*-$73,757 [-2.8%]

- Seattle

  LCC of air-cooled plant = **$2,585,643** *(including water costs)*
  LCC of water-cooled plant = $2,778,022 *(including water costs)* +$192,379 [+7.4%]

  LCC of air-cooled plant = $2,585,643 *(excluding water costs)*
  LCC of water-cooled plant = **$2,522,842** *(excluding water costs)*-$62,801 [-2.4%]

Conservation Matters



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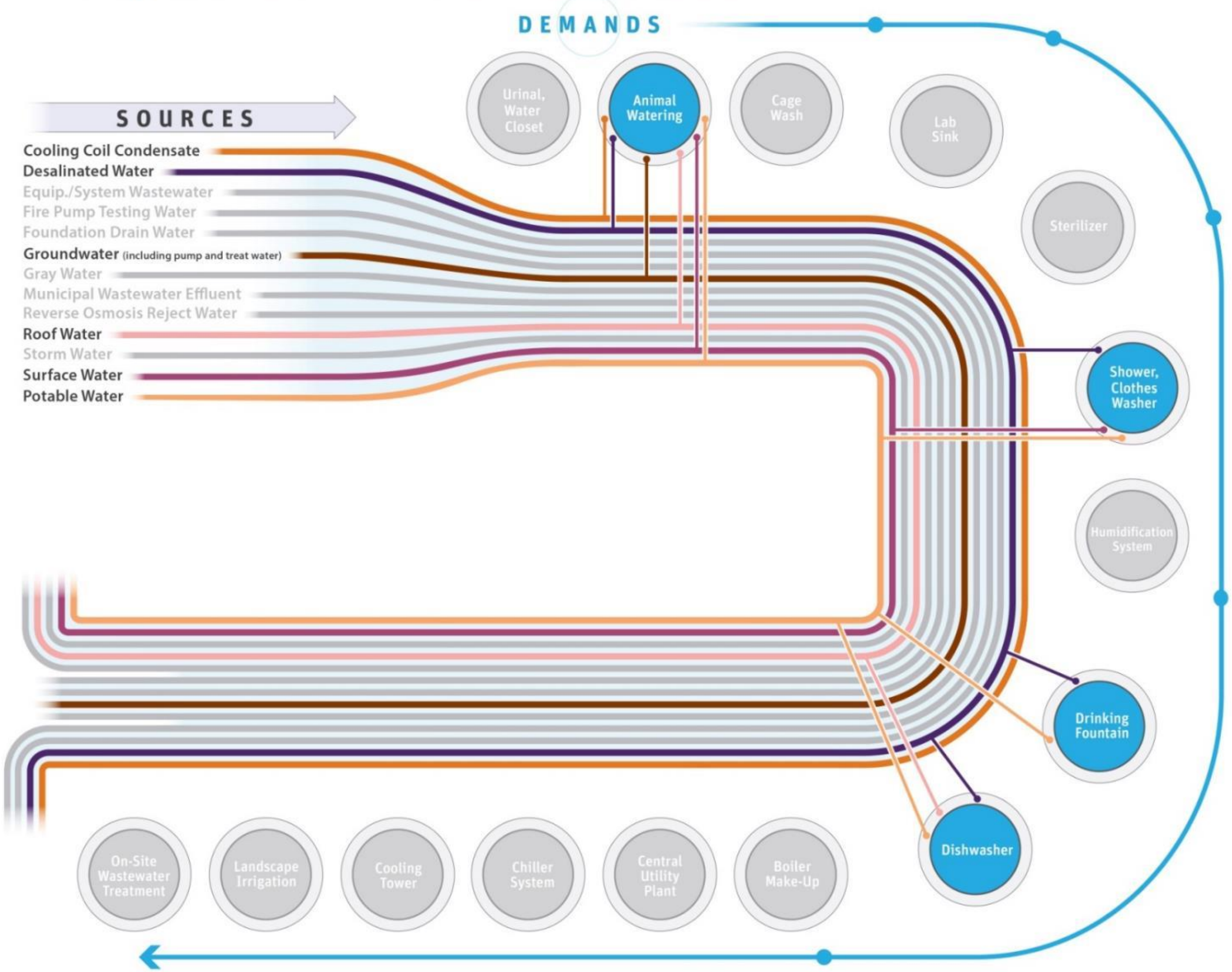
Matching Water Demand and Sources: Least Flexible



Matching Water Demand and Sources: More Flexible