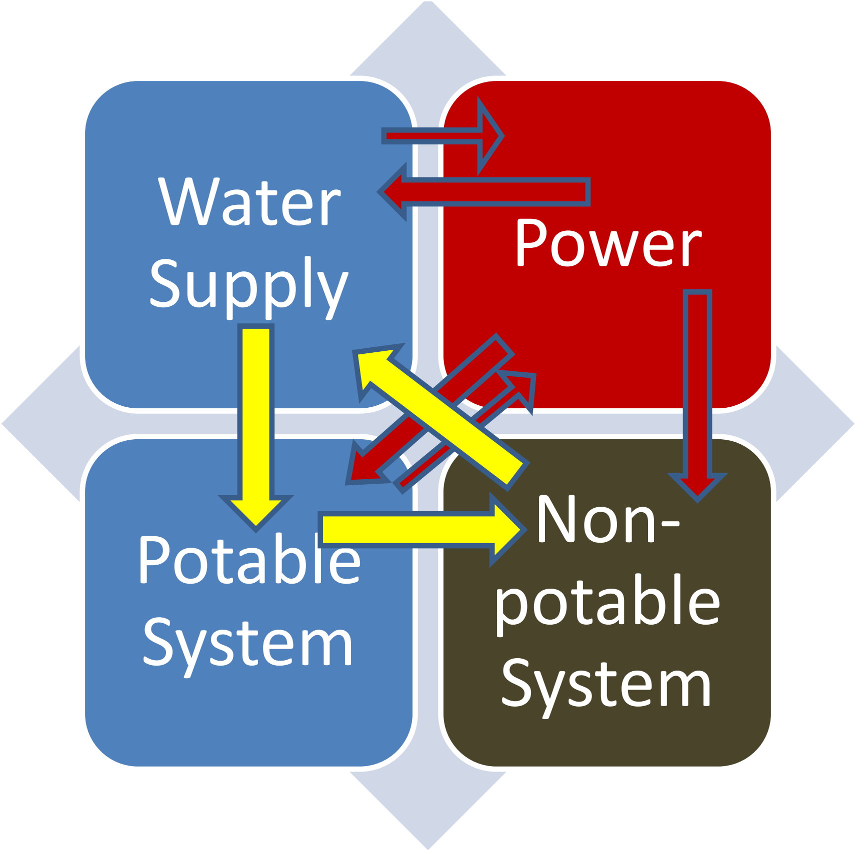
The Limits of Conservation and the Real Water/Energy Nexus: A systems approach



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Elements of the water problem

Even with best technology it takes water to run and feed a livable city.

Without deprivation or extra-ordinary measures it takes ~100 gphd for indoor water uses

This can be dropped to ~70 gphd with leak control and recycling gray water for toilet flushing. (Hard to do in existing structures.)

In areas west of the 100^{th} meridian it takes ~ the same amount of water for landscapes/gardens.

Parks and open space irrigation adds 10% of residential

ICI requires 50% of residential demands.

This sets a minimum amount of water required for a city with a good quality of life.

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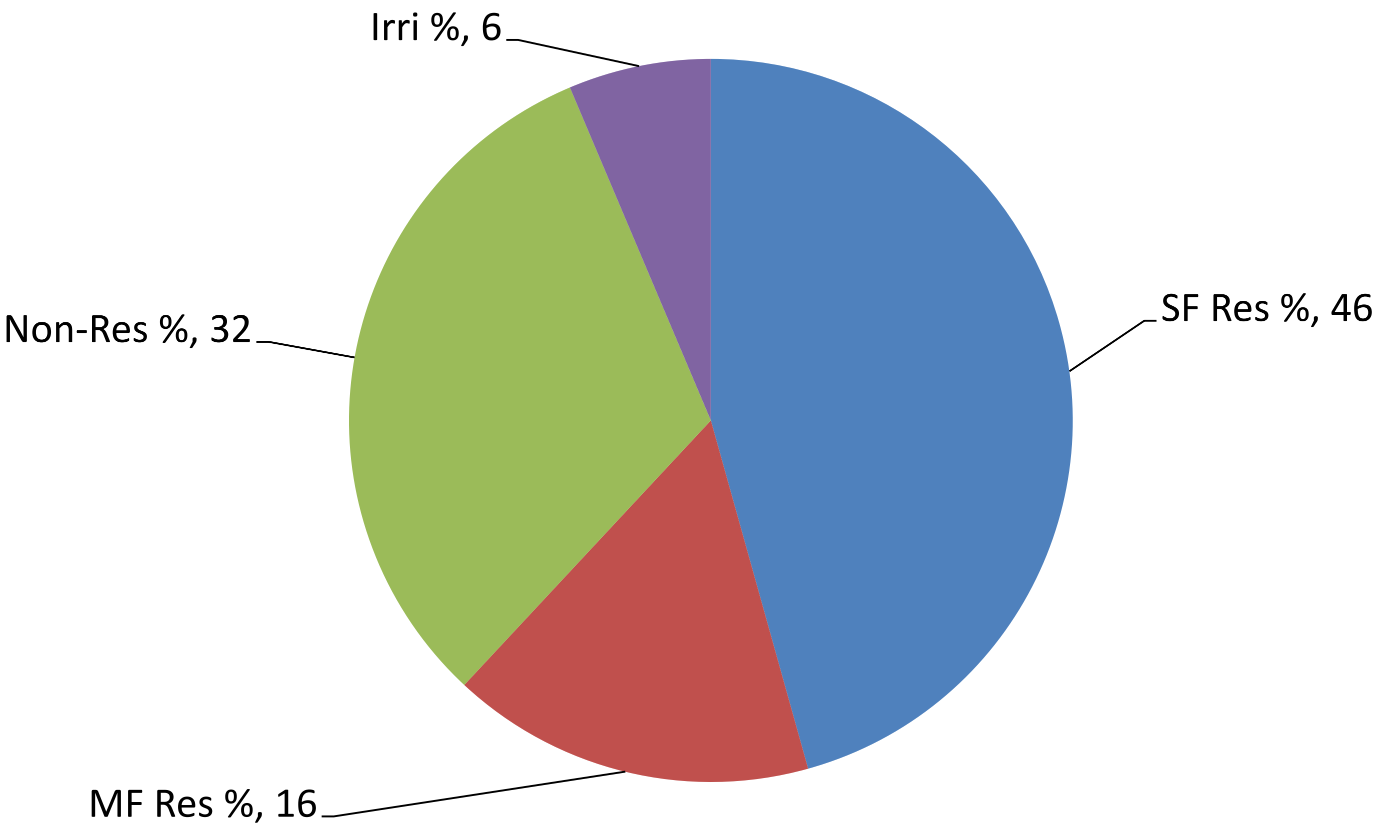
Typical breakdown of Muni Use



Residential = 61%
Non-Res (ICI)= 32%
Irrigation =6%

Source: DeOreo, W.B.., and P. Mayer. 2015. "Residential End Uses of Water Study Update." Denver, Colo.: Water Research Foundation, forthcoming. Reprinted with permission of the Water Research Foundation.

Case Study: How much water will the South Platte Basin need in 2050?

Population is expected to grow from 3.5 million to 6.4 million persons

SF Households will grow from 967,000 to 1,740,000.

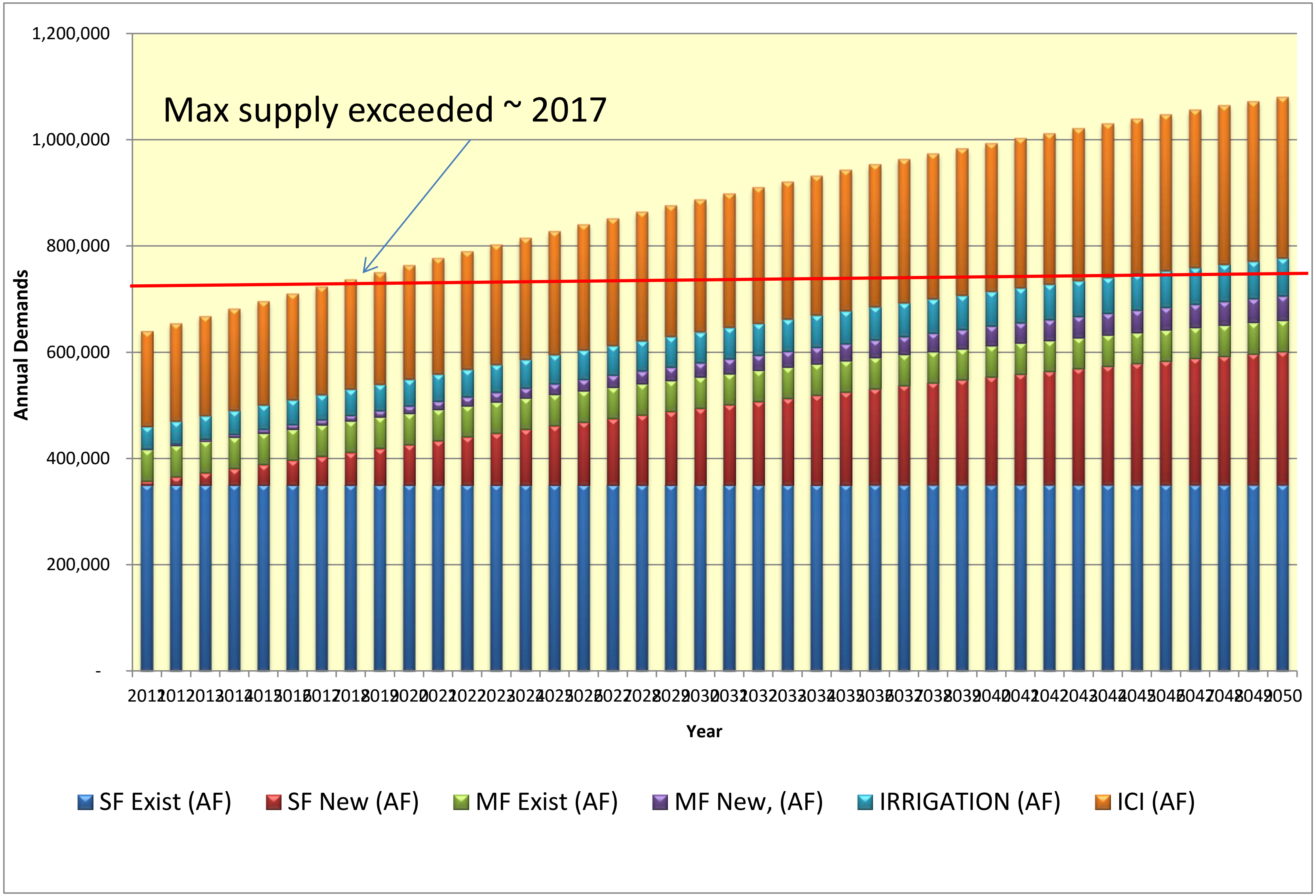
MF Households will grow from 378,000 to 679,000. An increase of 80% for both cats.

Max estimated water supply (assuming several new projects are successfully built) is 736,000 AF

Water demands could grow to 1,140,000 AF

This leaves a "gap" of 404,000 AF (minimum)

Baseline water demands could grow to 1.14 MAF



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Passive/Indoor Savings

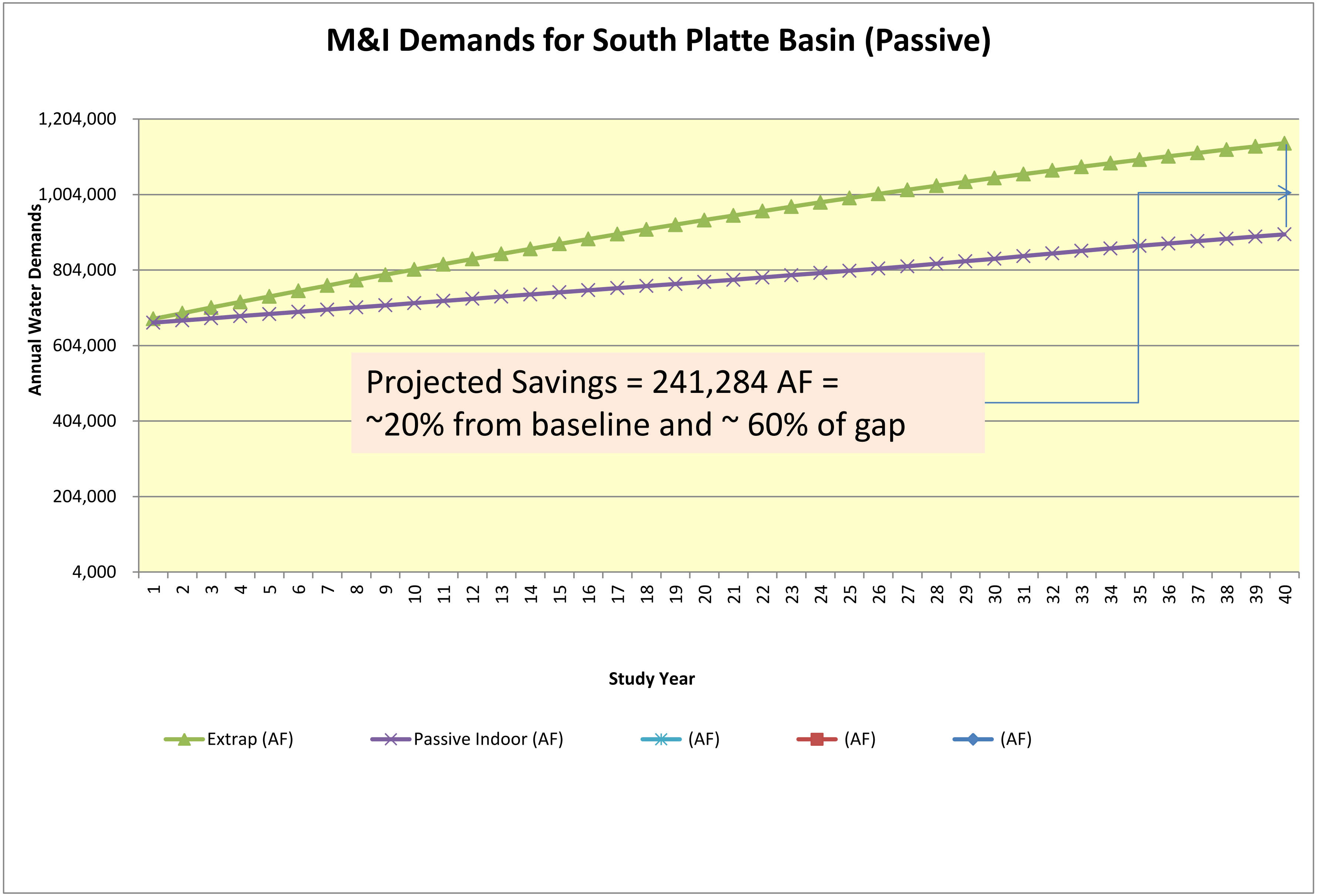
Goal is to use best technology and avoid waste; not to deprive people of use

All new homes built to WaterSense Standards + Energy Star clothes washer.

Existing homes brought to Standard (80% max saturation)

~ 20% reduction in ICI & Irrigation use from baseline by applying BAT to new ICI projects and irrigation efficiencies

No changes in Residential Irrigation uses


M&I Demands for South Platte Basin (Passive)
Annual Water Demands
1,204,000
1,004,000
804,000
604,000
404,000
204,000
4,000
Projected Savings = 241,284 AF =
~20% from baseline and ~ 60% of gap
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Study Year
Extrap (AF)
Passive Indoor (AF)
(AF)
(AF)
(AF)

Reduce the % of homes and businesses that are over-irrigating

Reduce rates by 33%. (from 30% to 20%)

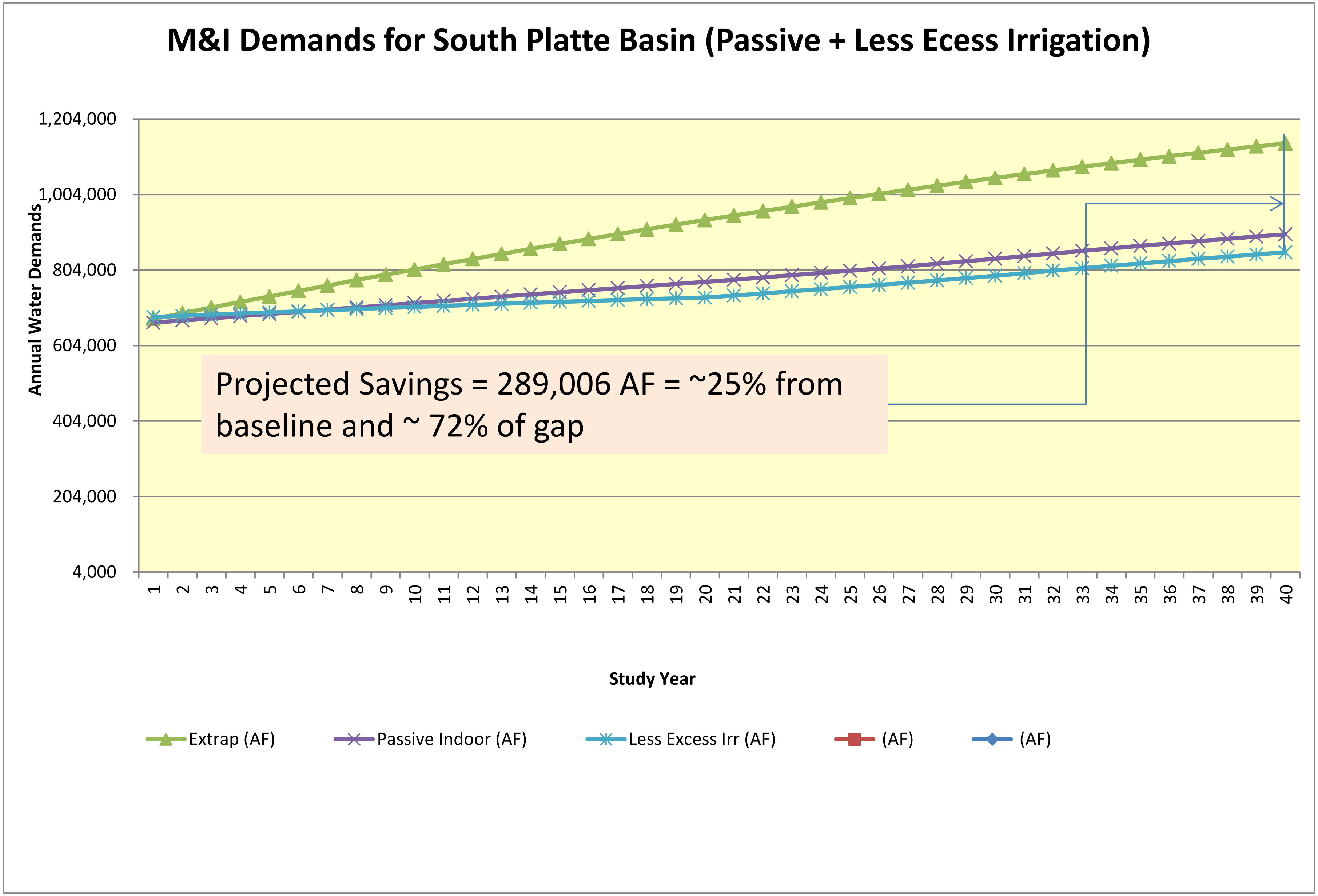
Leave irrigated areas unchanged

Do not use advanced methods such as leak sensing and use of recycled water for toilet flushing.

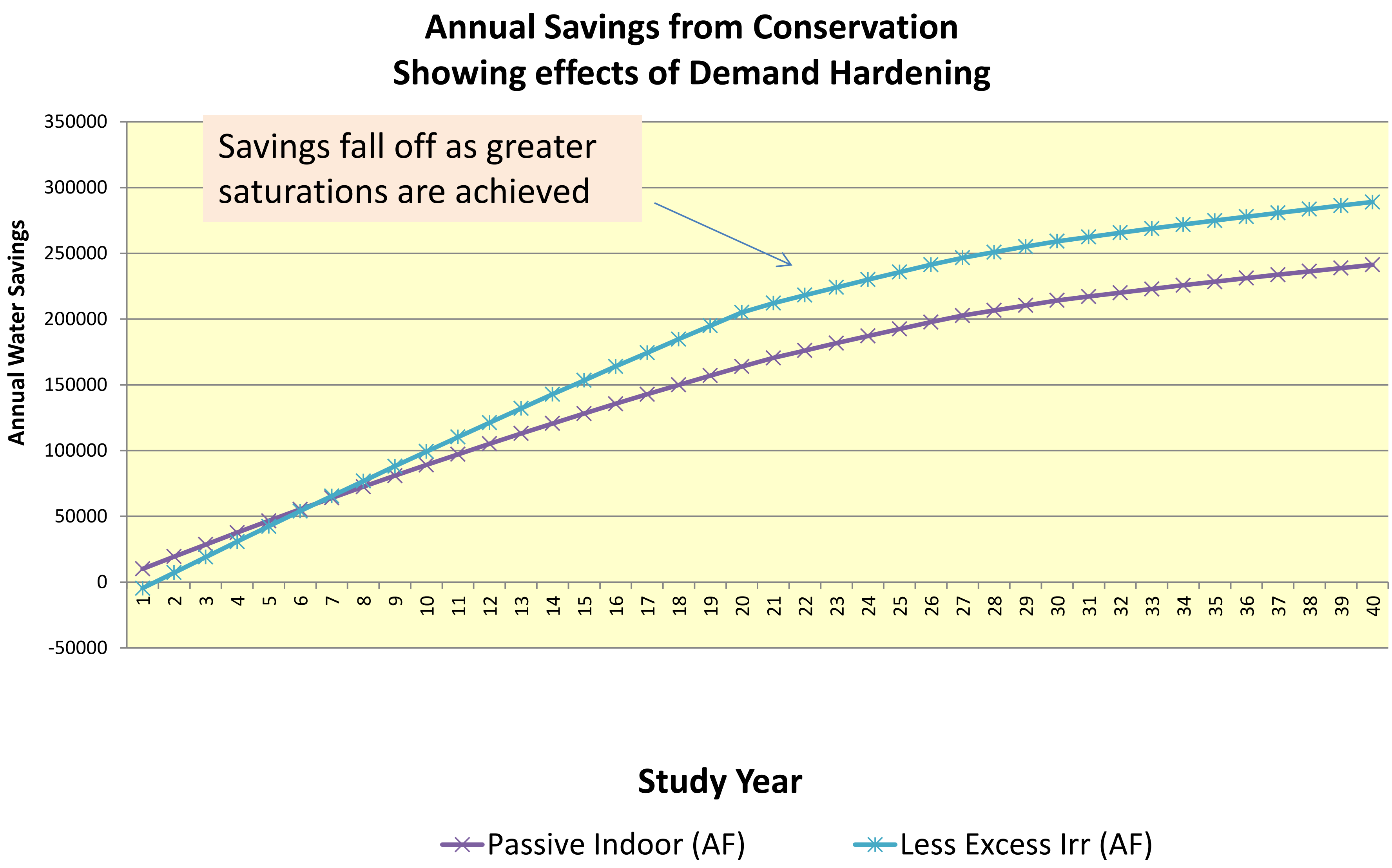
This meets the criteria of achieving savings through efficiency and elimination of wasteful irrigation.

Still leaves some conservation savings on the table, but avoids costs of new technology.

Remaining gap is 115,000 AF.



M&I Demands for South Platte Basin (Passive + Less Ecess Irrigation)
Annual Water Demands
1,204,000
1,004,000
804,000
604,000
404,000
204,000
4,000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Study Year
Projected Savings = 289,006 AF = ~25% from baseline and ~ 72% of gap
Extrap (AF)
Passive Indoor (AF)
Less Excess Irr (AF)
(AF)
(AF)



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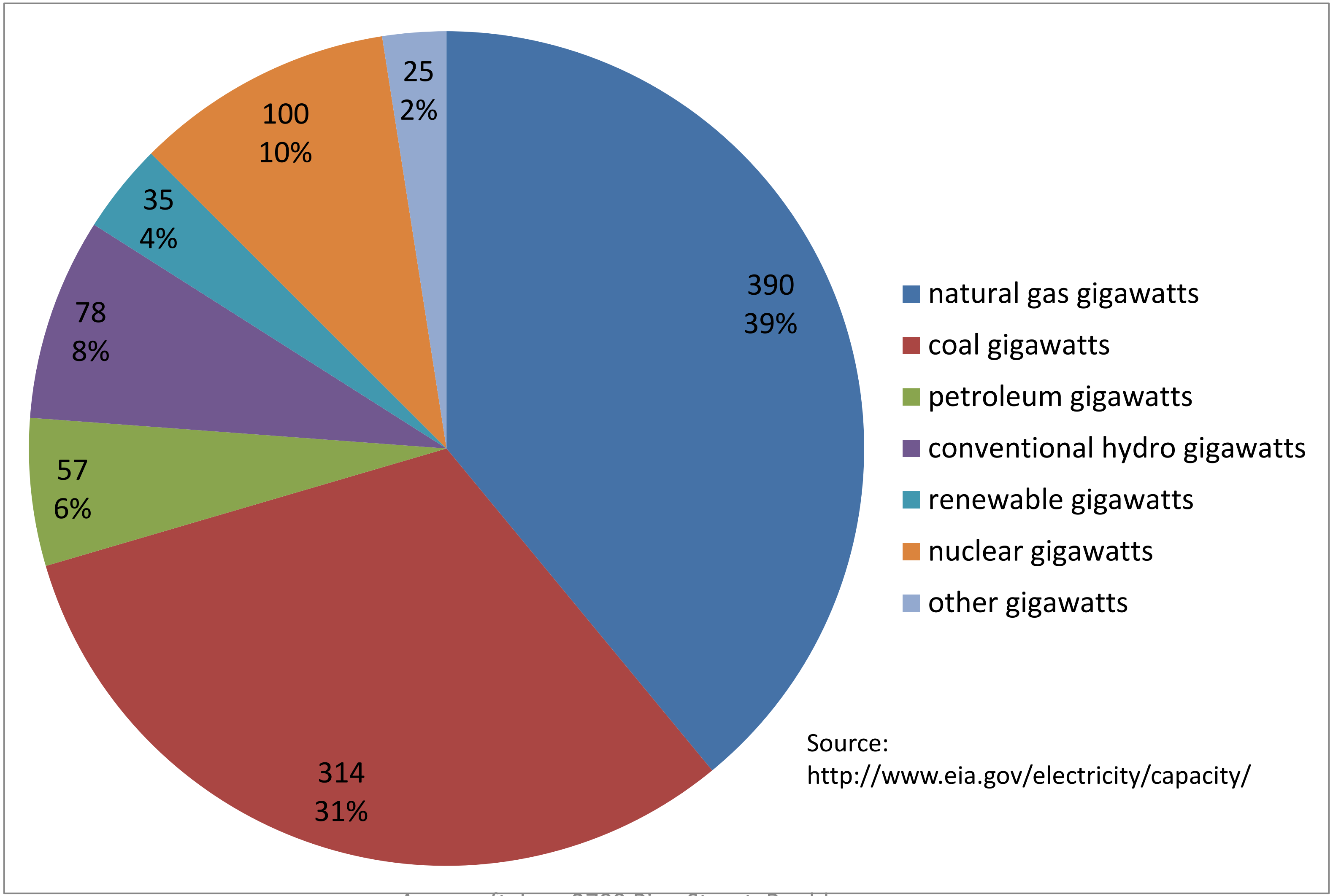
How to cover 114,000 AF gap?

- Additional trans basin imports (bad)
- Agricultural transfers and dry-ups (bad)
- Cutting demands into the quality of life areas (bad)
- Recycling of reusable return flows (good if practical)
- 114,000 AF is equivalent to 103 MGD of treated water delivery (24/7/365).
- Each option requires varying amounts of energy, with reuse/recycling needing the most.

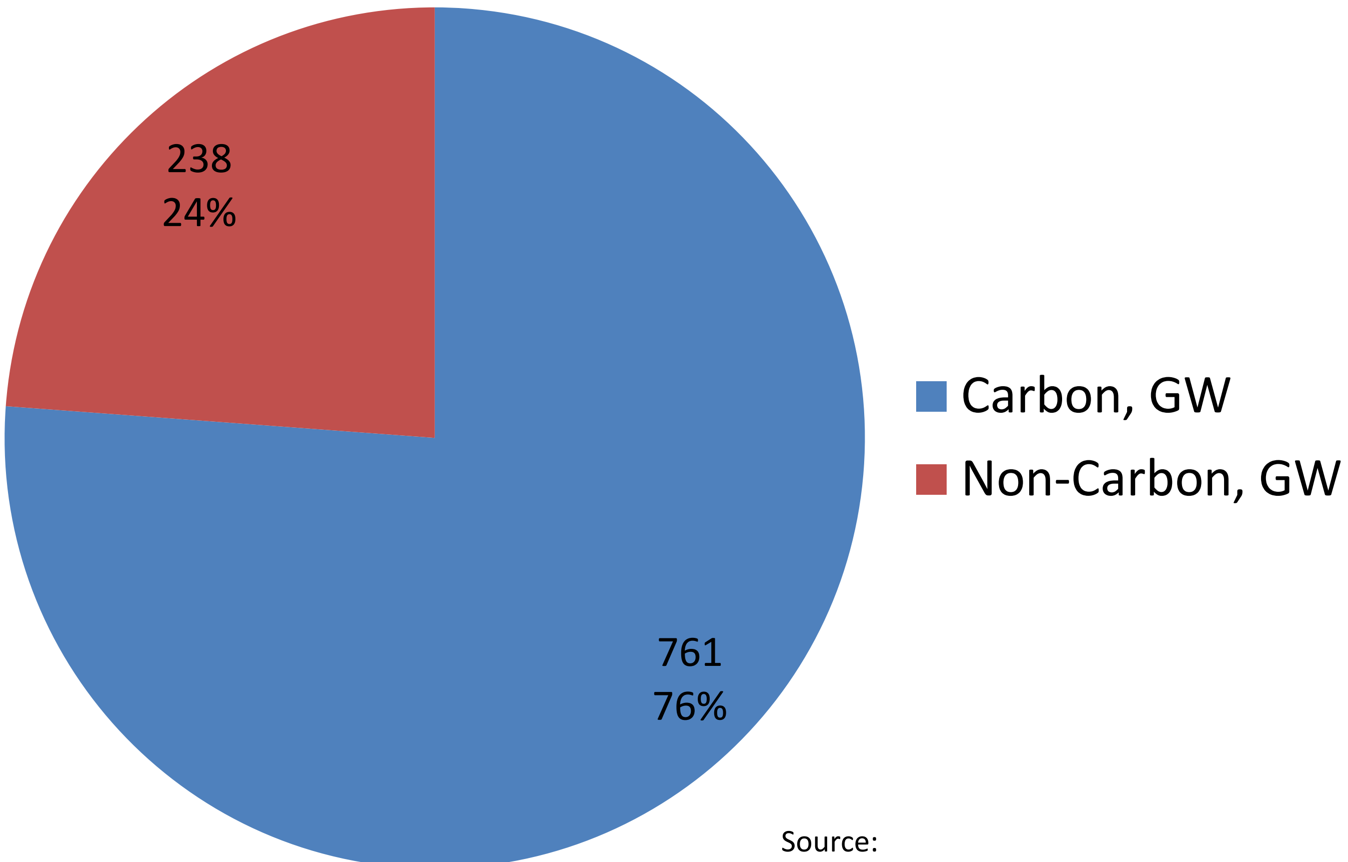
U.S. Energy Dilemma

- 1000 GW of power generating capacity
- Most energy is generated from coal, oil or natural gas (~800 1000 MW plants)
- ~10% of energy comes from older nuclear power plants
- Small percentage of energy comes from hydro, wind and solar
- It will be necessary to convert the existing fleet of fossil fuel burners to avoid destruction of oceans and atmosphere (global warming and ocean acidification)
- Old nuclear plants will be decommissioned over next 20 years
- Hydro sites are taken
- Wind and solar are intermittent; not good base load providers, but could supplement a base load

Power generation capacity by type



76% of Power comes from carbon based sources + 10% from nuclear that will be retiring over next 25 years.



Source: http://www.eia.gov/electricity/capacity/

The Water/Energy Nexus

- Every water plan has energy impacts
- Energy needed for
  - Raw water pumping
  - Treatment
  - Pumping for delivery
- When energy comes from fossil fuel water use links to carbon emissions
- Under this scenario, the more we rely on water the more we are contributing to a global problem of warming and ocean acidification

Windy Gap pumps on Colorado River

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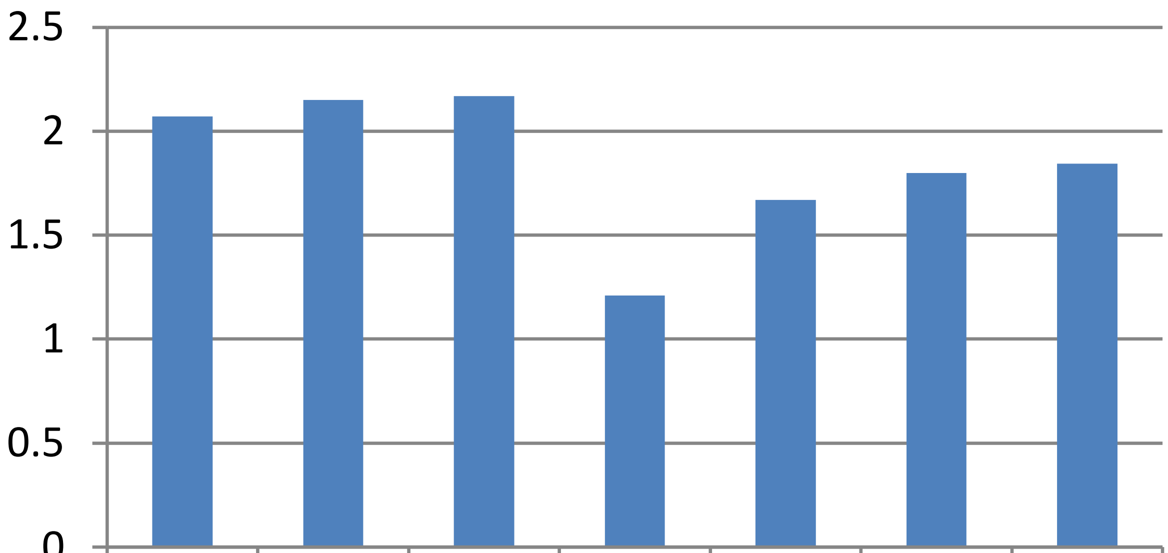
Pounds of CO_2 per kWh



	Bituminous	Sub-bituminous	Lignite	Natural gas	Distillate oil (No. 2)	Residual oil (No. 6)	Average
Pounds of CO2 per kWh	2.07	2.15	2.17	1.21	1.67	1.8	1.845

Source: www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

Pumping 103 MGD for 50 miles through a 6' Diameter pipe requires:

14 MW of power

123,000,000 kWH/year

3.33 kWH/Kgal

Release of 115,000 Tons of CO_2/year

Water and Power in systems approach

Water

- Local
- Imports
- Non-potable

Power (E+T)

- Base Supply
- Intermittent

Recycle

- Wastewater
- Thermal Distillation
- R.O.

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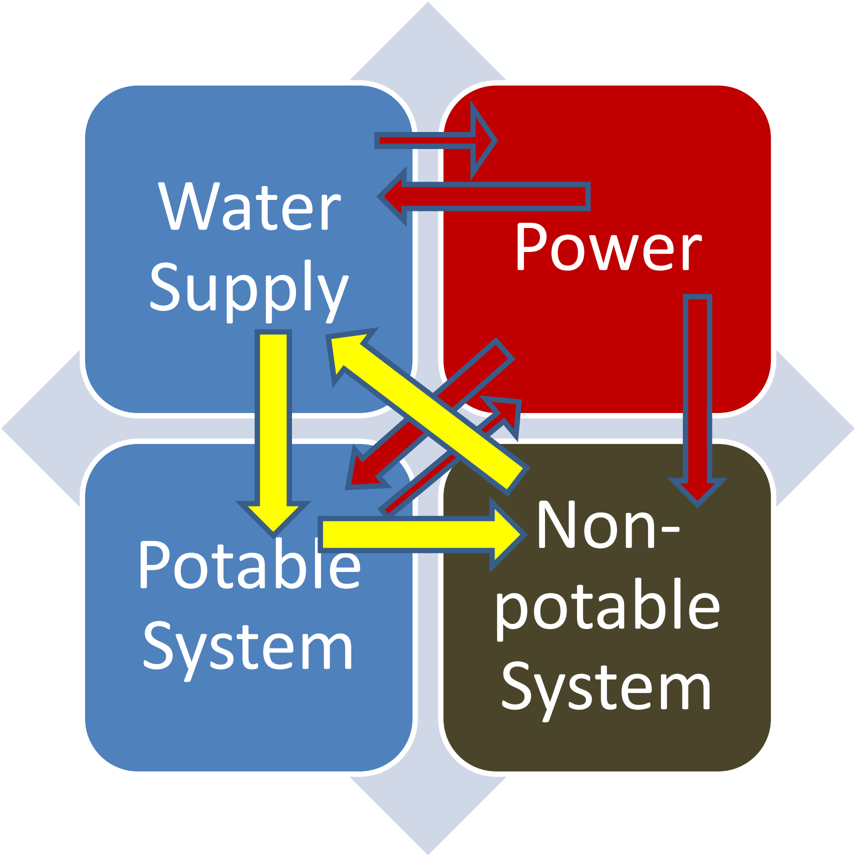
The real water/energy nexus is the use of energy to collect, treat, recycle, and deliver water for all municipal uses.



The Water Energy Nexus

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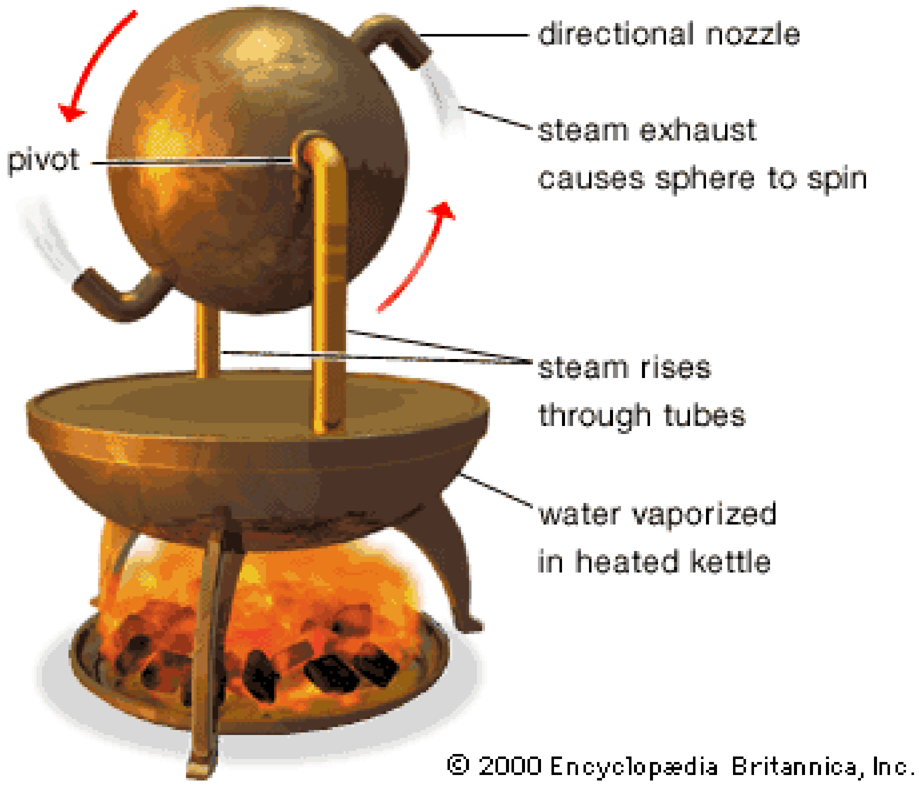
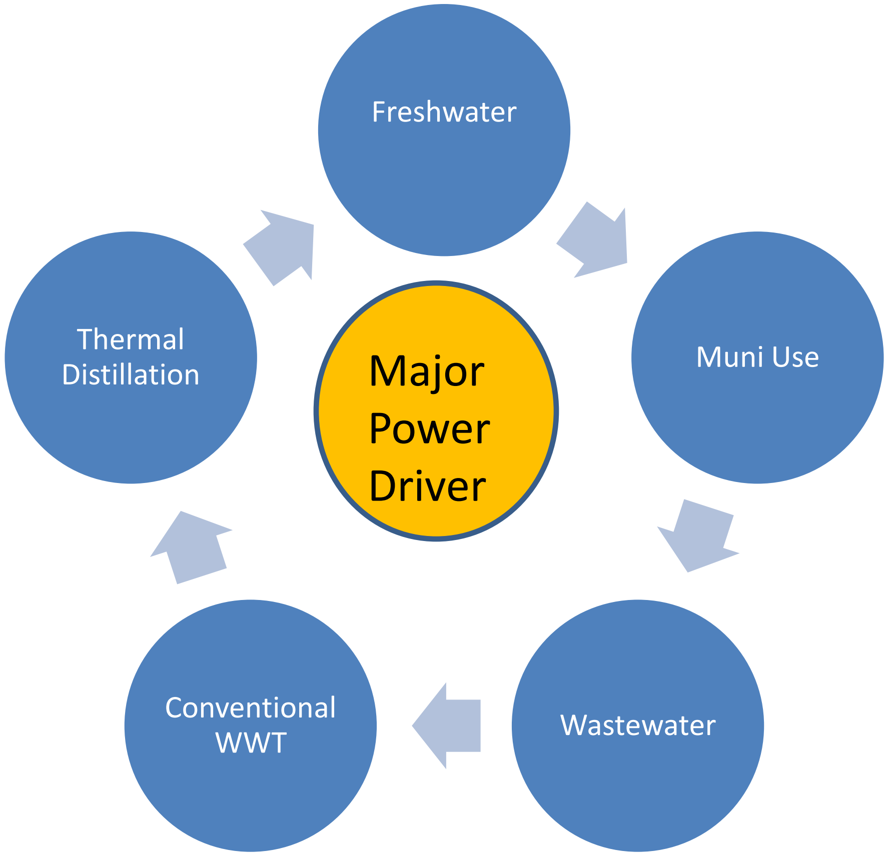
Roman Steam Toy; not Engine



If this had been connected to a pump we all might be speaking Latin

Having power allows us to use water in a closed loop



Requirements for a Major Power Driver

1. Provides large quantities of both electrical and thermal power 24/7/365
2. Economic (cheaper than coal)
3. Abundant
4. Non-carbon emitting
5. Safe and clean
6. Scalable and responsive

Only Advanced Nuclear Satisfies all Categories

	1	2	3	4	5	6
	24/7/365	$<Coal	Abundant	No CO2	Safe & Clean	Scalable
Coal	Yes	Yes	Yes	NO!	NO!	Yes
Petroleum	Yes	No	No	No	No	Yes
Gas	Yes	No	No	No	No	Yes
Hydro	Yes	Yes	No	Yes	Yes	No
Renewables	No	No	??	Yes	Yes	??
Advanced Nuclear	Yes	Yes	Yes	Yes	Yes	Yes

What is Advanced Nuclear?

- Gen IV Designs
- Operate at atmospheric pressure
- Do not use water for cooling
- Some Dissolve fuel in molten salt (MSR)
  - 400 deg F melting point; 1400 deg F boiling point
- Operate at high temperatures (600+ Deg F)
- Consume 99.5% of fuel (vs < 1% for old reactors)
  - Much less high level waste
- Can generate enough heat for electricity and thermal distillation (using waste heat from turbines)

Fuels for MSR's

Burners (Thousands of years of supply)

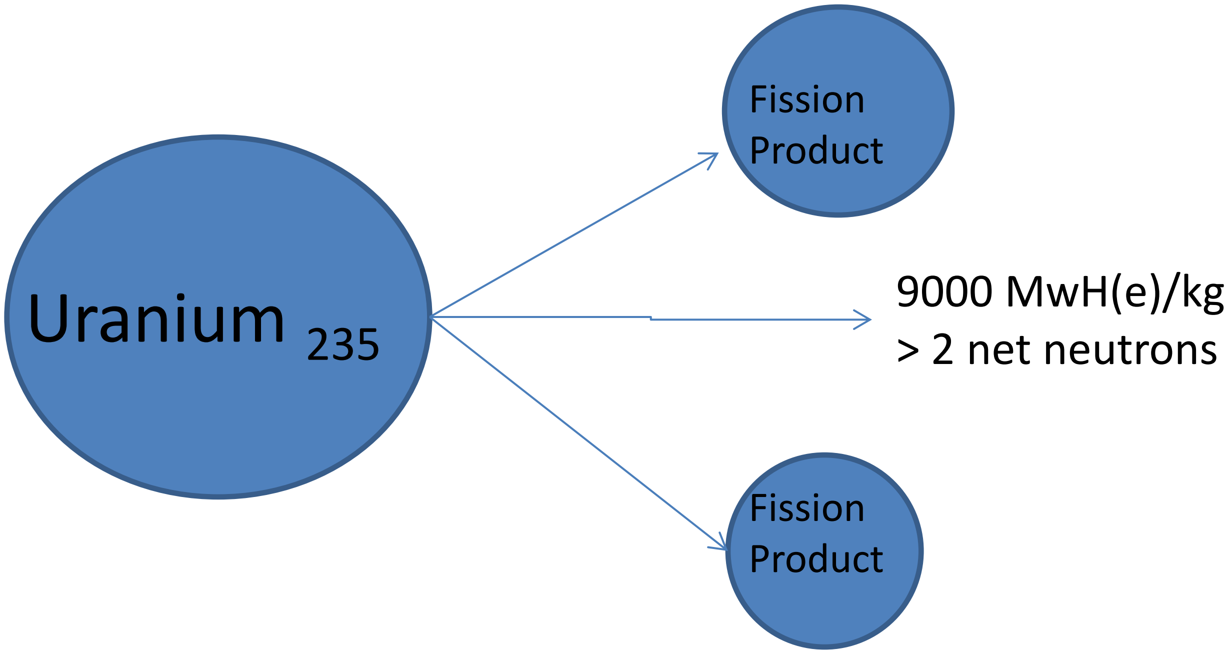
- Uranium 235 (from enrichment)
- Uranium 233 (from Thorium)
- Pultonium 239 (from Uranium 238)

Breeders (Millions of years of supply)

- Thorium to Uranium 233
- Uranium to Plutonium 239

Uranium Burner

(Uranium235 derived from mining & enrichment, but a good intermediate choice, while breeders are developed)



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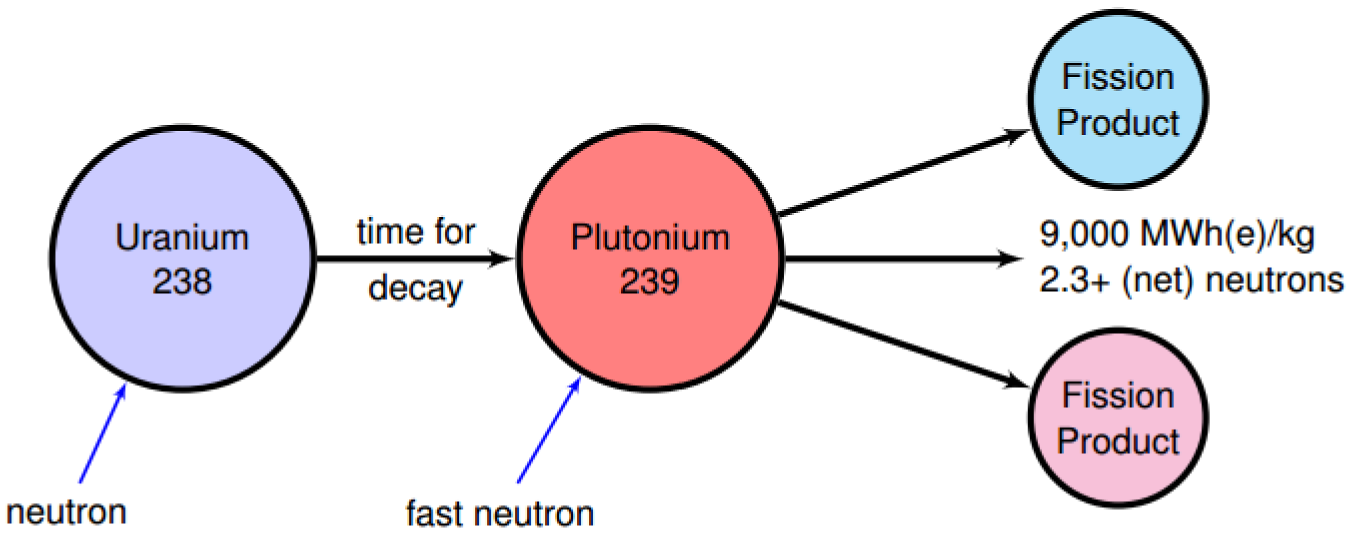
Uranium/Plutonium Fast Breeder

(difficult and uses a lot of plutonium)



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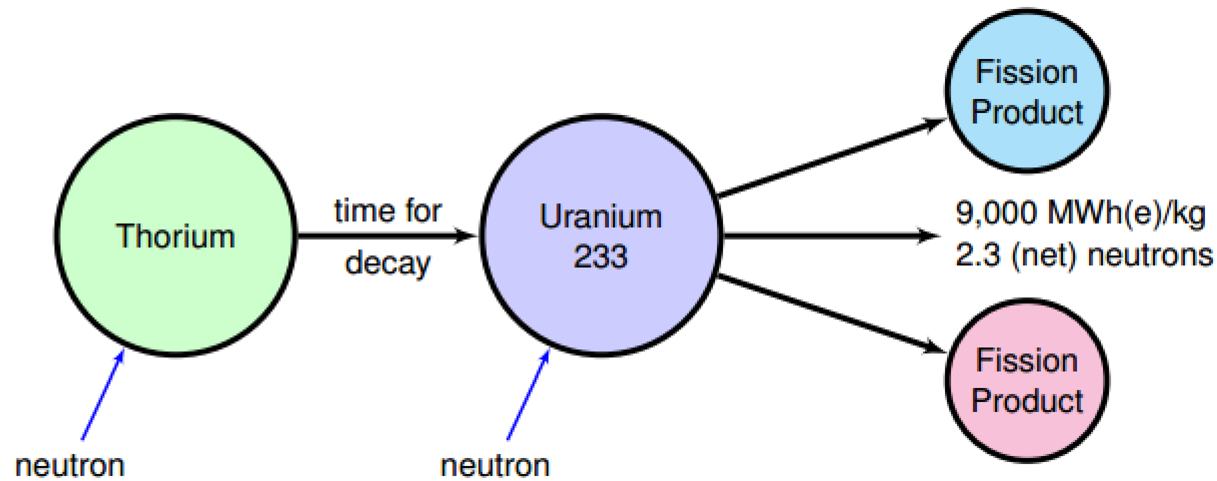
Thorium/Uranium233 Breeder (the ultimate goal)



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U.S. Energy Consumption

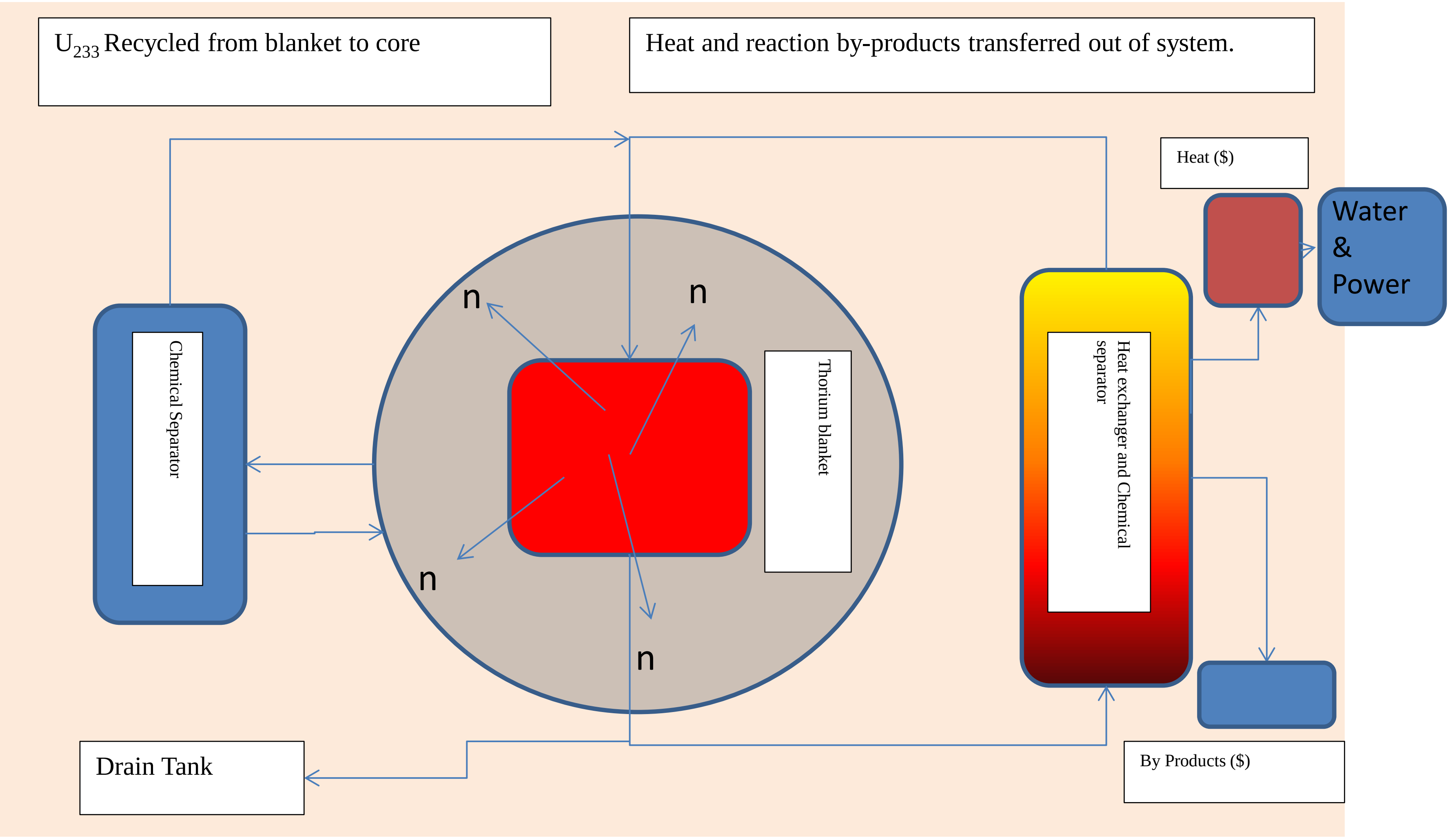
96 Quadrillion (10^{15}) BTU for all types (9.6×10^{16} BTU)

This is equal to 2.8×10^{13} KwH (@3412 btu/Kwh)

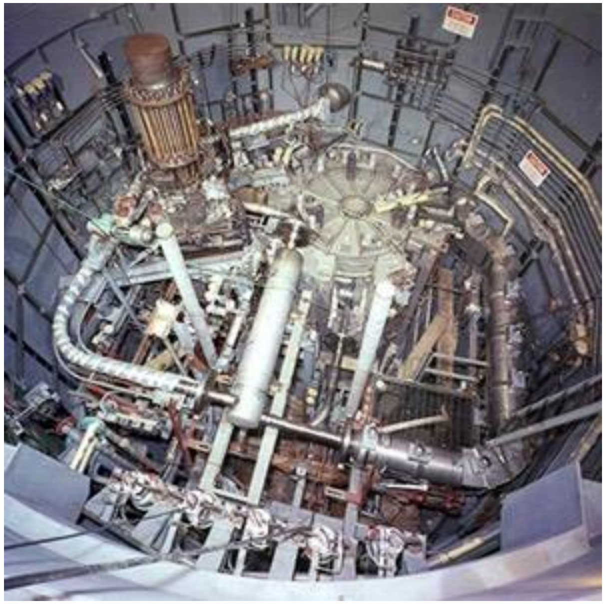
@9000 MWh/kg of fission fuel it would take 691 T/yr of fission fuel to replace all other energy sources (7 RR Cars/year). One large coal plant will use 14,000 tons of coal per day, or 140 RR cars per day!) http://www.tva.gov/power/coalart.htm

If MSR's used this would generate 3.4 Tons of high level waste/yr. Most of which could be recycled for fuel.

Thorium Breeder Reactor: the million energy year supply



Molten Salt Demo Reactor ORNL (~1970)



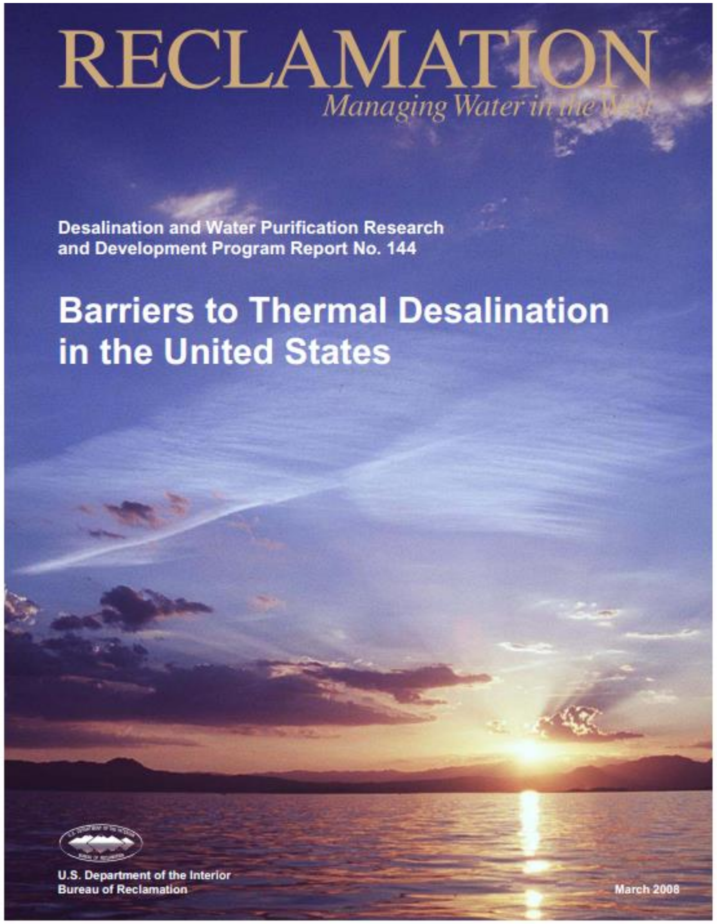
- Built to demonstrate feasibility of Thorium fueled molten salt reactors.
- Operated for five years
- Reaction followed the load: when load dropped reaction slowed down
- Required no active cooling on shut down.
- Cancelled in favor of plutonium breeder in mid 1970's

Comparison of MSR to Pressurized Water Reactors

Molten Salt Thorium Reactor	Pressurized Water Reactor
1 Atmosphere	30+ Atmospheres
Consumes 99.5% of fuel	Consumes <1% of fuel
Walk away safe. Does not need active cooling in emergency shut down	Requires weeks/months of cooling to control decay heat
Continuous operation	Must be shut down every 18-24 months for refueling
Produces very little high level waste	Produces large amounts of high level waste (plutonium) left in spent fuel rods.

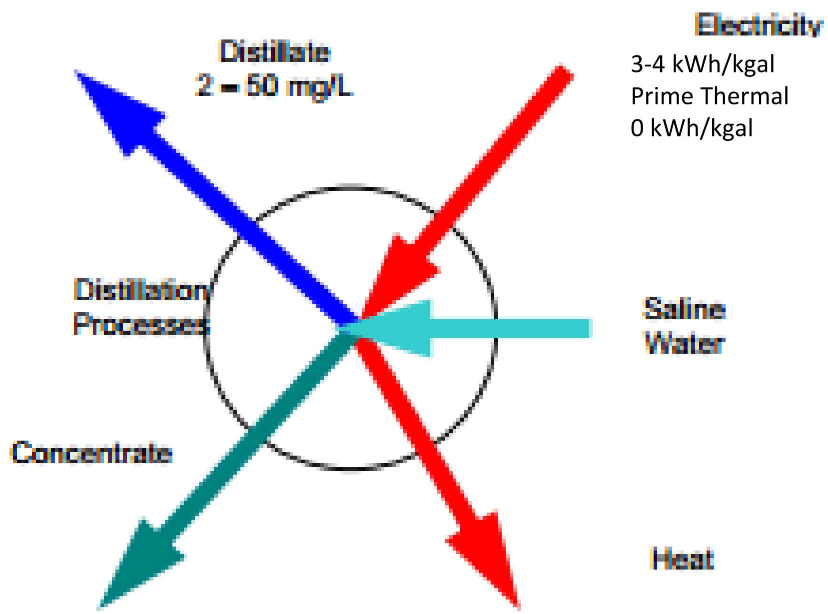
Thermal Desalination

- Better than RO when using waste heat from power plants.
- Produces better quality product water
- Can be linked with MSR's to produce power and water



Source: Tonner, John. "Barriers to Thermal Desalination in the U.S. ". U.S. Bureau of Reclamation. www.usbr.gov/pmts/water/publications/reports.html

Waste Heat Thermal Distillation



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Thermal Distillers

"The lure of cogeneration is quite simply to try to use the heat from burning fuel for two purposes: first to turn turbines to make electricity, secondly to condense in a desalination plant to make water."

Simply boiling water to make steam takes ~2400 kWh/kgal . This would never be practical without large and reliable energy supply.

Modern distiller designs are capable of producing water at far less than the theoretical value.

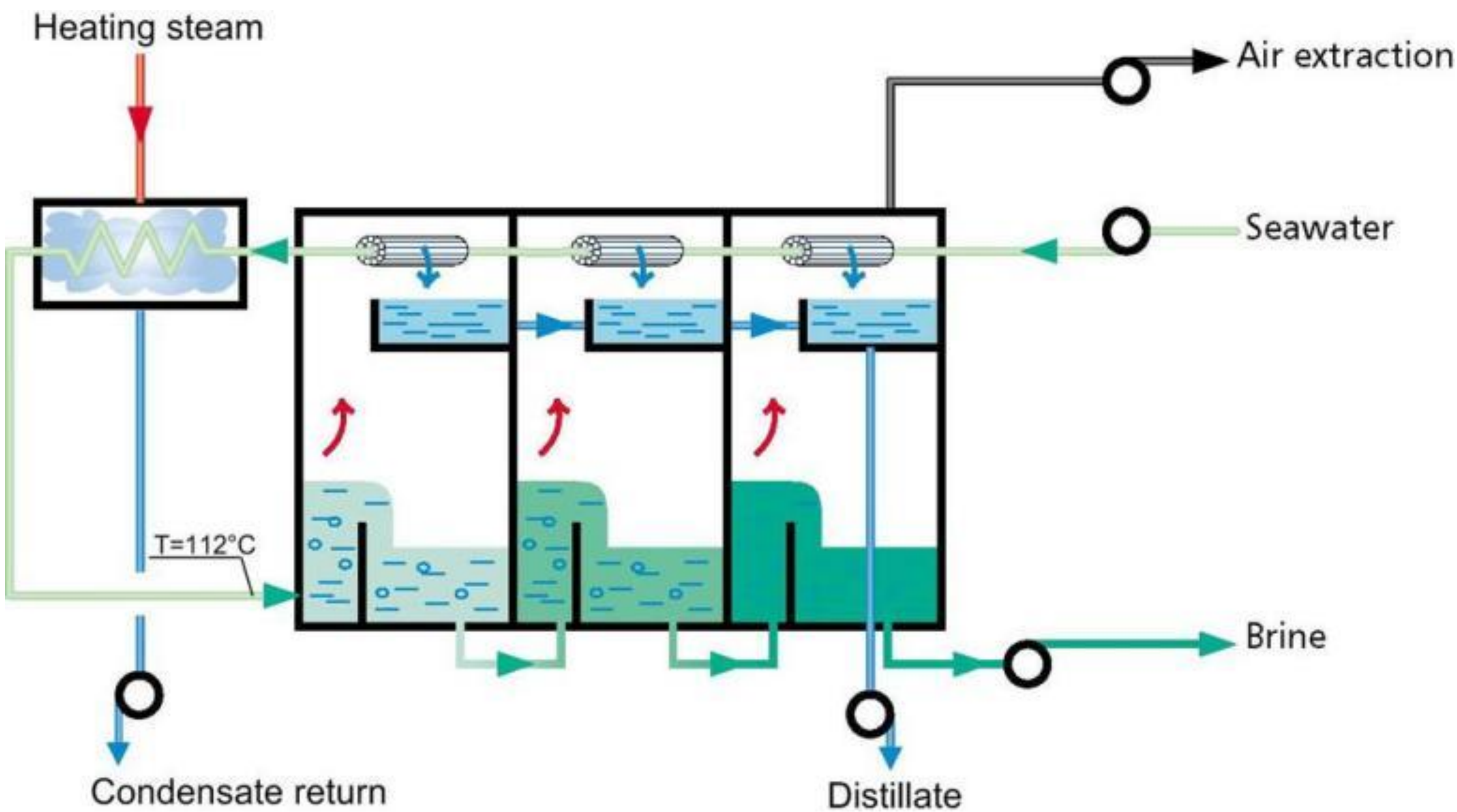
Output rated on MGD of product water/MW of installed thermal capacity of plant.

Waste Heat Recovery is the Key

- Electrical power production systems have an efficiency ranging from 35 to 50%. This poor efficiency rate is the result of much heat - between half and two-third of the total heat generated - being rejected in the atmosphere in the form of low grade heat. Since thermal desalination systems can be driven by low grade heat, they can recover and give value to this rejected heat by producing fresh water downstream of the power generation system. The overall energy cycle is optimized.

Source http://www.sidem-desalination.com/en/Process/Cogeneration/

Multi Stage Flash Distillation



Source: http://www.sidem-desalination.com/en/Process/MSF/

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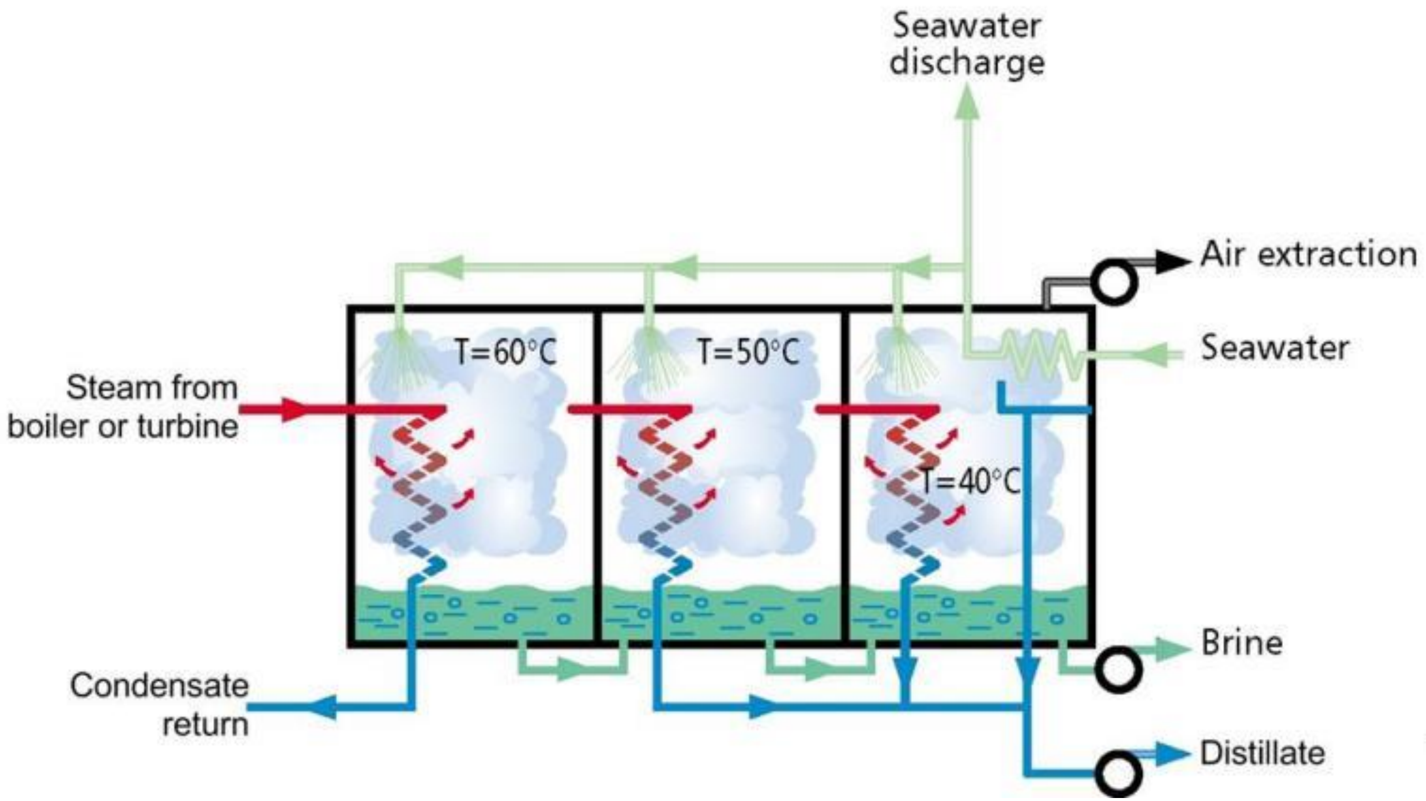
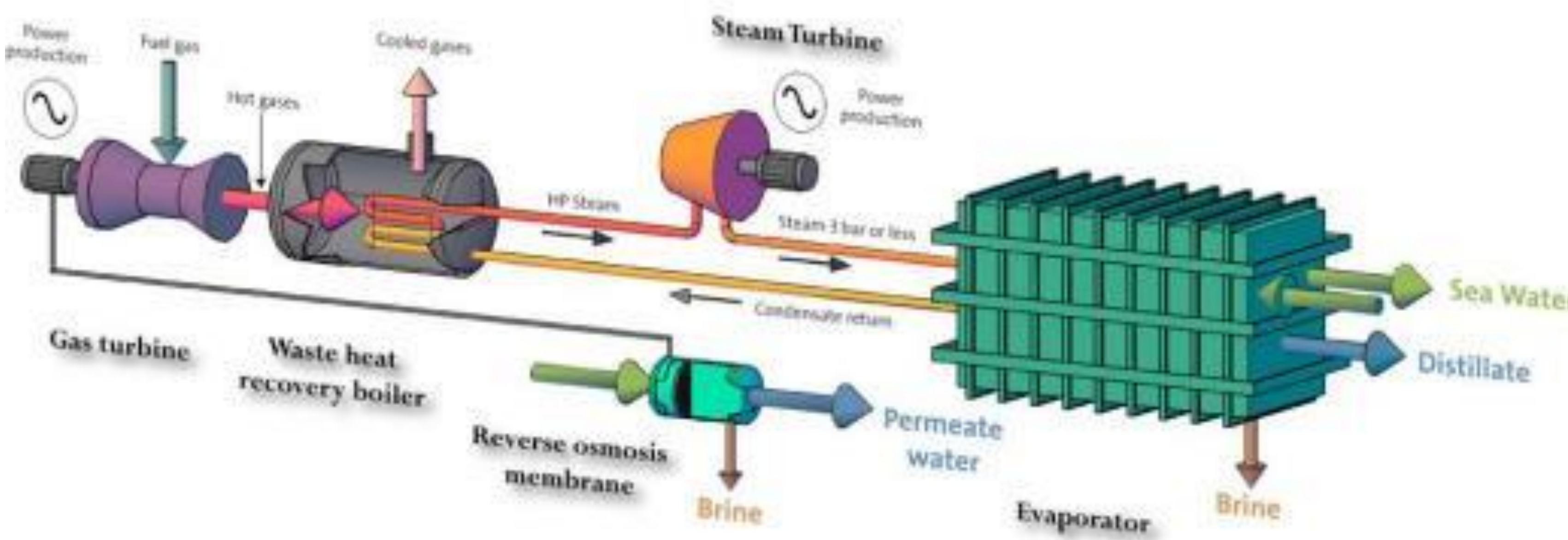
Multiple Effect Distillation

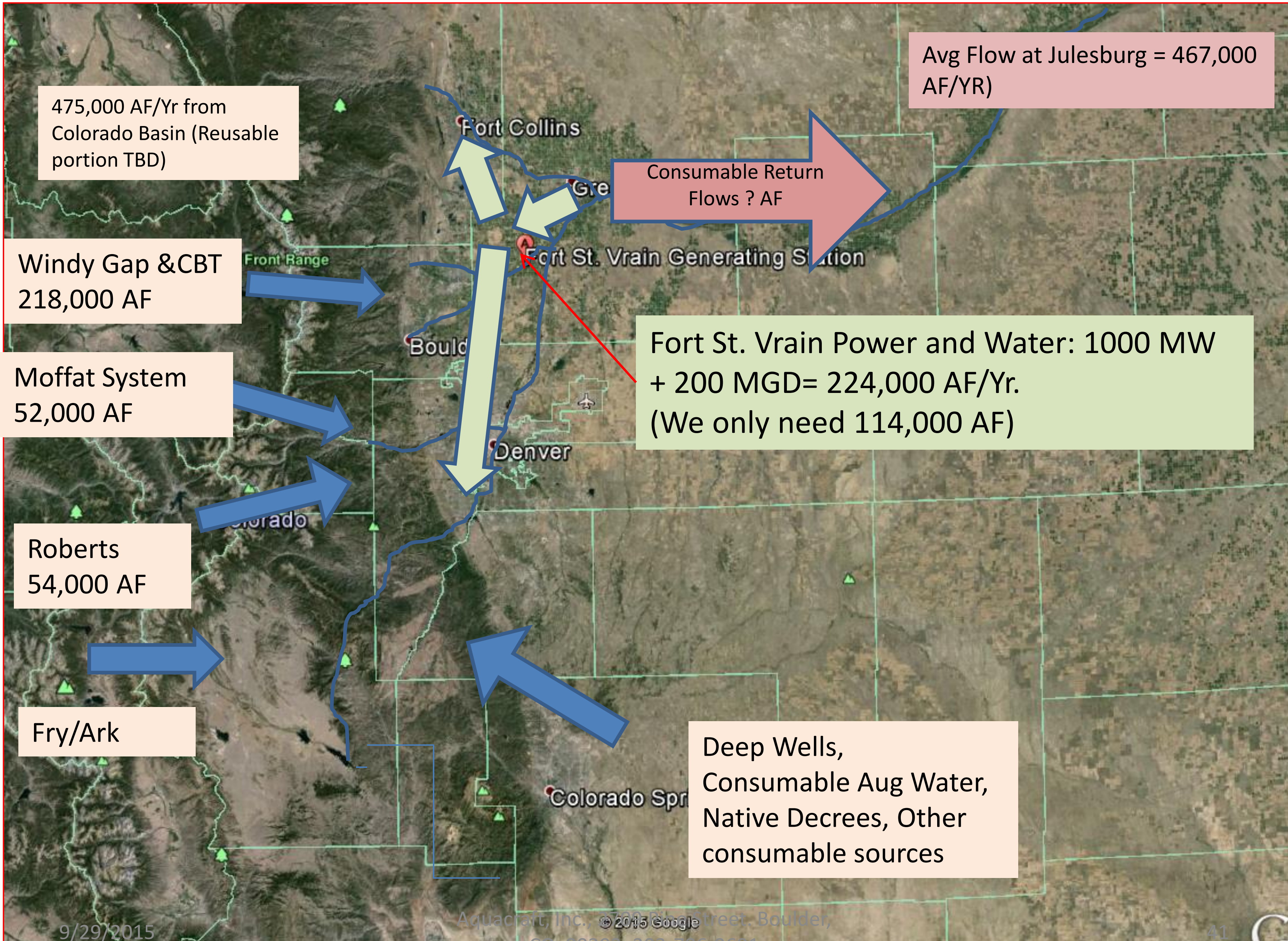


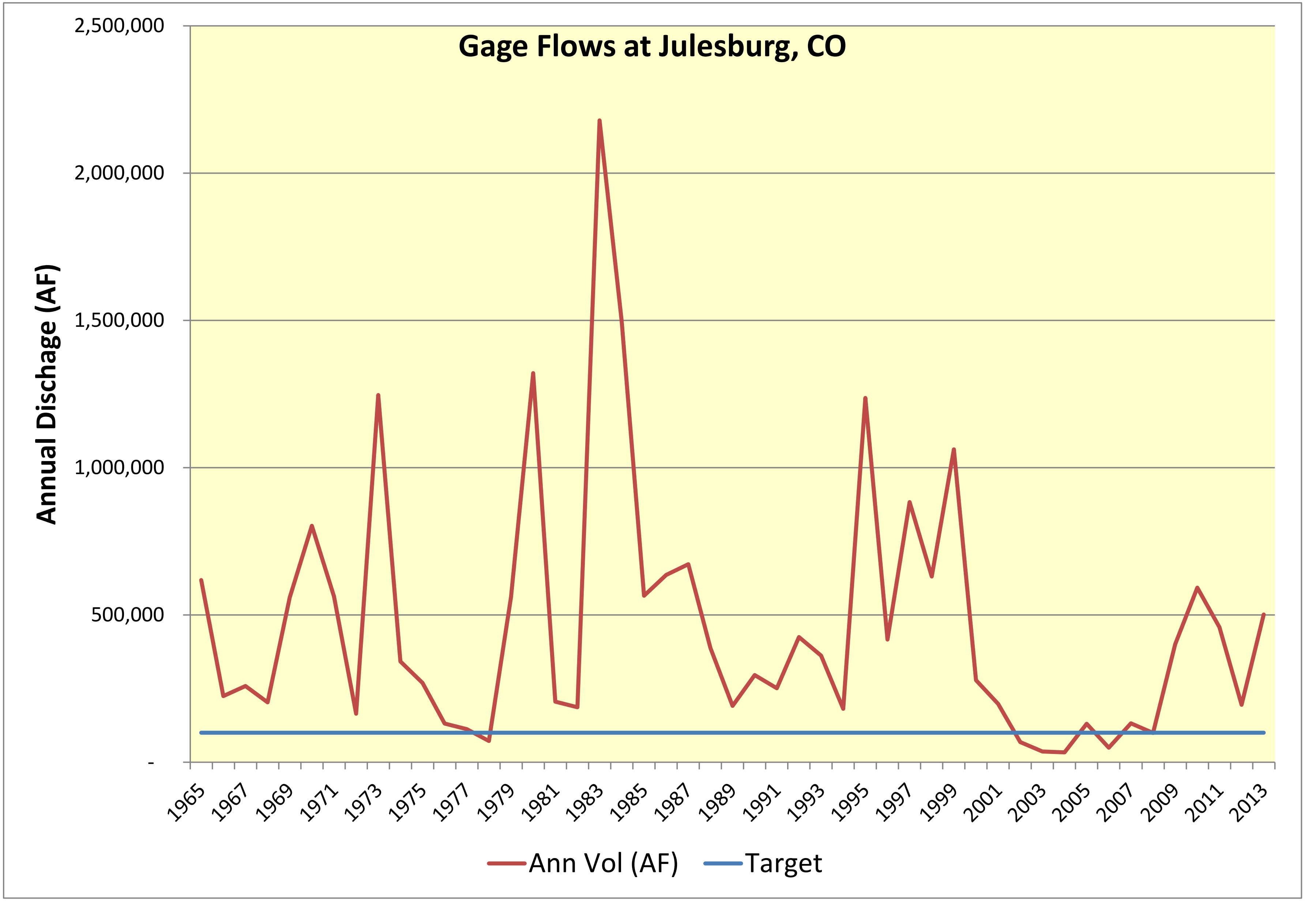
Gas Turbine/Distillation Cogeneration



Water to Power Ratios

Type of Distiller	Electricity (MW/MGD)	Thermal Energy (MW/MGD)	Total Energy (MW/MGD)
Back pressure steam(MSF)	0.2	4.17	4.19
Gas Turbine Brayton Cycle(MSF)	0.2	6.67	6.87
Back Pressure Steam (MED)	0.2	2.92	3.12
Gas Turbine Heat Recovery	0.2	5.0	5.2
AVG Power to Water ratio	0.2	4.7	4.9
Water to Power Ratio			0.1-0.2MGD/MW


475,000 AF/Yr from Colorado Basin (Reusable portion TBD)
Avg Flow at Julesburg = 467,000 AF/YR)
Fort Collins
Consumable Return Flows ? AF
Front Range
Fort St. Vrain Generating Station
Windy Gap &CBT 218,000 AF
Fort St. Vrain Power and Water: 1000 MW + 200 MGD= 224,000 AF/Yr. (We only need 114,000 AF)
Moffat System 52,000 AF
Denver
Roberts 54,000 AF
Fry/Ark
Deep Wells, Consumable Aug Water, Native Decrees, Other consumable sources
Colorado Spr
© 2015 Google


Gage Flows at Julesburg, CO
Annual Dischage (AF)
2,500,000
2,000,000
1,500,000
1,000,000
500,000
-
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Ann Vol (AF)
Target

Fort St. Vrain Generating Station (1000 MW gas turbines. Convert to MSR when possible)

Thermal Distillation Plan

- 14 MW for pumping return flows up to Chatfield area
- 20 MW for process use in distillation (34 MW=3% of total capacity of plant)
- Reliance on advanced nuclear power to replace natural gas burners is essential
- Thermal Distillation to use waste heat from 1000 MW_e Power Station
- Generation of ~114,000 AF of recycle water each year.
- Will use 280 GWh of electric energy (3% of Station output of 8,760 GWh)
- @ $.09/kWh annual costs =$1.36/kgal
- No CO_2, Minimizes reliance on imports from West Slope, Optimizes Water/Energy

Summary

Conservation can bridge ~ 70% of the raw water gap in S.P. Basin

This leaves 114,000 AF remaining gap

Rather than more West Slope diversion, or Ag dry-ups a combined water and power plant at Platteville (Fort St. Vrain) could supply 1000 MW of electricity and up to 200 mgd (224,000 AF/Yr) of distilled water

This would bridge the gap with a local and environmentally friendly water supply.

The technology for doing this is either available or under development; it could be done if we choose.

An abundant supply of water and power must rely on re-discovery of nuclear energy using Gen IV design, like MSRs.

Bibliography 1

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  - Deaths by Kilowatt:
- https://www.youtube.com/watch?v=4E2GTg7W7Rc&index=2&list=PLKfir74hxWhPsAXSrCy--ORaxxbXdWnXK
  - Nuclear fuel, liquid vs solid:
- https://www.youtube.com/watch?v=2S9gCbEew5s&index=3&list=PLKfir74hxWhPsAXSrCy--ORaxxbXdWnXK
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- https://www.youtube.com/watch?v=4E2GTg7W7Rc&index=2&list=PLKfir74hxWhPsAXSrCy--ORaxxbXdWnXK
  - Nuclear fuel, liquid vs solid:
- https://www.youtube.com/watch?v=2S9gCbEew5s&index=3&list=PLKfir74hxWhPsAXSrCy--ORaxxbXdWnXK
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- https://www.youtube.com/watch?v=X9bUPFT6A6g&index=5&list=PLKfir74hxWhPsAXSrCy--ORaxxbXdWnXK
  - Atomic Fission
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