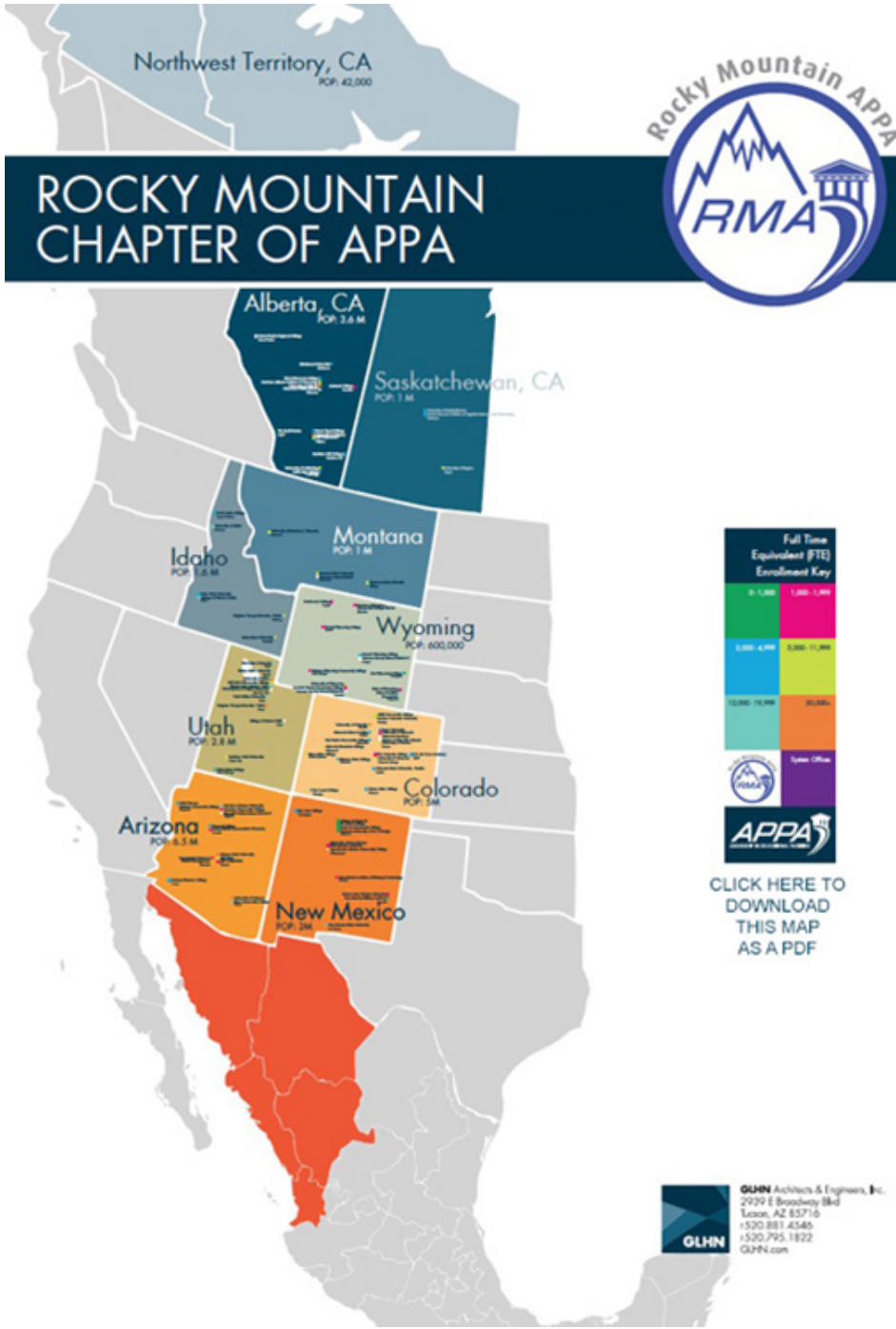


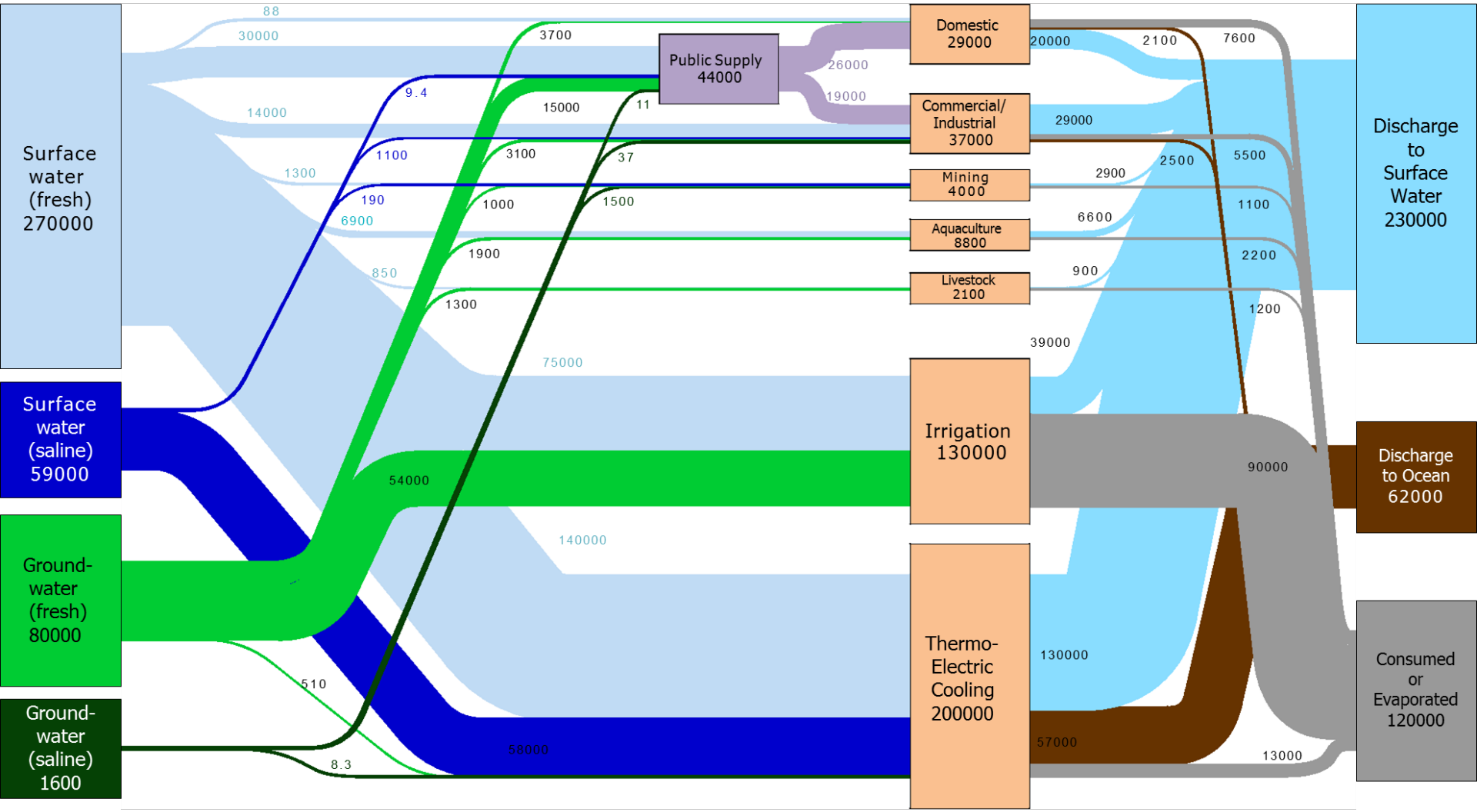
Water Energy Nexus for Campus Utilities in the Rocky Mountains

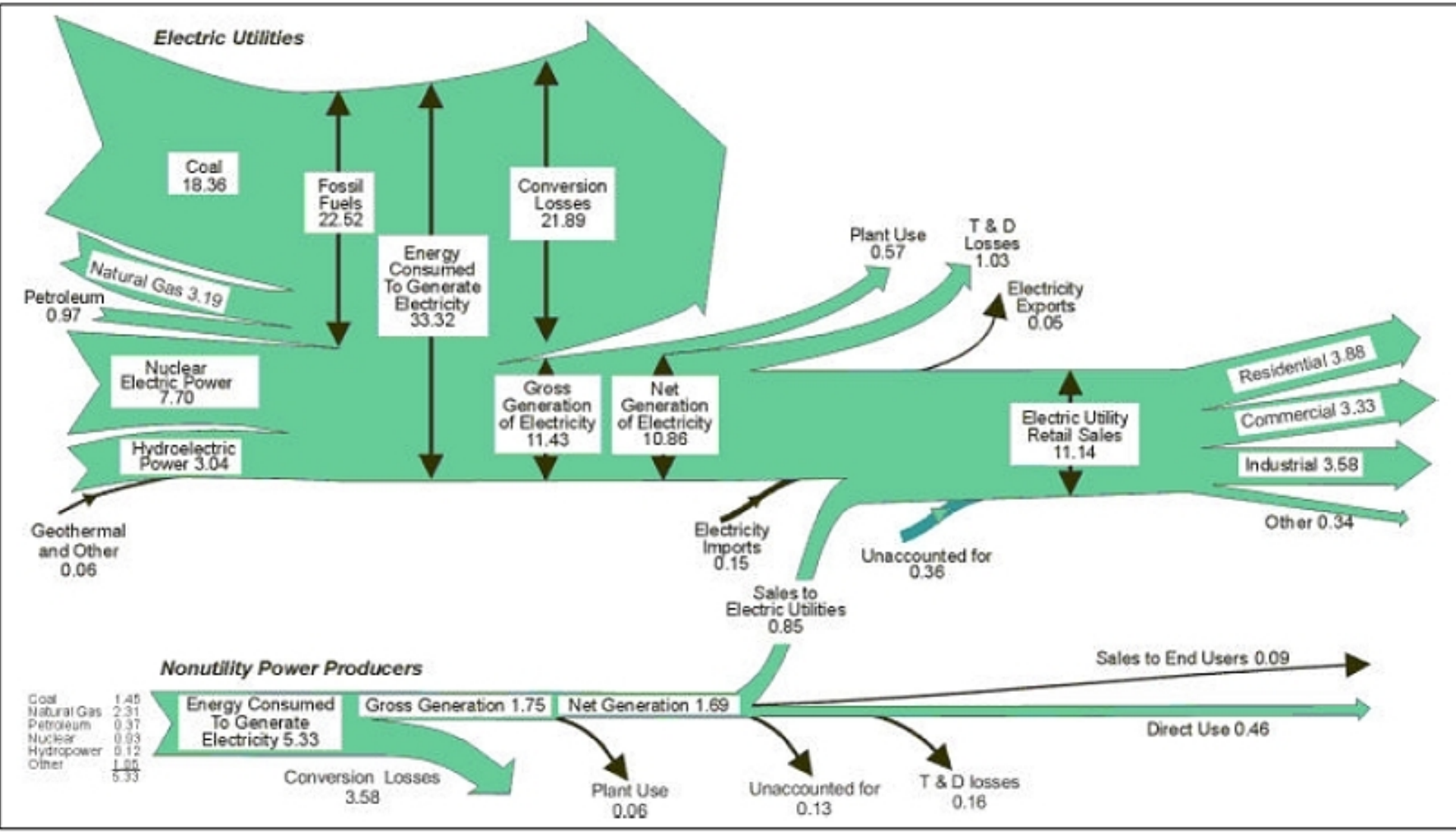
Henry Johnstone, P.E.

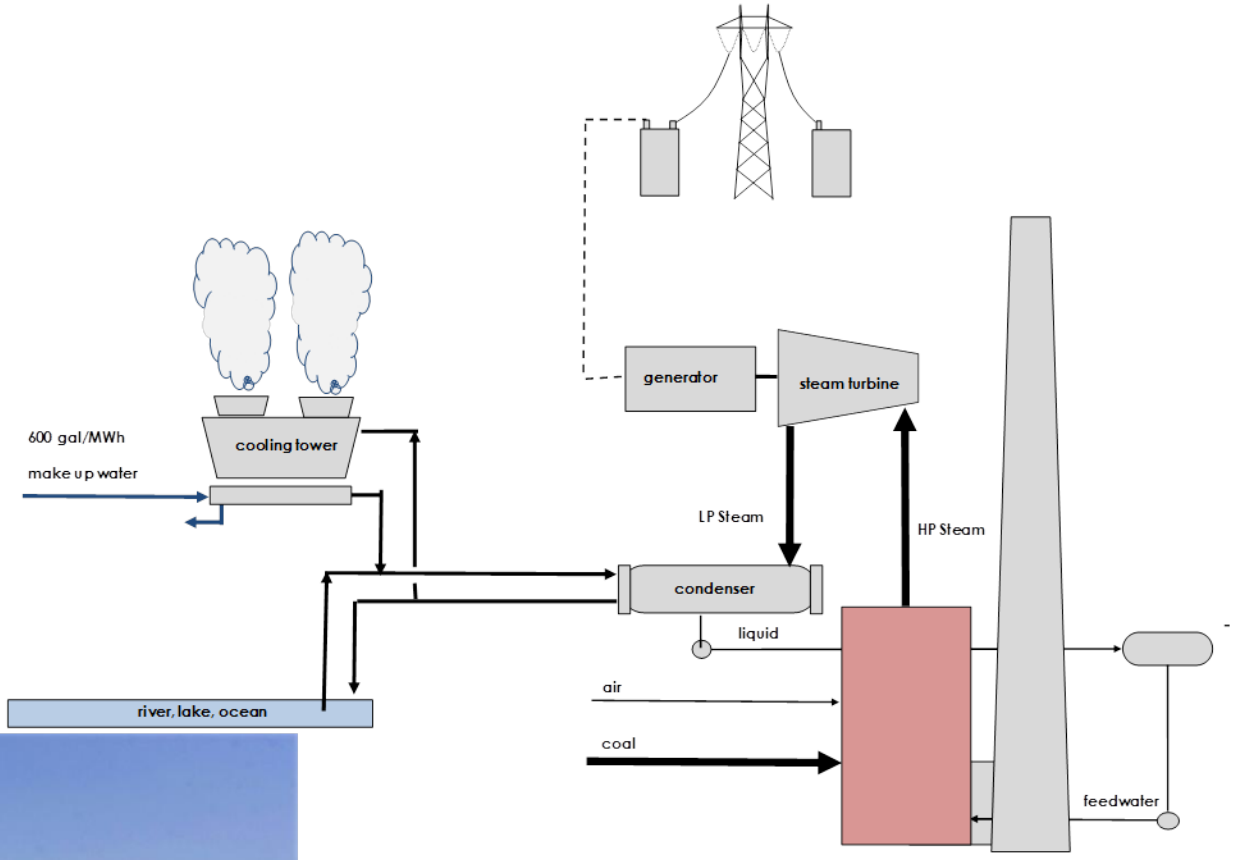
GLHN

ARCHITECTS & ENGINEERS, INC

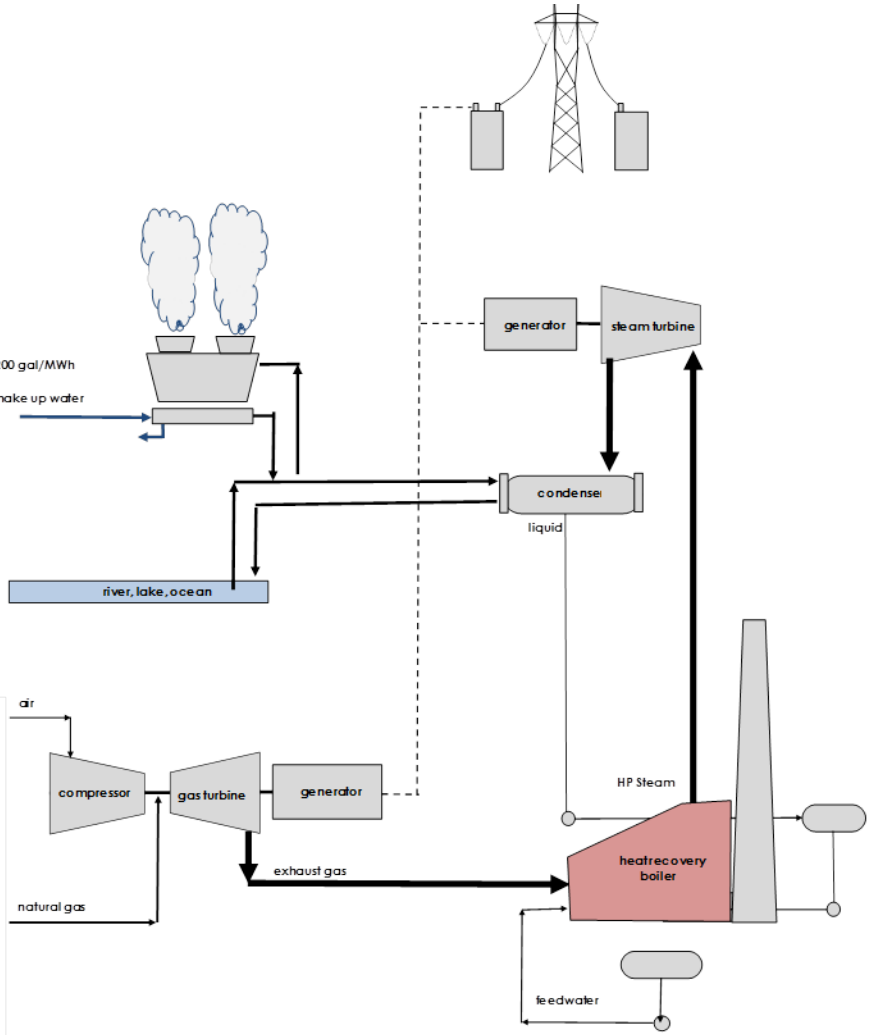
Estimated United State Water Flow in 2005:
410000 Million Gallons/Day




Electric Utilities
Coal 18.36
Natural Gas 3.19
Petroleum 0.97
Nuclear Electric Power 7.70
Hydroelectric Power 3.04
Geothermal and Other 0.06
Fossil Fuels 22.52
Energy Consumed To Generate Electricity 33.32
Conversion Losses 21.89
Gross Generation of Electricity 11.43
Net Generation of Electricity 10.86
Plant Use 0.57
T & D Losses 1.03
Electricity Exports 0.05
Electric Utility Retail Sales 11.14
Residential 3.88
Commercial 3.33
Industrial 3.58
Other 0.34
Electricity Imports 0.15
Unaccounted for 0.36
Sales to Electric Utilities 0.85
Nonutility Power Producers
Coal 1.45
Natural Gas 2.31
Petroleum 0.37
Nuclear 0.03
Hydropower 0.12
Other 1.05
5.33
Energy Consumed To Generate Electricity 5.33
Gross Generation 1.75
Net Generation 1.69
Conversion Losses 3.58
Plant Use 0.06
Unaccounted for 0.13
T & D losses 0.16
Sales to End Users 0.09
Direct Use 0.46

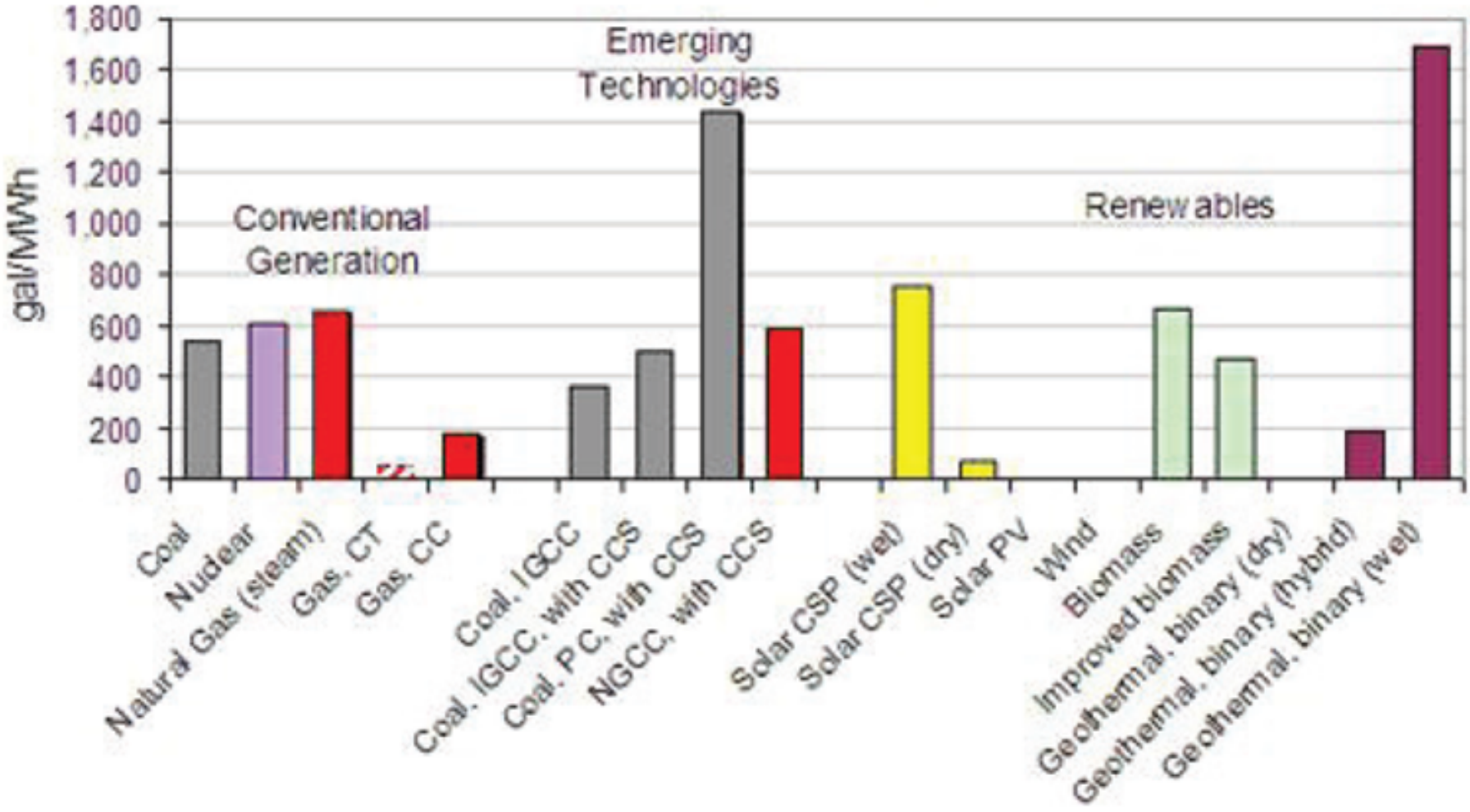


Coal Fired Steam Cycle



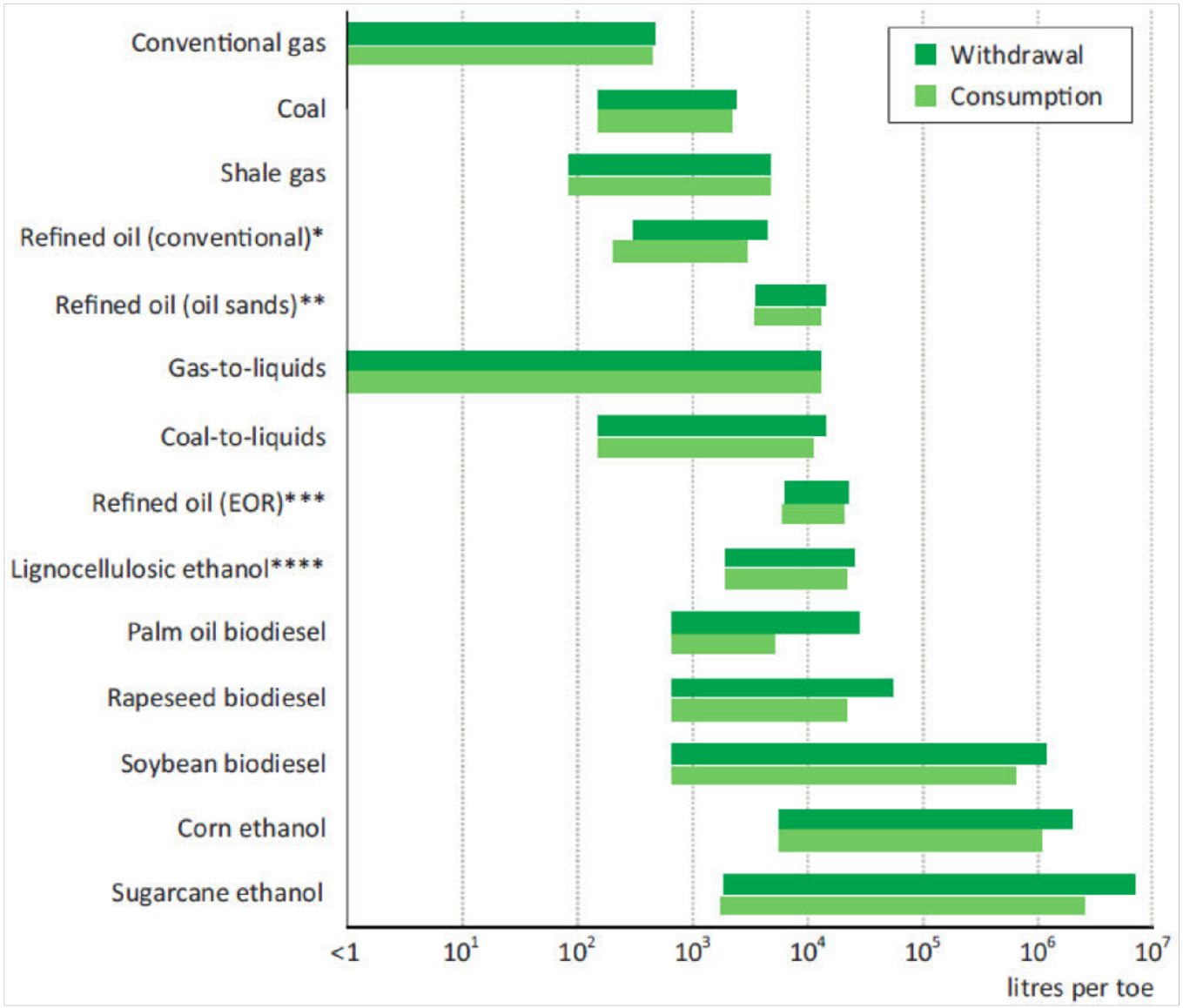
Combined Cycle Gas Turbine

Figure 11: Water Intensity by Fuel Source



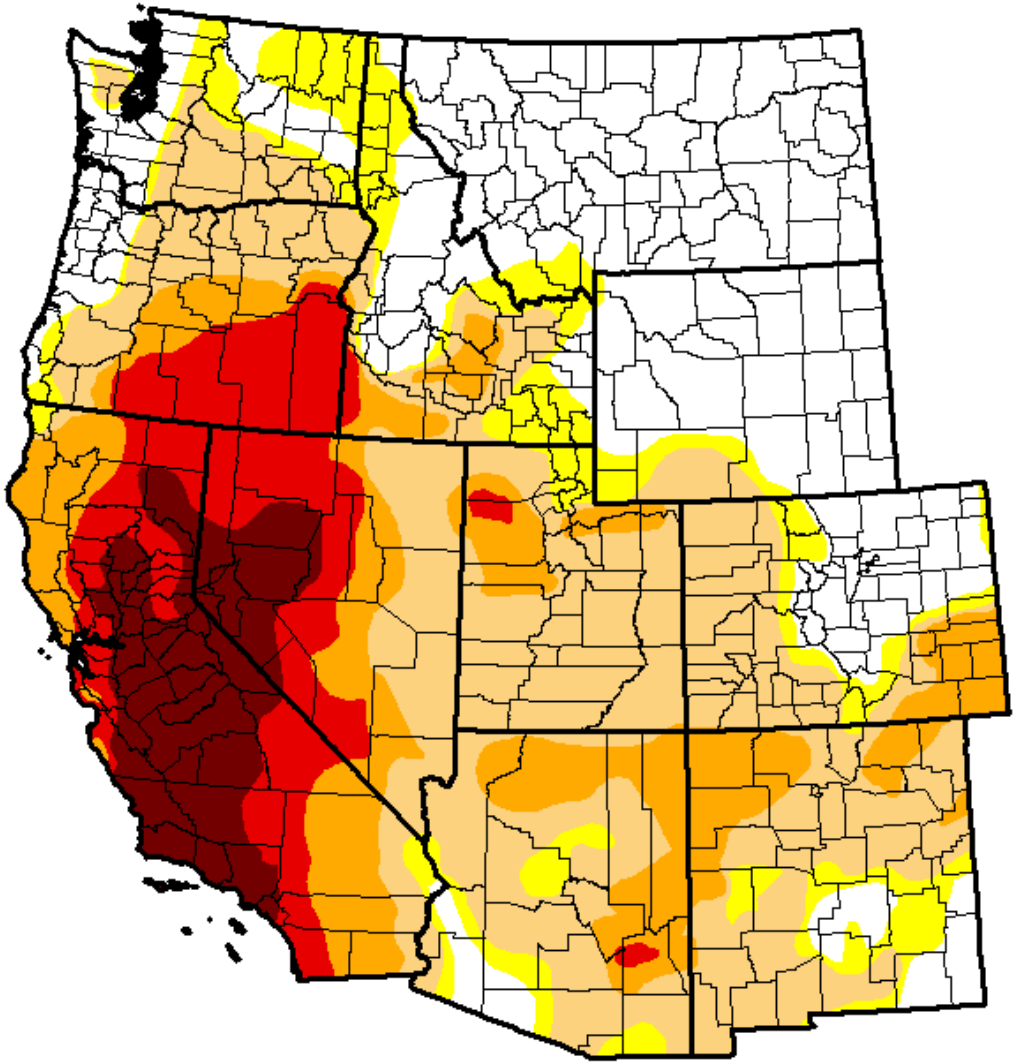
Source: Western Resource Advocates, Water Use for Energy, accessed July 12, 2012, http://www.westernresourceadvocates.org/water/waterenergy.php.

Water Use in Primary Energy Production



Source: IEA World Energy Outlook 2012

U.S. Drought Monitor
West



March 17, 2015

(Released Thursday, Mar. 19, 2015)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	29.93	70.07	60.29	31.01	16.62	7.04
Last Week *3/10/2015*	29.72	70.28	59.80	29.93	16.62	7.04
3 Months Ago *12/16/2014*	34.51	65.49	54.85	33.90	18.75	5.40
Start of Calendar Year *12/30/2014*	34.76	65.24	54.48	33.50	18.68	5.40
Start of Water Year *9/30/2014*	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago *3/18/2014*	28.49	71.51	60.44	41.95	16.19	3.61

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

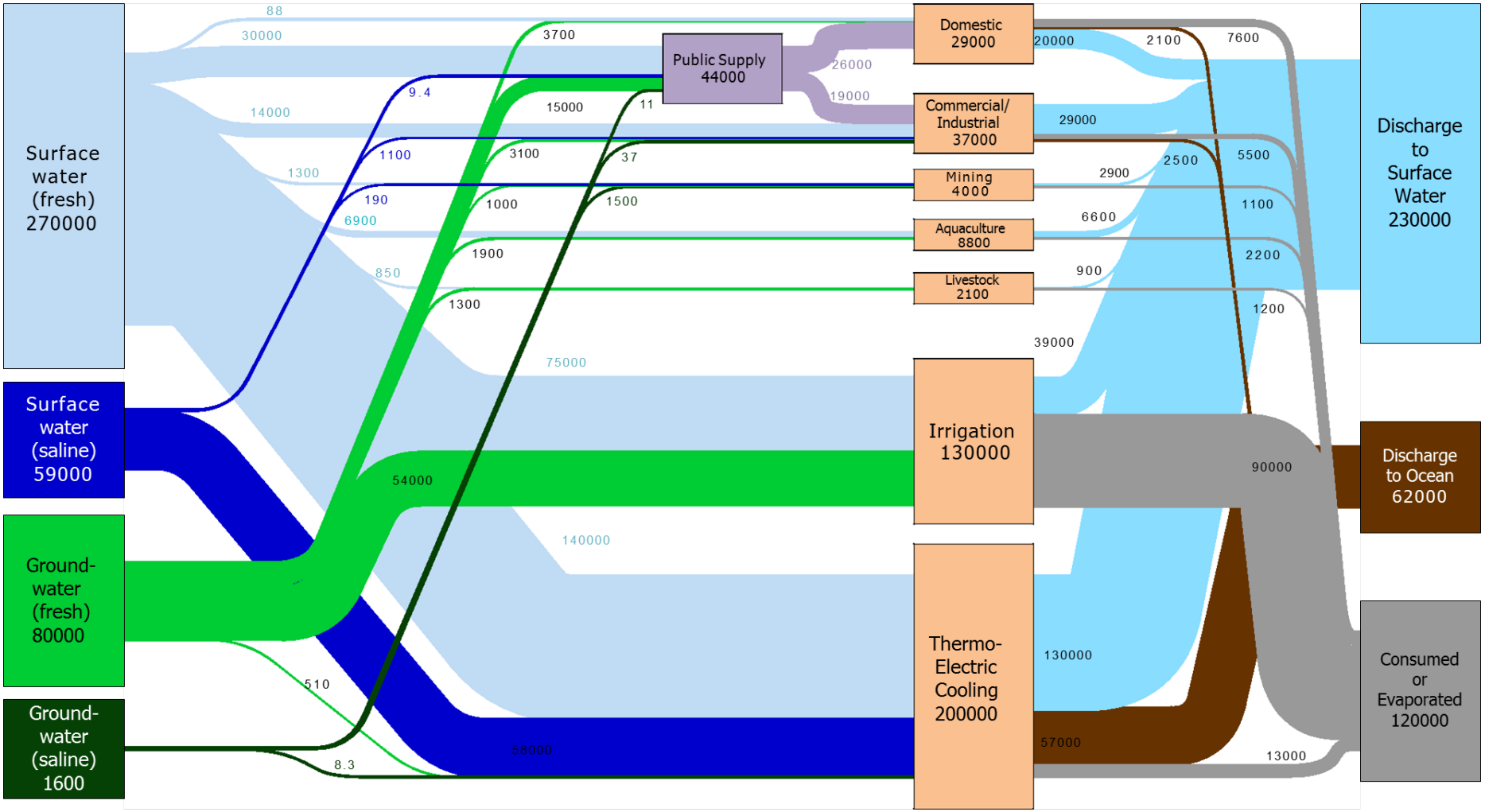
Author:
Chris Fenimore
NCDC/NESDIS/NOAA

http://droughtmonitor.unl.edu/

Nexus Implications

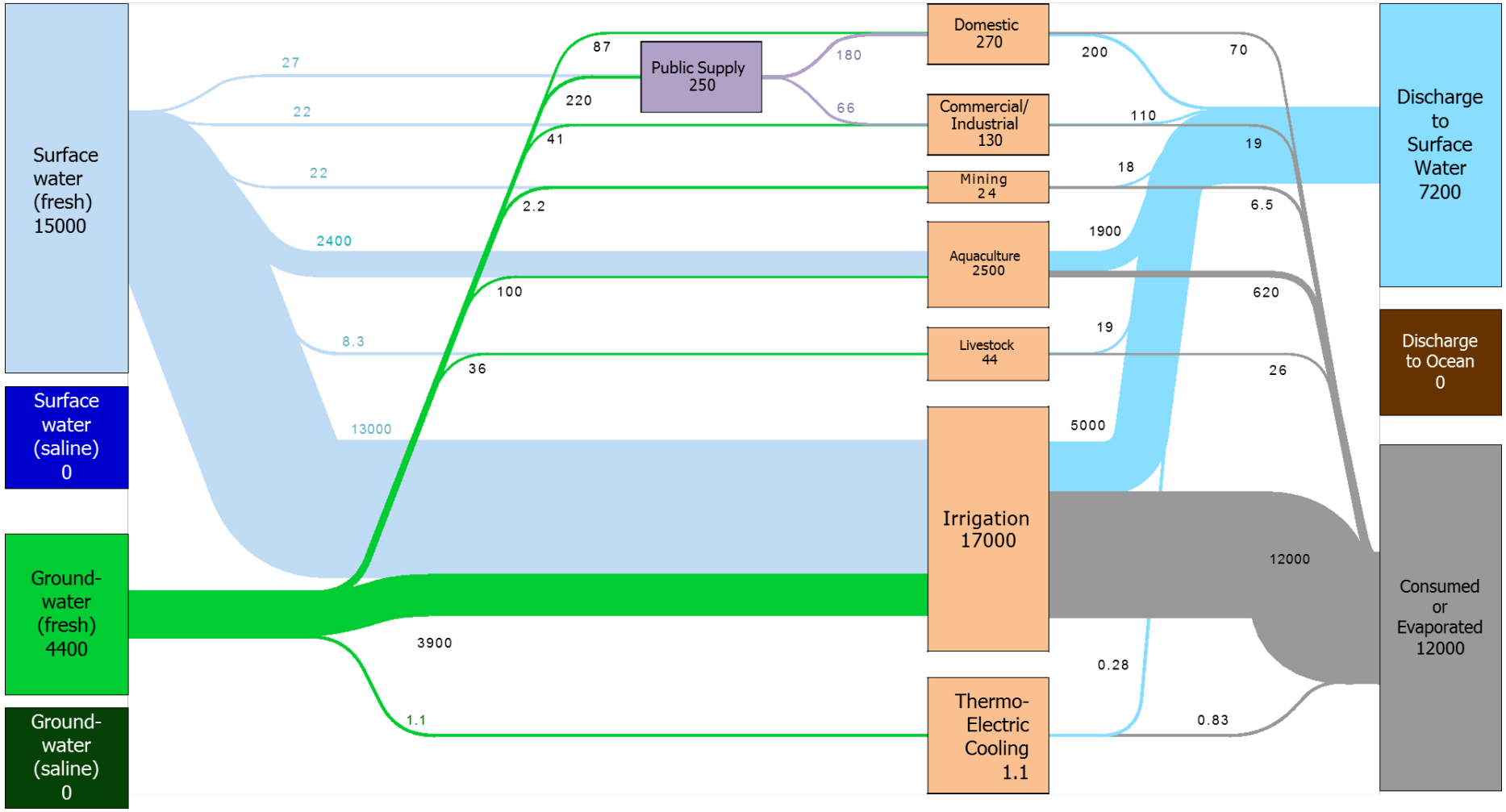
- Scarcity
- Cost
- Reliability
- Resiliency
- Carbon Emissions

Estimated United State Water Flow in 2005:
410000 Million Gallons/Day



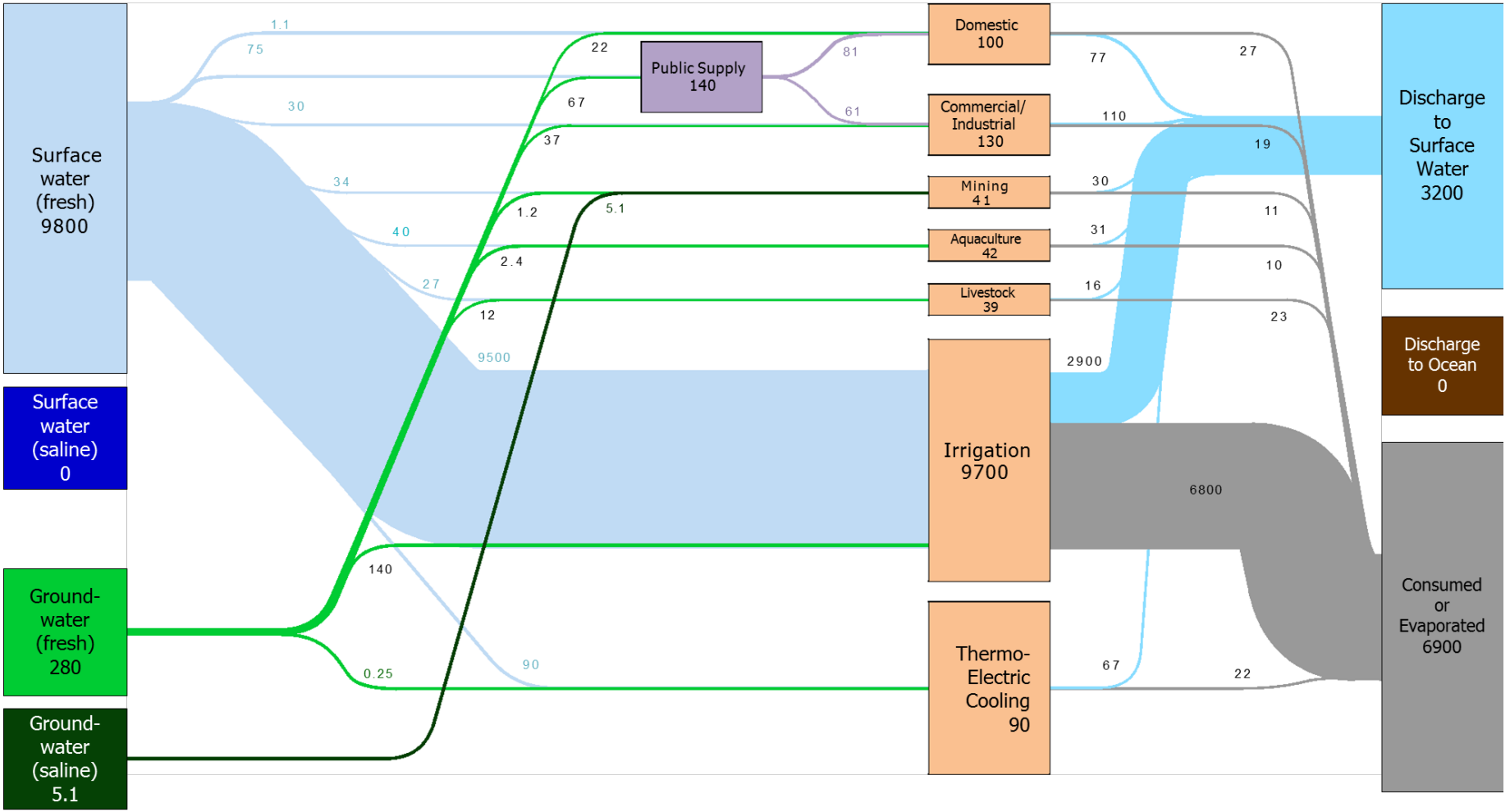
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772

Estimated Idaho Water Flow in 2005: 20000 Million Gallons/Day



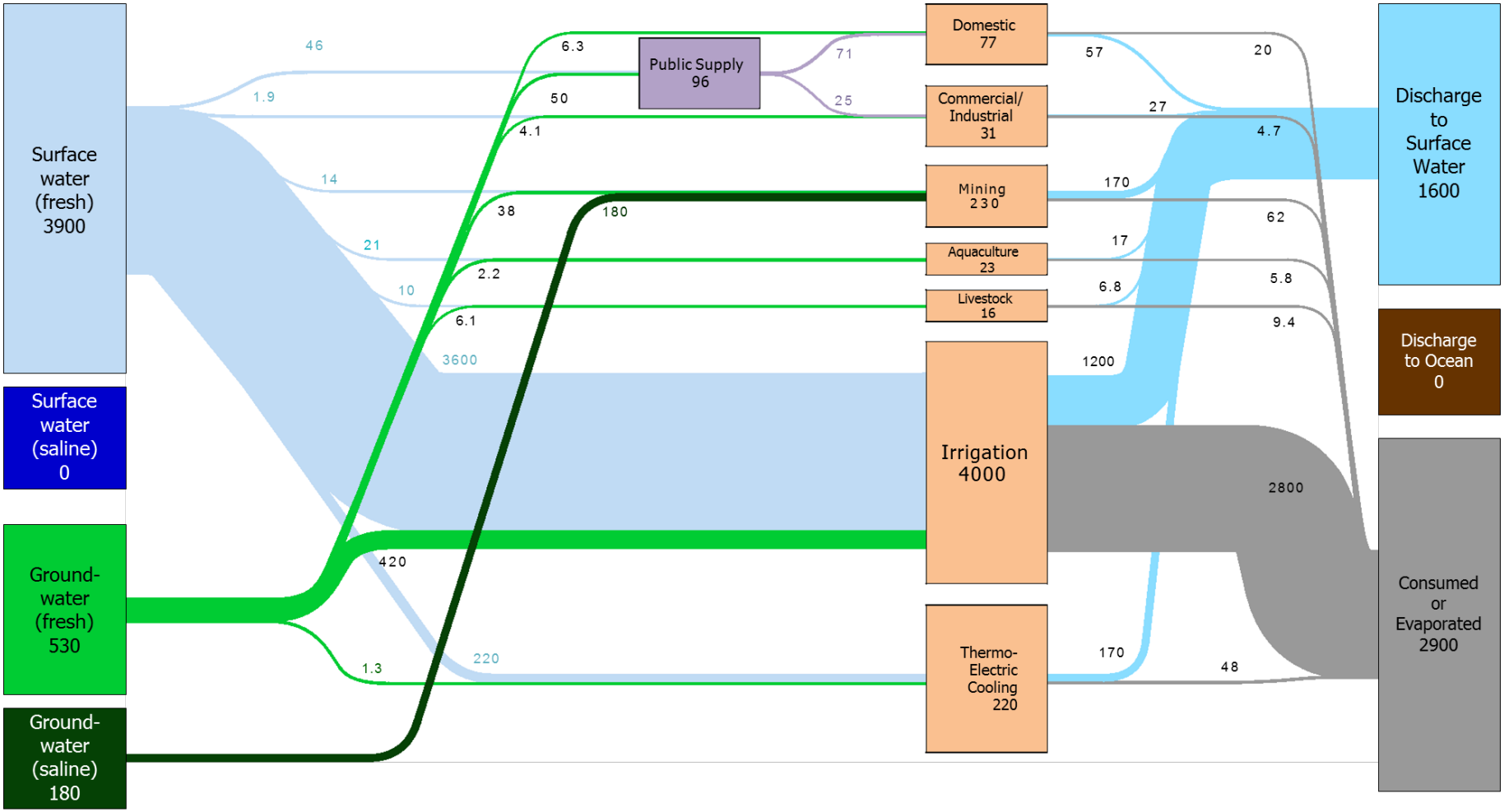
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Montana Water Flow in 2005:
10000 Million Gallons/Day



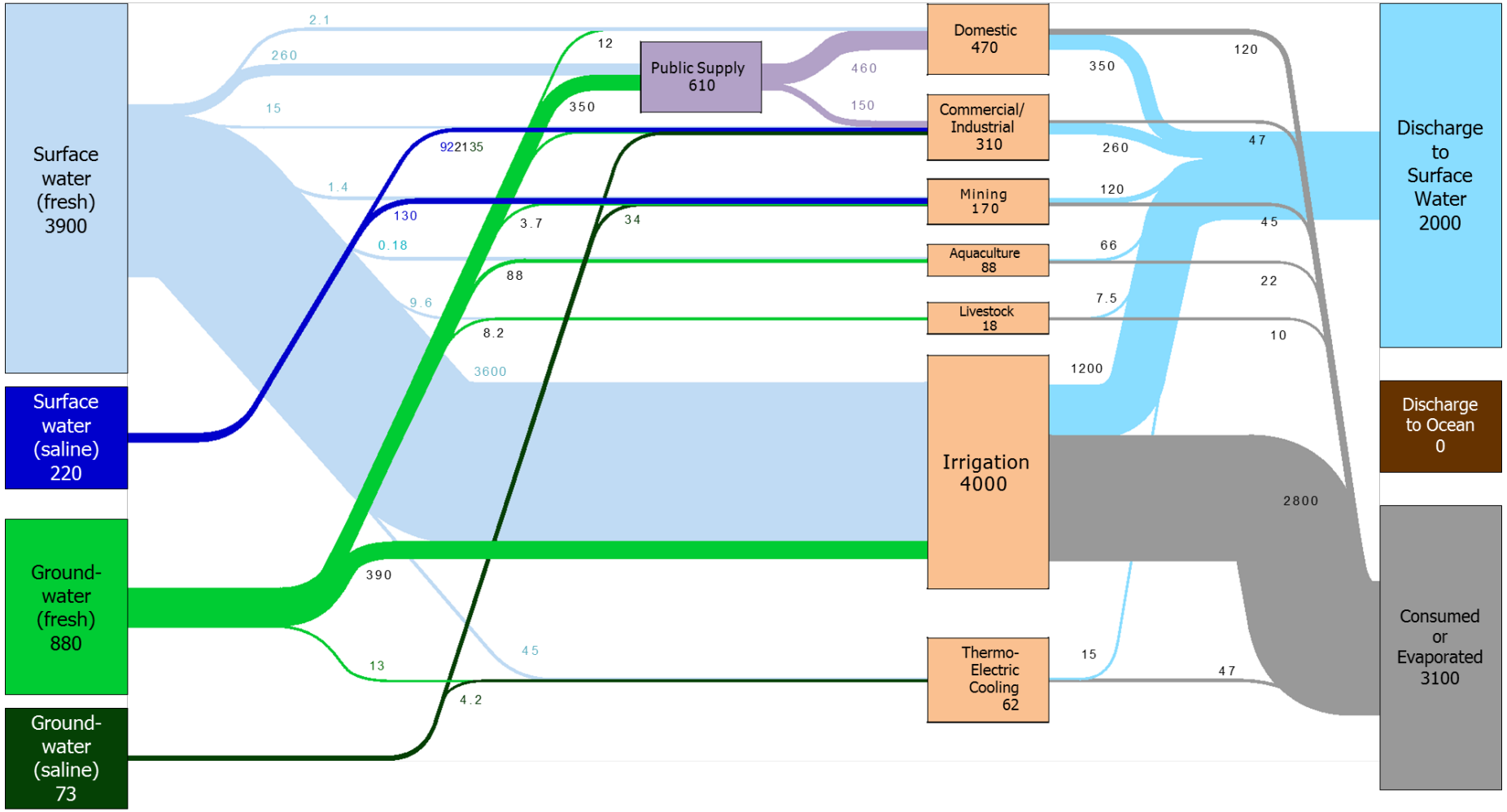
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Wyoming Water Flow in 2005: 4600 Million Gallons/Day



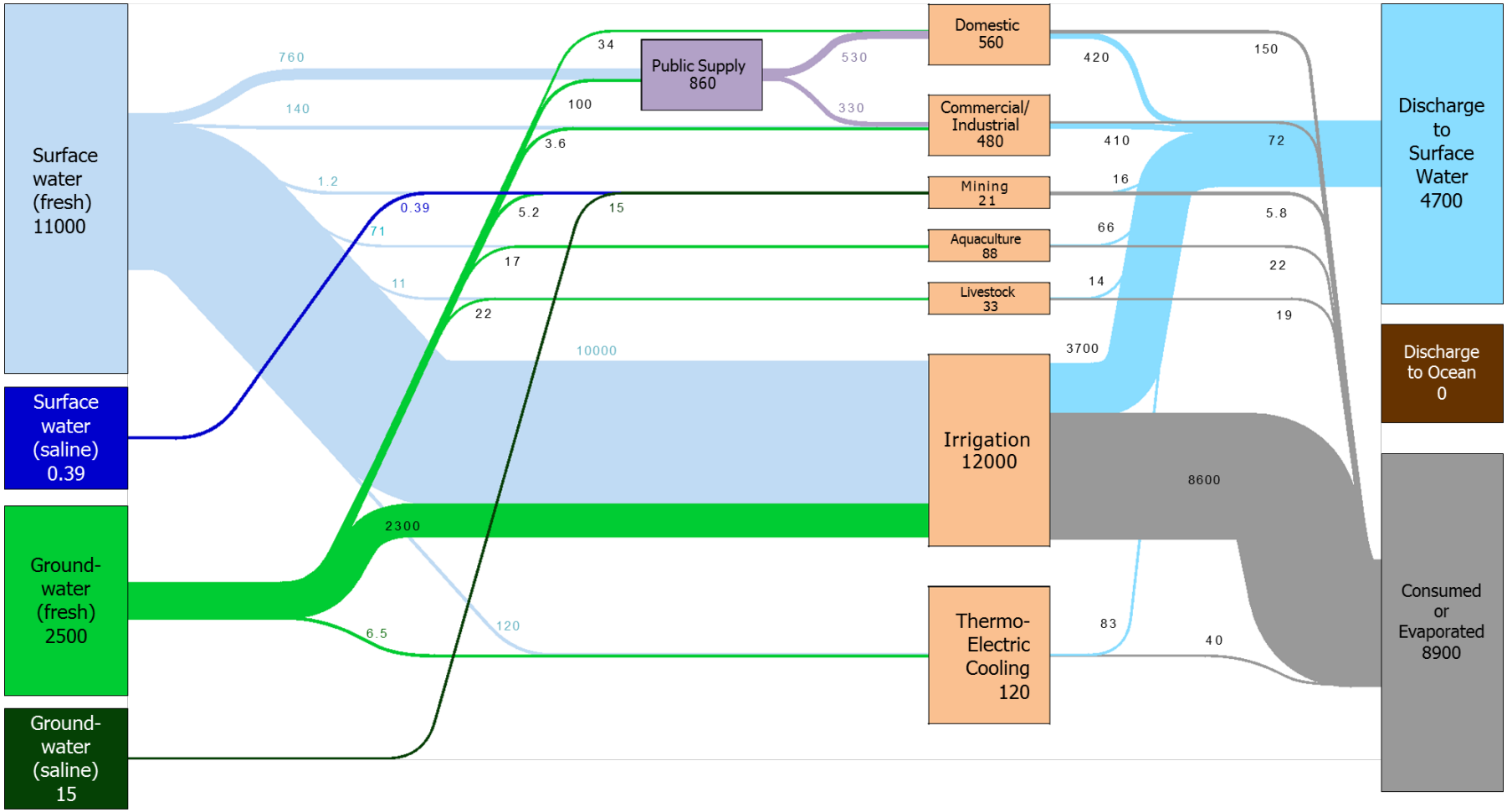
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Utah Water Flow in 2005:
5100 Million Gallons/Day



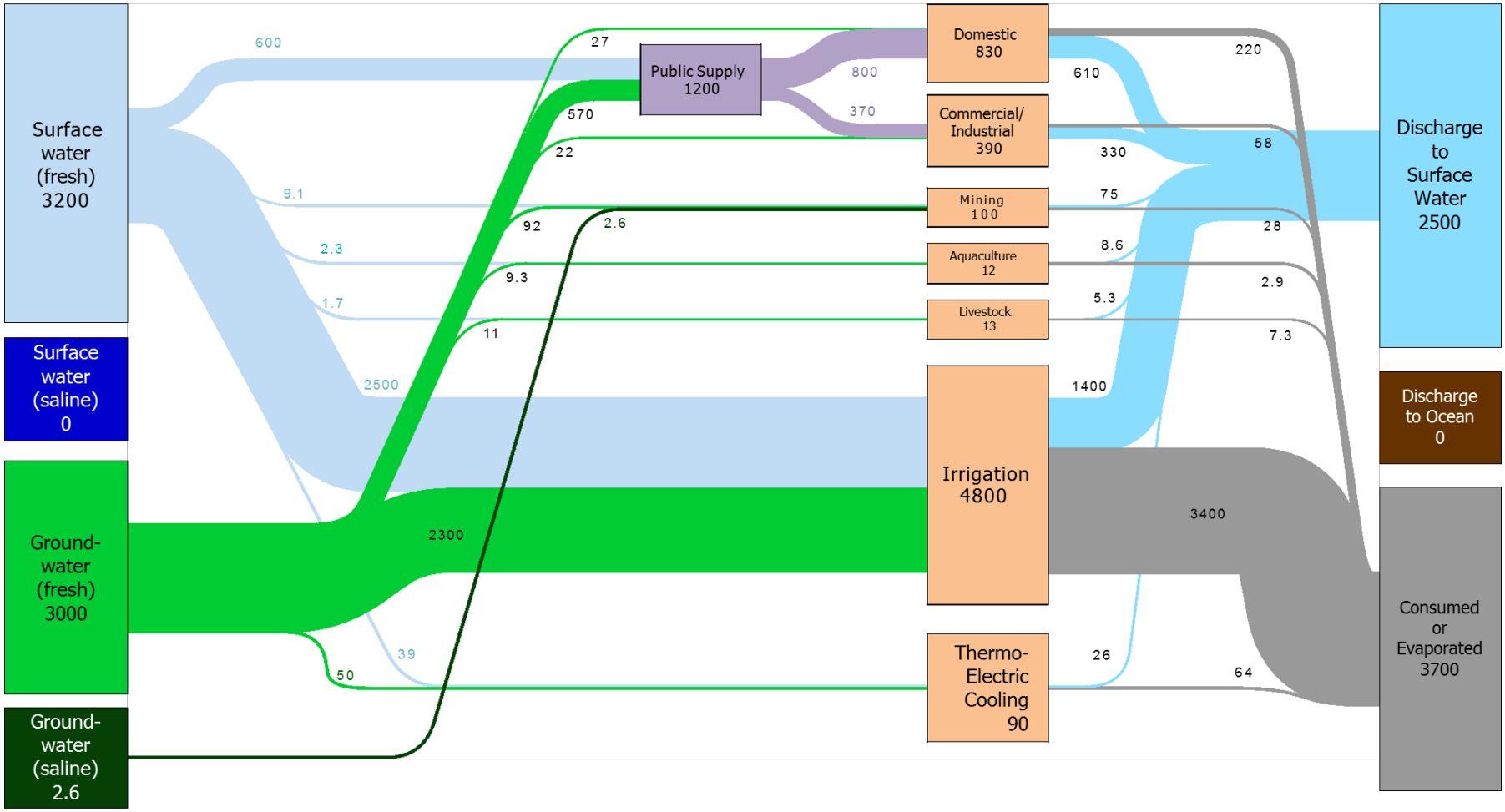
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Colorado Water Flow in 2005:
14000 Million Gallons/Day



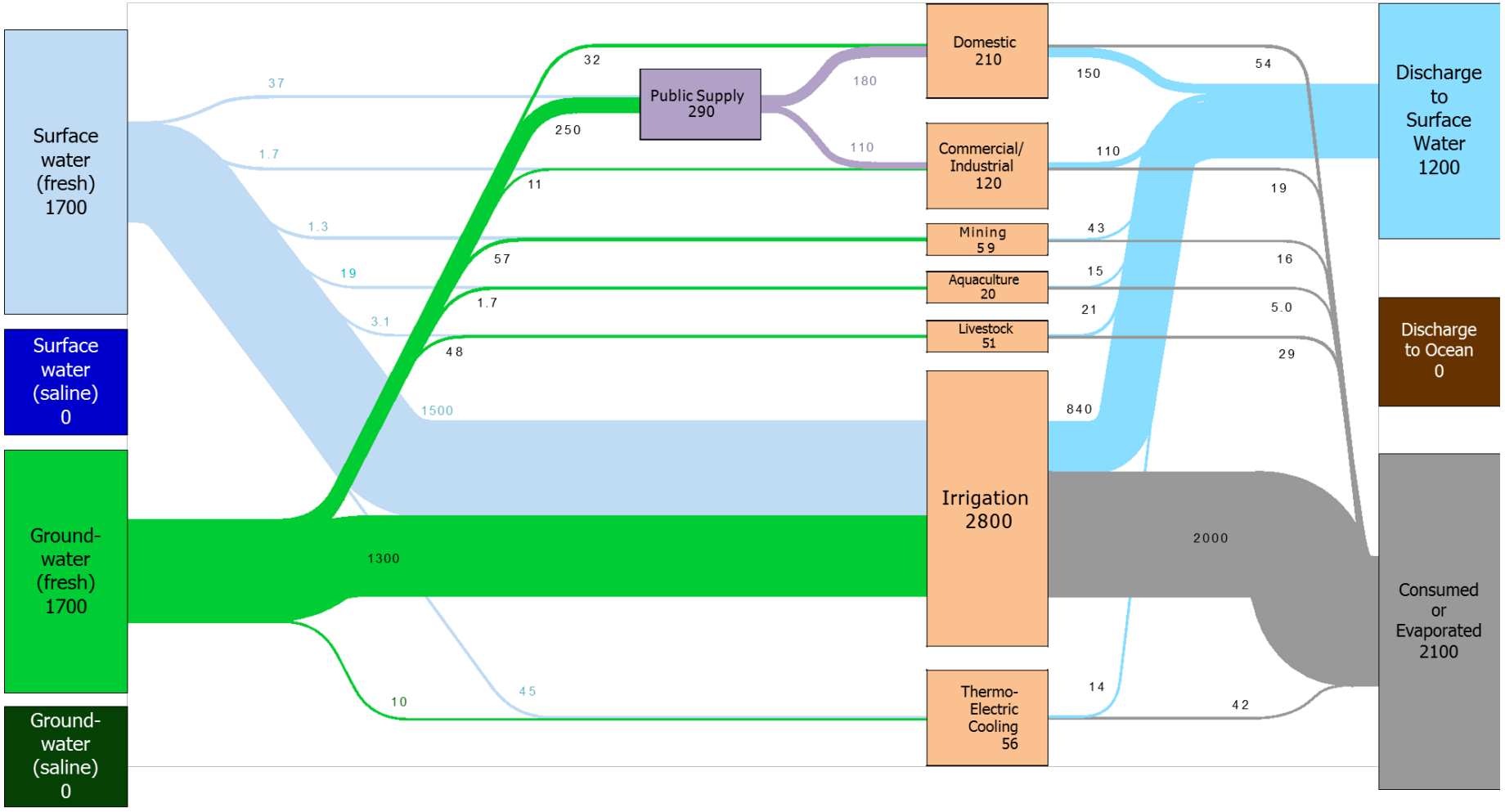
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Arizona Water Flow in 2005:
6200 Million Gallons/Day

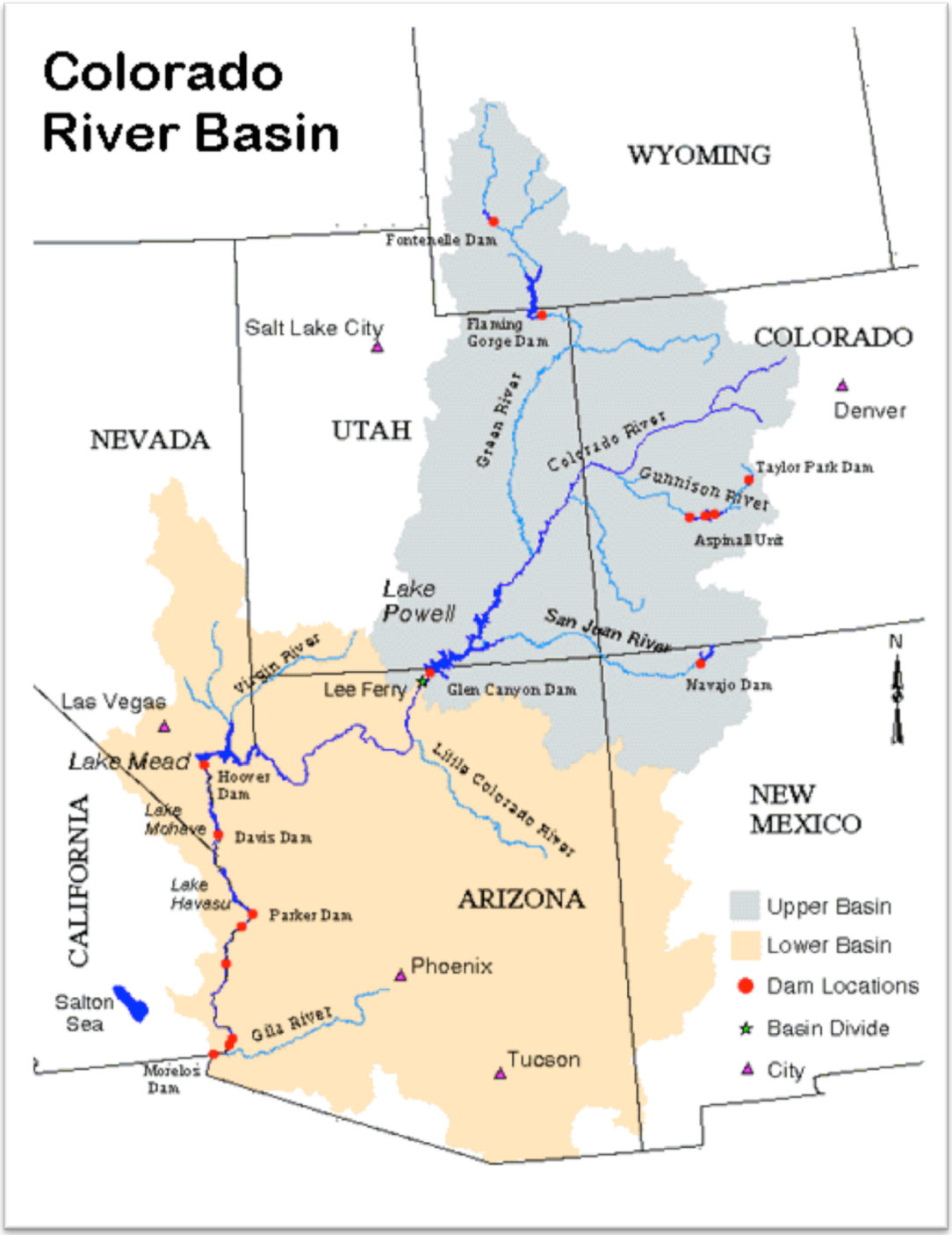


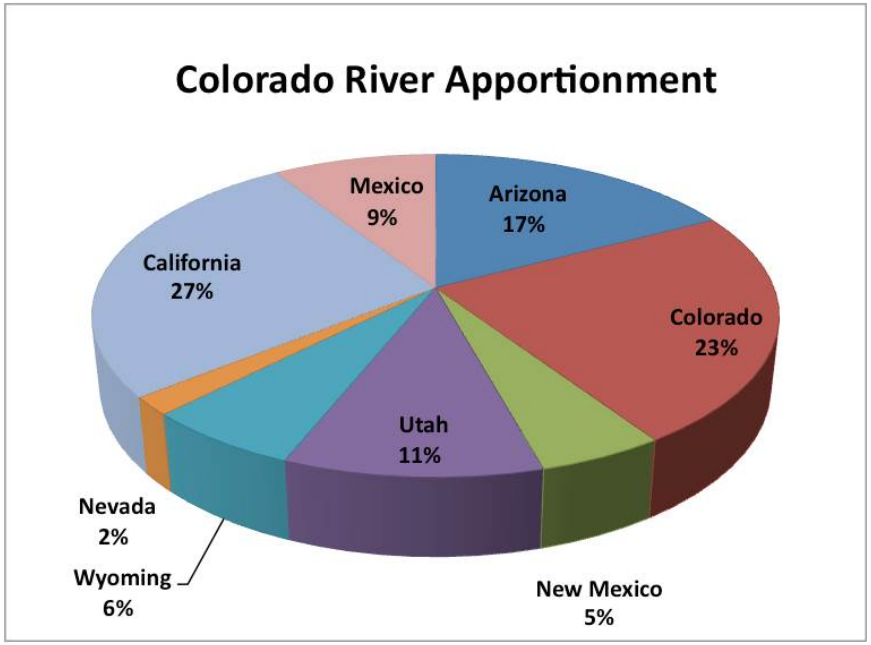
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated New Mexico Water Flow in 2005:
3300 Million Gallons/Day

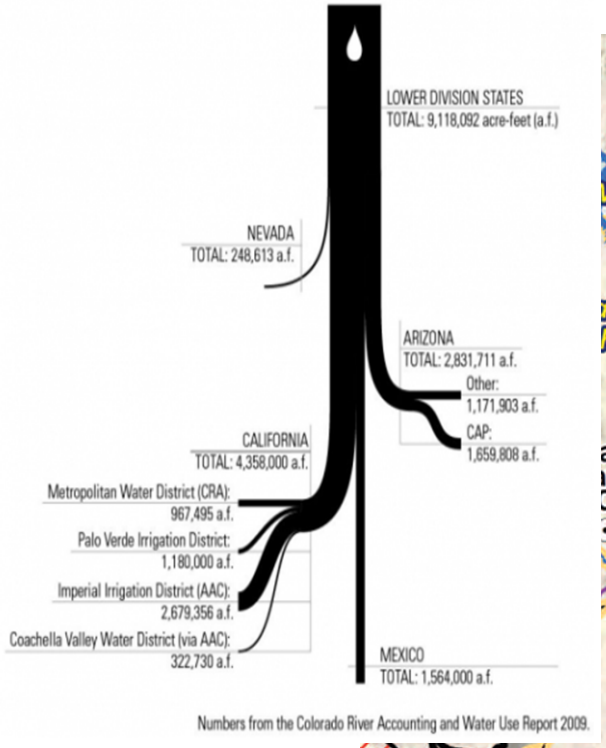


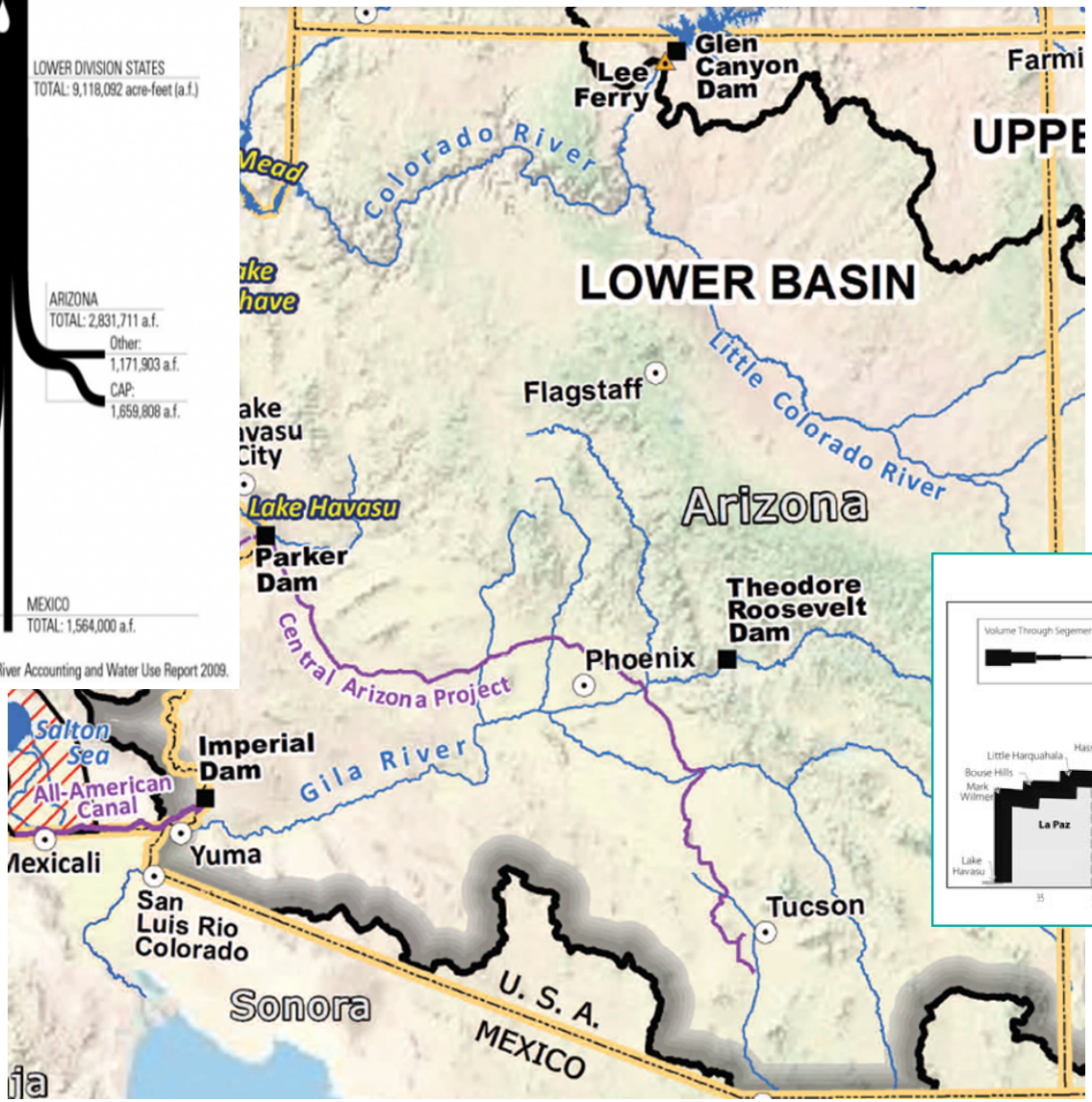
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

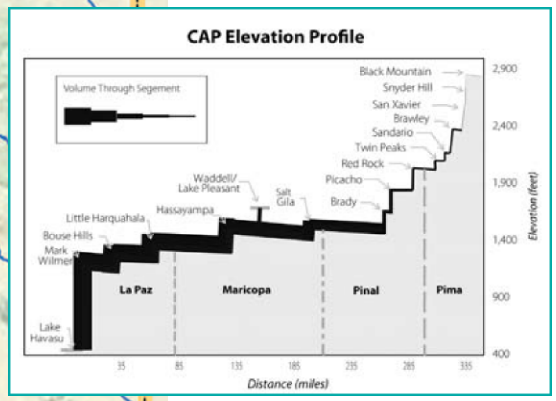

Colorado River Basin
WYOMING
COLORADO
NEVADA
UTAH
NEW MEXICO
ARIZONA
CALIFORNIA
Fontenelle Dam
Flaming Gorge Dam
Salt Lake City
Denver
Green River
Colorado River
Gunnison River
Taylor Park Dam
Aspinall Unit
Lake Powell
San Juan River
Navajo Dam
Glen Canyon Dam
Lee Ferry
Virgin River
Las Vegas
Lake Mead
Hoover Dam
Lake Mohave
Davis Dam
Lake Havasu
Parker Dam
Little Colorado River
Phoenix
Tucson
Gila River
Salton Sea
Morelos Dam
N
Upper Basin
Lower Basin
Dam Locations
Basin Divide
City


Colorado River Apportionment
Mexico
9%
Arizona
17%
California
27%
Colorado
23%
Utah
11%
Nevada
2%
Wyoming
6%
New Mexico
5%

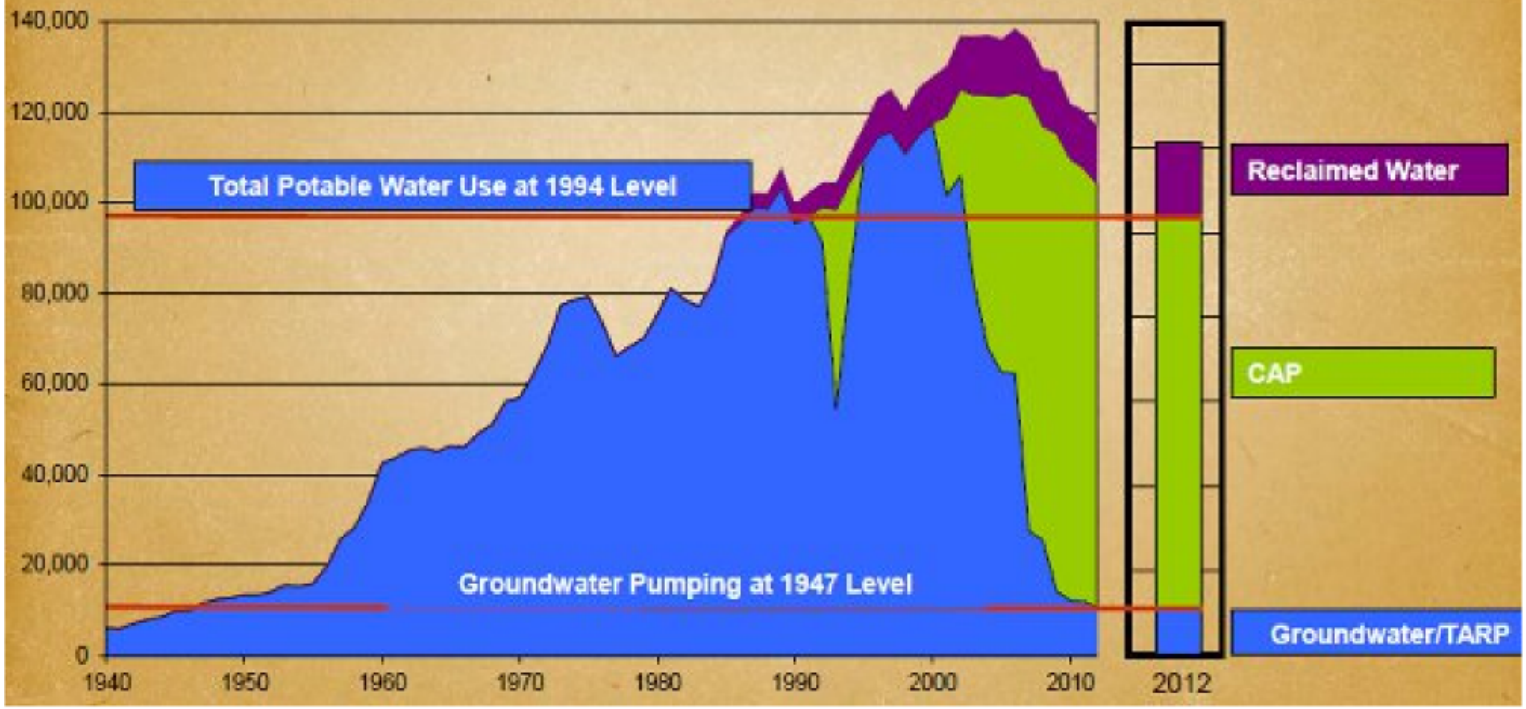

Maximum (1229 feet)
Average (1173 feet)
Drought (1125 feet)
Ration Regime I (1075 feet)
Ration Regime II (1050 feet)
Ration Regime III (1025 feet)
Pump Limit (1000 feet)
Lake Mead Water Level
1240
1220
1200
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

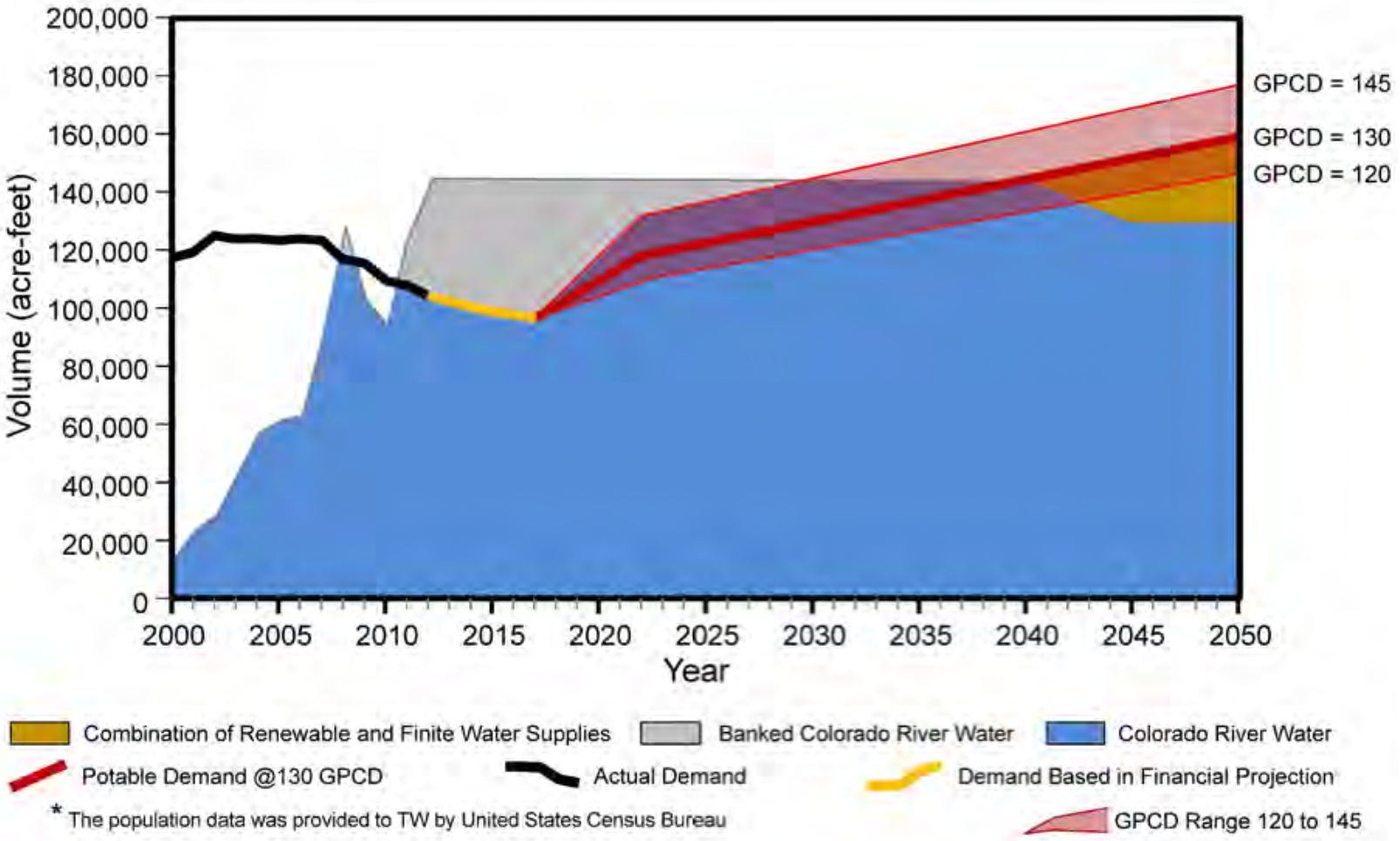

LOWER DIVISION STATES
TOTAL: 9,118,092 acre-feet (a.f.)
NEVADA
TOTAL: 248,613 a.f.
ARIZONA
TOTAL: 2,831,711 a.f.
Other:
1,171,903 a.f.
CAP:
1,659,808 a.f.
CALIFORNIA
TOTAL: 4,358,000 a.f.
Metropolitan Water District (CRA):
967,495 a.f.
Palo Verde Irrigation District:
1,180,000 a.f.
Imperial Irrigation District (AAC):
2,679,356 a.f.
Coachella Valley Water District (via AAC):
322,730 a.f.
MEXICO
TOTAL: 1,564,000 a.f.
Numbers from the Colorado River Accounting and Water Use Report 2009.


Glen Canyon Dam
Lee Ferry
Colorado River
Mead
UPPE
LOWER BASIN
Flagstaff
Little Colorado River
Lake Havasu City
Lake Havasu
Parker Dam
Arizona
Theodore Roosevelt Dam
Phoenix
Central Arizona Project
Gila River
Salton Sea
All-American Canal
Imperial Dam
Mexicali
Yuma
San Luis Rio Colorado
Tucson
Sonora
U. S. A.
MEXICO

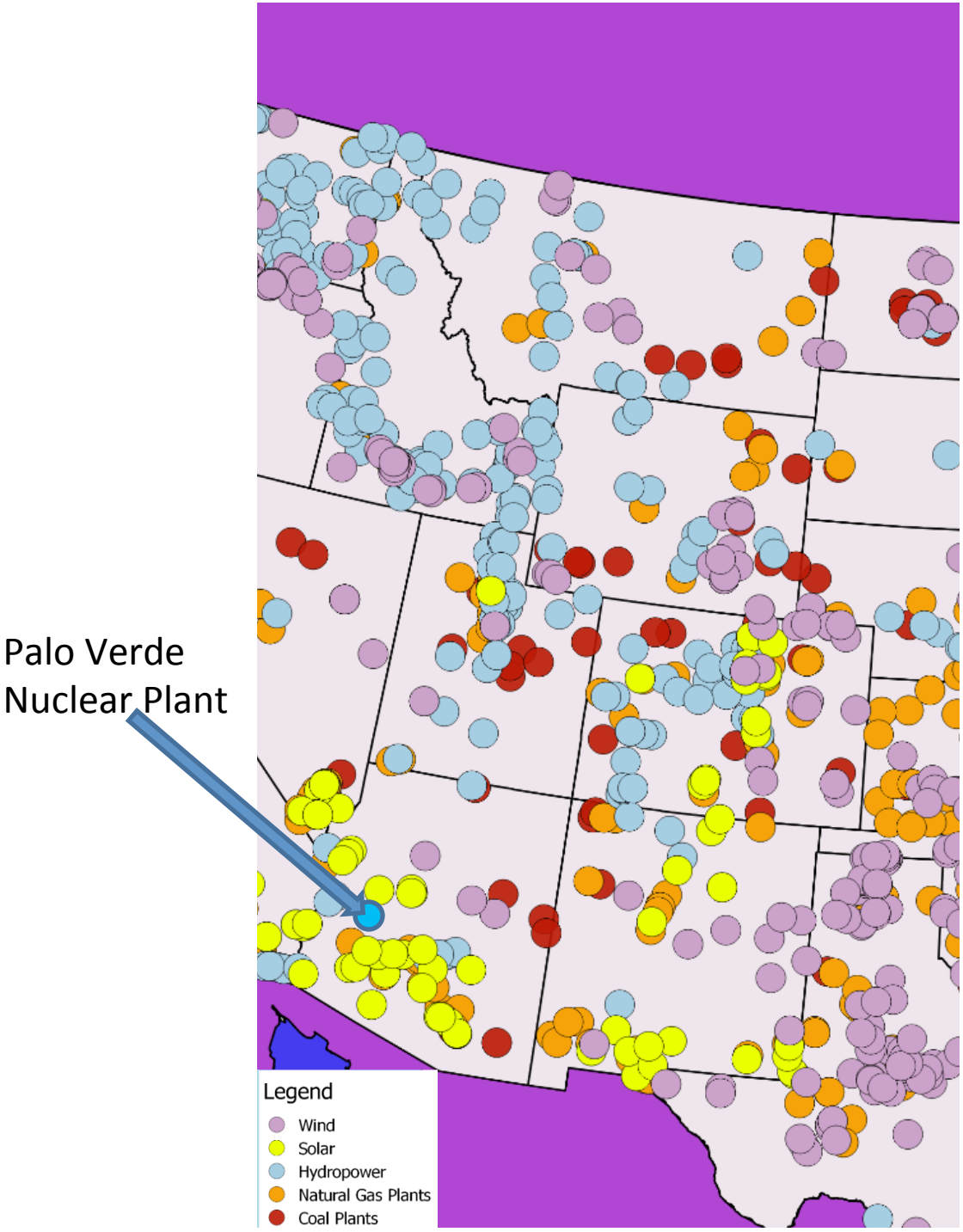

CAP Elevation Profile
Volume Through Segement
Black Mountain
Snyder Hill
San Xavier
Brawley
Sandario
Twin Peaks
Red Rock
Picacho
Brady
Waddell/ Lake Pleasant
Salt Gila
Hassayampa
Little Harquahala
Bouse Hills
Mark Wilmer
Lake Havasu
La Paz
Maricopa
Pinal
Pima
2,900
2,400
1,900
1,400
900
400
Elevation (feet)
35
85
135
185
235
285
335
Distance (miles)

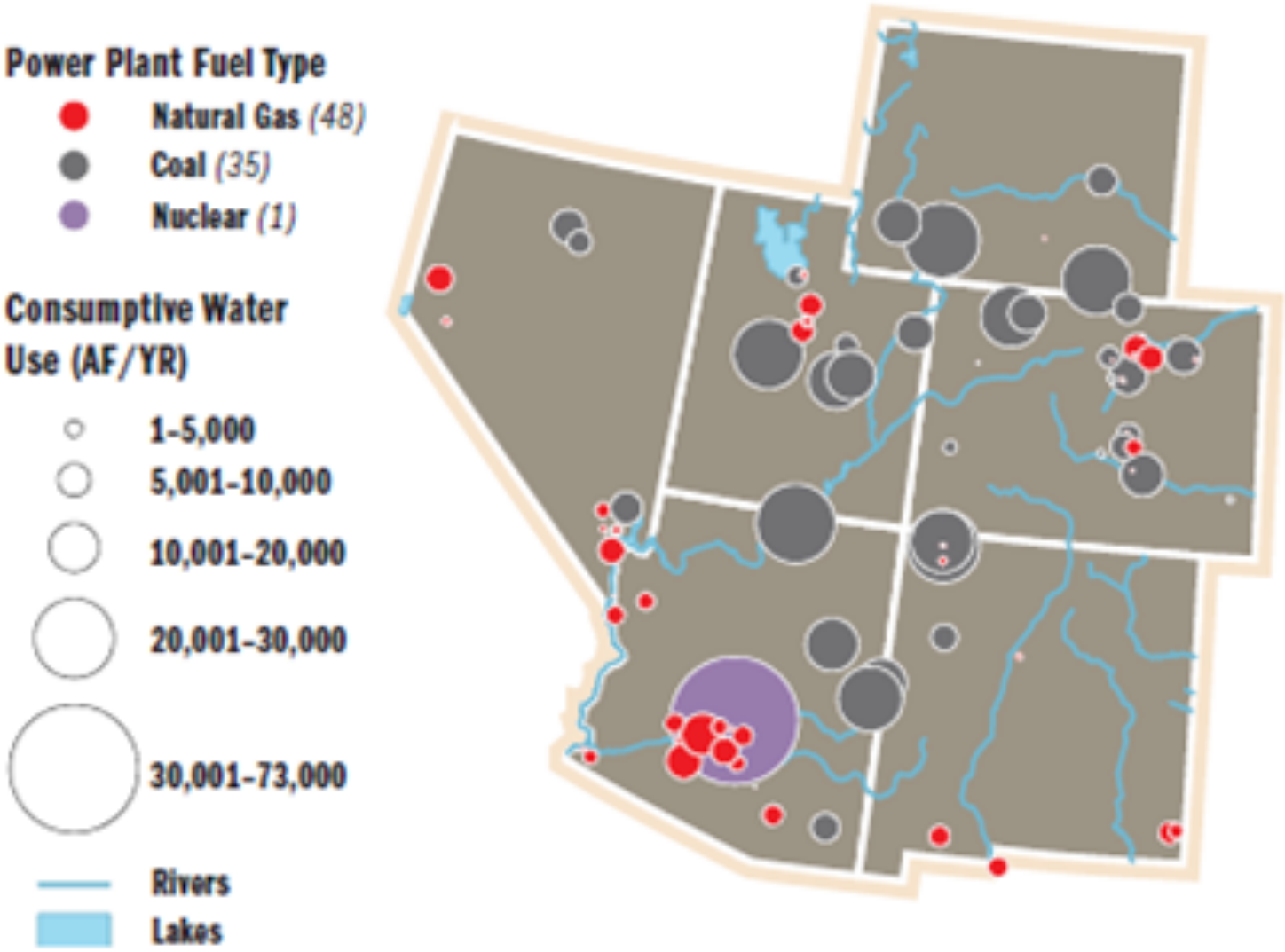
Transition to Renewable Supplies (1940-2012)



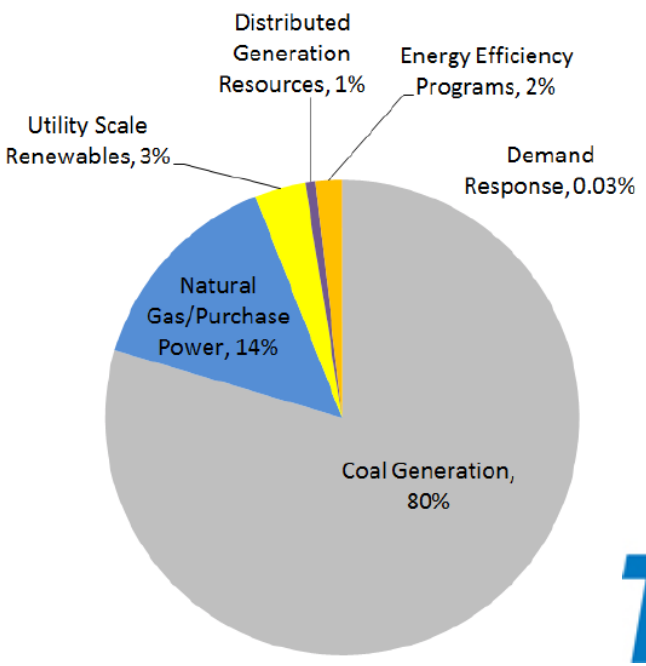


* The population data was provided to TW by United States Census Bureau

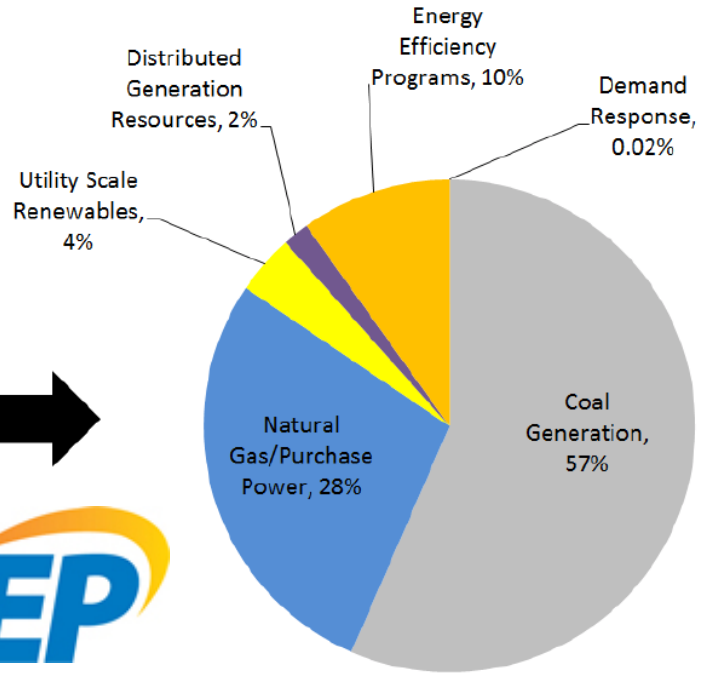

Palo Verde
Nuclear Plant
Legend
Wind
Solar
Hydropower
Natural Gas Plants
Coal Plants


Power Plant Fuel Type
Natural Gas (48)
Coal (35)
Nuclear (1)
Consumptive Water Use (AF/YR)
1-5,000
5,001-10,000
10,001-20,000
20,001-30,000
30,001-73,000
Rivers
Lakes

2013 Portfolio Energy Mix



2020 Portfolio Energy Mix

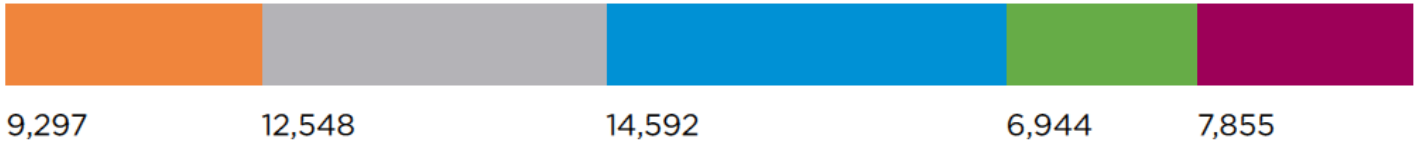


TEP

COMPOSITION OF ENERGY MIX BY RESOURCE (GWH)

2014

2029

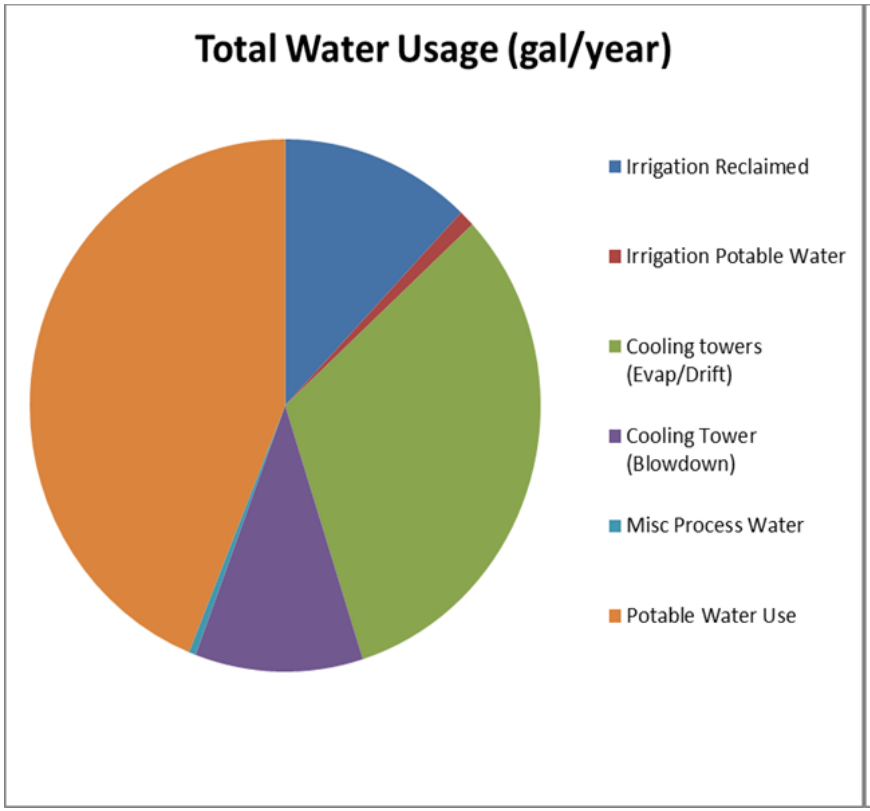


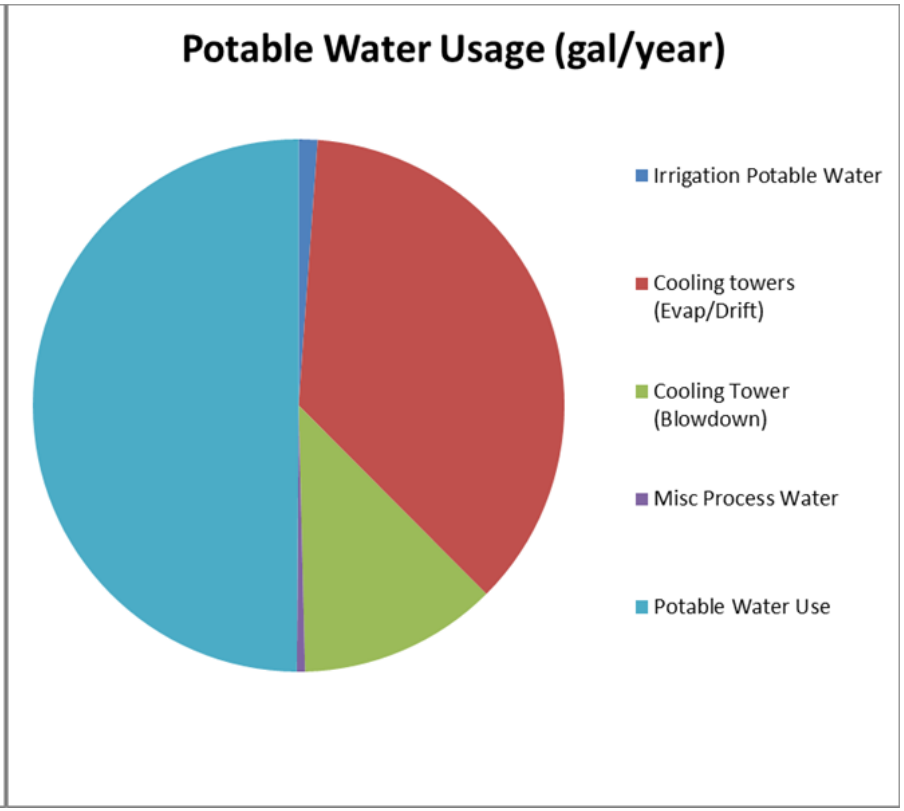
Nuclear Coal Natural Gas Renewable Energy Energy Efficiency

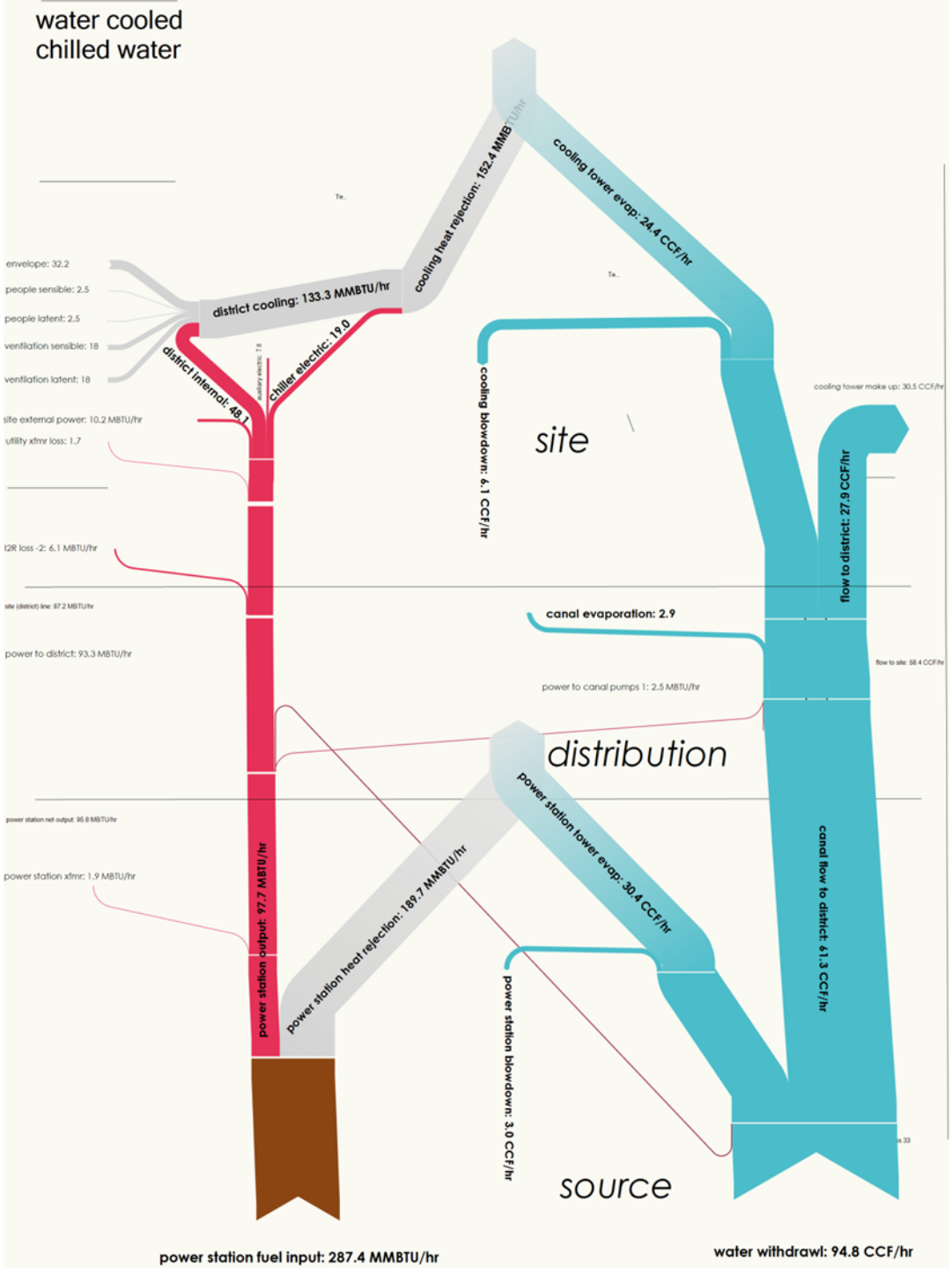
Improves Environmental Performance:

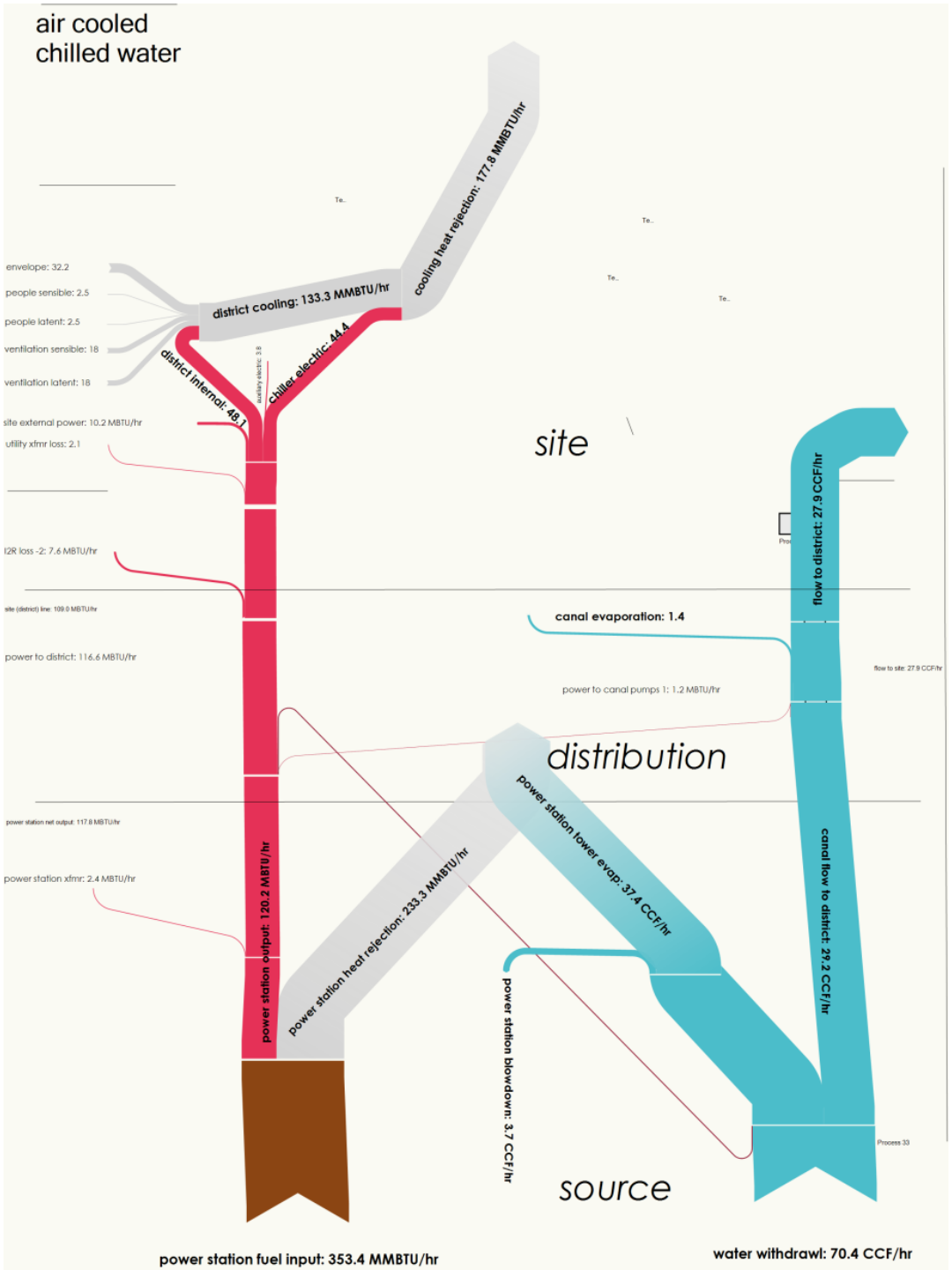
- CO2 Intensity ▼ 14%
- Water Intensity ▼ 24%

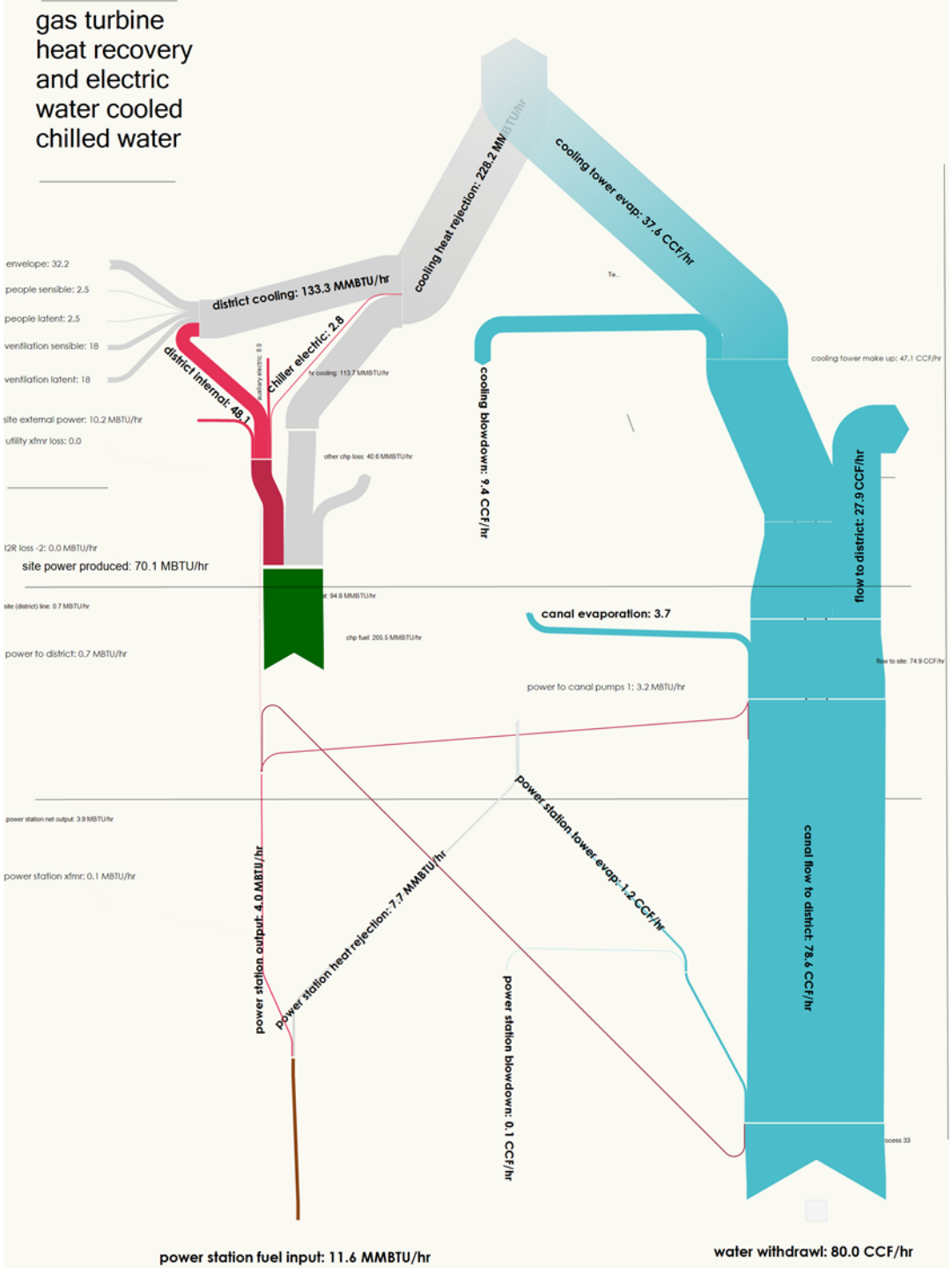
aps


Total Water Usage (gal/year)
Irrigation Reclaimed
Irrigation Potable Water
Cooling towers (Evap/Drift)
Cooling Tower (Blowdown)
Misc Process Water
Potable Water Use


Potable Water Usage (gal/year)
Irrigation Potable Water
Cooling towers (Evap/Drift)
Cooling Tower (Blowdown)
Misc Process Water
Potable Water Use


water cooled
chilled water
envelope: 32.2
people sensible: 2.5
people latent: 2.5
ventilation sensible: 18
ventilation latent: 18
district cooling: 133.3 MMBTU/hr
cooling heat rejection: 152.4 MMBTU/hr
cooling tower evap: 24.4 CCF/hr
district internal: 48.1
chiller electric: 19.0
site external power: 10.2 MBTU/hr
utility xfmr loss: 1.7
I2R loss -2: 6.1 MBTU/hr
power to district: 93.3 MBTU/hr
cooling blowdown: 6.1 CCF/hr
site
cooling tower make up: 30.5 CCF/hr
flow to district: 27.9 CCF/hr
canal evaporation: 2.9
power to canal pumps 1: 2.5 MBTU/hr
distribution
power station xfmr: 1.9 MBTU/hr
power station output: 97.7 MBTU/hr
power station heat rejection: 189.7 MMBTU/hr
power station tower evap: 30.4 CCF/hr
canal flow to district: 61.3 CCF/hr
power station blowdown: 3.0 CCF/hr
source
power station fuel input: 287.4 MMBTU/hr
water withdrawl: 94.8 CCF/hr


air cooled
chilled water
envelope: 32.2
people sensible: 2.5
people latent: 2.5
ventilation sensible: 18
ventilation latent: 18
district cooling: 133.3 MMBTU/hr
cooling heat rejection: 177.8 MMBTU/hr
district internal: 49.1
auxiliary electric: 3.8
chiller electric: 44.4
site external power: 10.2 MBTU/hr
utility xfmr loss: 2.1
I2R loss -2: 7.6 MBTU/hr
site (district) line: 109.0 MBTU/hr
power to district: 116.6 MBTU/hr
site
flow to district: 27.9 CCF/hr
canal evaporation: 1.4
flow to site: 27.9 CCF/hr
power to canal pumps 1: 1.2 MBTU/hr
distribution
power station net output: 117.8 MBTU/hr
power station xfmr: 2.4 MBTU/hr
power station output: 120.2 MBTU/hr
power station heat rejection: 233.3 MMBTU/hr
power station tower evap: 37.4 CCF/hr
canal flow to district: 29.2 CCF/hr
power station blowdown: 3.7 CCF/hr
Process 33
source
power station fuel input: 353.4 MMBTU/hr
water withdrawl: 70.4 CCF/hr


gas turbine
heat recovery
and electric
water cooled
chilled water
envelope: 32.2
people sensible: 2.5
people latent: 2.5
ventilation sensible: 18
ventilation latent: 18
site external power: 10.2 MBTU/hr
utility xfmr loss: 0.0
I2R loss -2: 0.0 MBTU/hr
site power produced: 70.1 MBTU/hr
site (district) line: 0.7 MBTU/hr
power to district: 0.7 MBTU/hr
power station net output: 3.9 MBTU/hr
power station xfmr: 0.1 MBTU/hr
district cooling: 133.3 MMBTU/hr
district internal: 48.1
Chiller electric: 2.8
hr cooling: 113.7 MMBTU/hr
other chp loss: 40.6 MMBTU/hr
chp fuel: 205.5 MMBTU/hr
cooling heat rejection: 228.2 MMBTU/hr
cooling tower evap: 37.6 CCF/hr
cooling tower make up: 47.1 CCF/hr
cooling blowdown: 9.4 CCF/hr
flow to district: 27.9 CCF/hr
canal evaporation: 3.7
flow to site: 74.9 CCF/hr
power to canal pumps 1: 3.2 MBTU/hr
power station tower evap: 1.2 CCF/hr
power station heat rejection: 7.7 MMBTU/hr
power station output: 4.0 MBTU/hr
power station blowdown: 0.1 CCF/hr
canal flow to district: 78.6 CCF/hr
power station fuel input: 11.6 MMBTU/hr
water withdrawl: 80.0 CCF/hr

Campus Critical Concerns

- Utility Costs
- Curtailment plan
- Hygiene and flushing
- Critical cooling for research and medical

Campus Utility Planning

- Behavior/Education
- Building low flow fixtures
- On-site production wells
- Storage
- Reclaimed water for landscape
- Blowdown cycles & recovery
- Reclaimed water for cooling towers
- Dry cooling alternatives