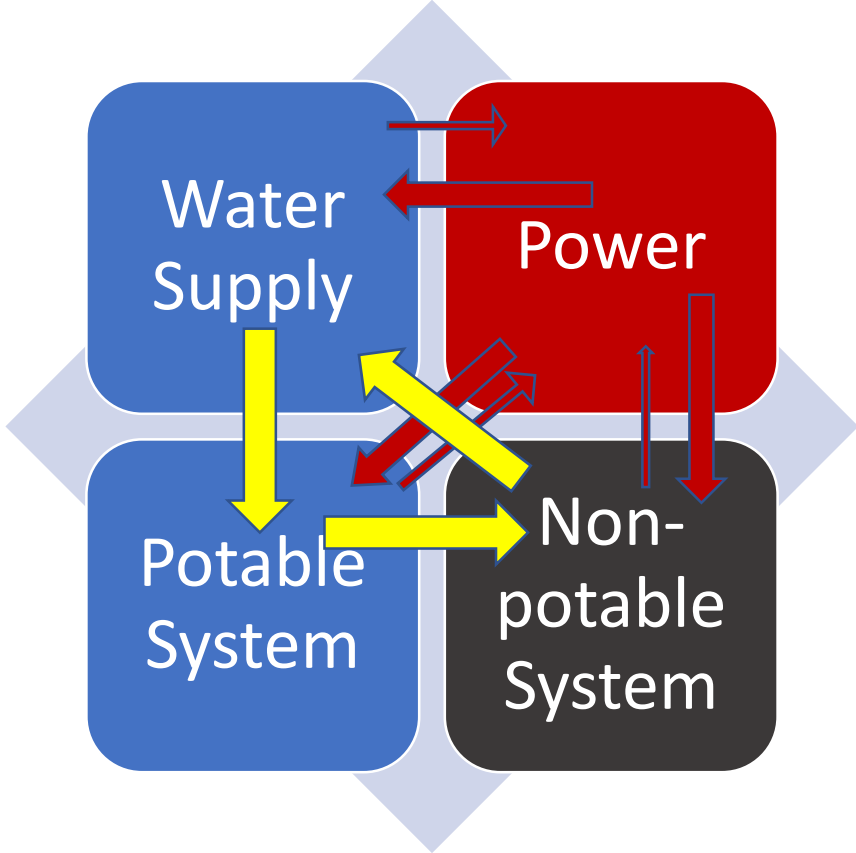


# This presentation premiered at WaterSmart Innovations

[watersmartinnovations.com](http://watersmartinnovations.com)



# The Molten Salt Reactor: A Water Smart Innovation



# U.S. Energy Dilemma

1000 GW of power generating capacity

Most energy is generated from coal, oil or natural gas (~800 1000 MW plants)

~20% of energy comes from nuclear power plants

Small percentage of energy comes from hydro, wind and solar

Strong desire to reduce dependence on carbon-based fuels

Old nuclear plants will be decommissioned over next 20 years

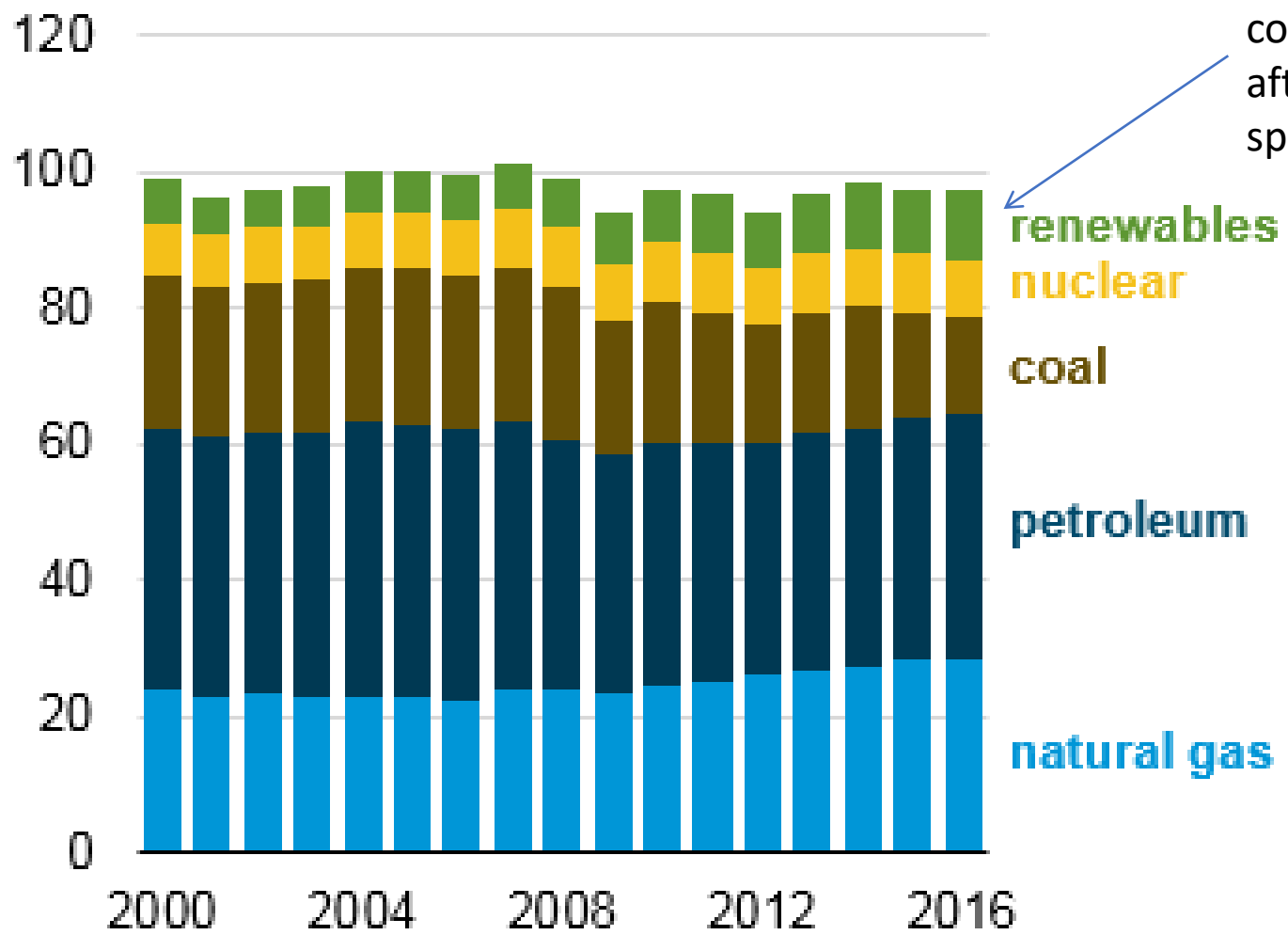
Hydro sites are taken

Wind and solar are intermittent; not good base load providers, but could supplement a base load

# President Carter's 1977 Speech on Energy: "Energy as The Moral Equivalent of War"



# United States total energy consumption (2000-2016) quadrillion British thermal units



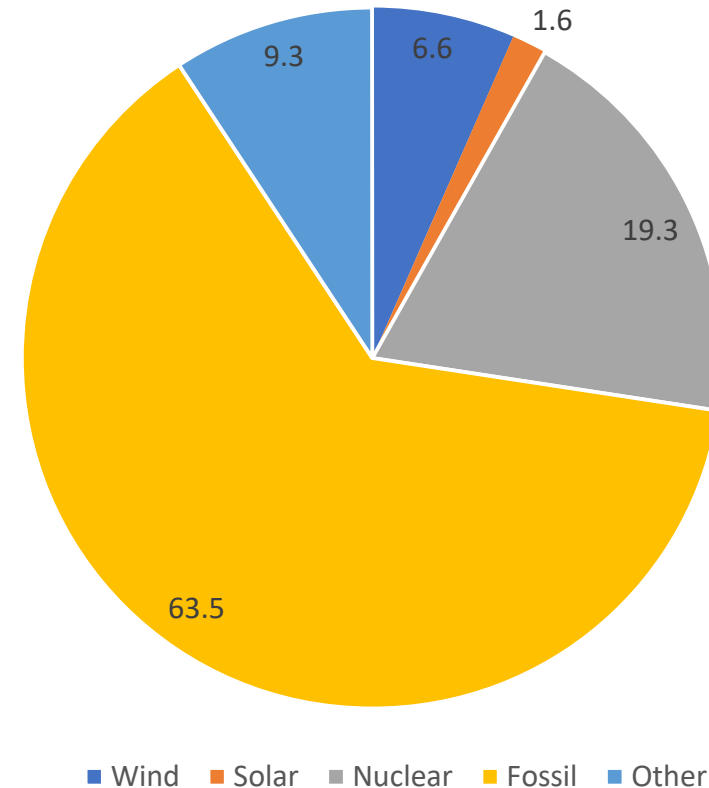
Renewables are still a minor contributor, nearly 40 years after President Carter's speech.

Source: U.S. Energy Information Administration, *Monthly Energy Review*

# Renewables still account for less than 10% of total electricity supply in 2018

- Total electrical use was 4.2 trillion kwh
- Despite federal, state and local subsidies renewable energy provided just 8.2% of electrical energy use in the United States in 2018.
- Fossil fuels were used to generate 63.5% of nations electricity
- Nuclear plants contributed 19.3% of electricity, despite lack of public support and old designs
- Many nuclear plants are nearing the end of their life spans
- How are we going to replace the fossil fuels and old nuclear sources?

Electrical Production 2018



Source US Energy Information Agency  
<https://www.eia.gov/tools/faqs/faq.php?id=427&t=3>

Water Production requires large amounts of on-demand energy.  
E.G. Pumping 100 MGD for 500 miles through a 6' Diameter pipe requires:

140 MW of power. (Enough to power a small city)

1.2 Billion kWh/year (0.03% of total 2018 electric demand)

3.33 kWh/Kgal

Release of 11.5 Million Tons of CO<sub>2</sub>/year

This is the energy demand of one proposed project for Denver

# • Rethinking Thorium

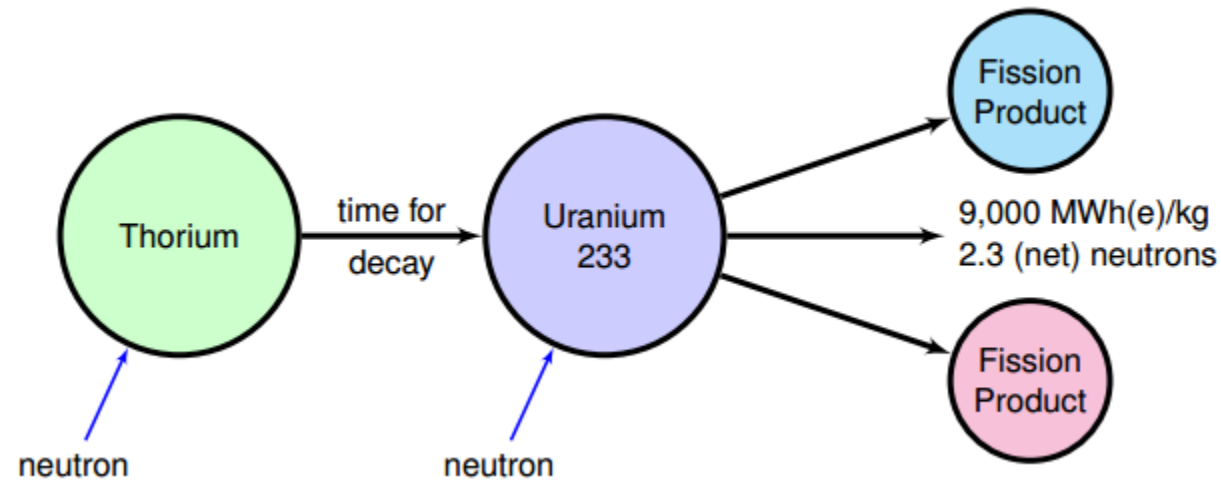
## What is Thorium?

- Considered a problem by regulators.
- No. 90 on the periodic table
- Atomic weight 233
- A fertile element...converts to fissionable U 233 when it absorbs a neutron
- All Thorium can do this
- X4 times more abundant than uranium
- Does not generate U235 or Pu239 (weapons materials)
- Does generate valuable medical isotope as fission by-products
- Classified as a weapons source material by NRC, so no one can possess it.
- Found in association with rare earth minerals; creates obstacles to rare earth production



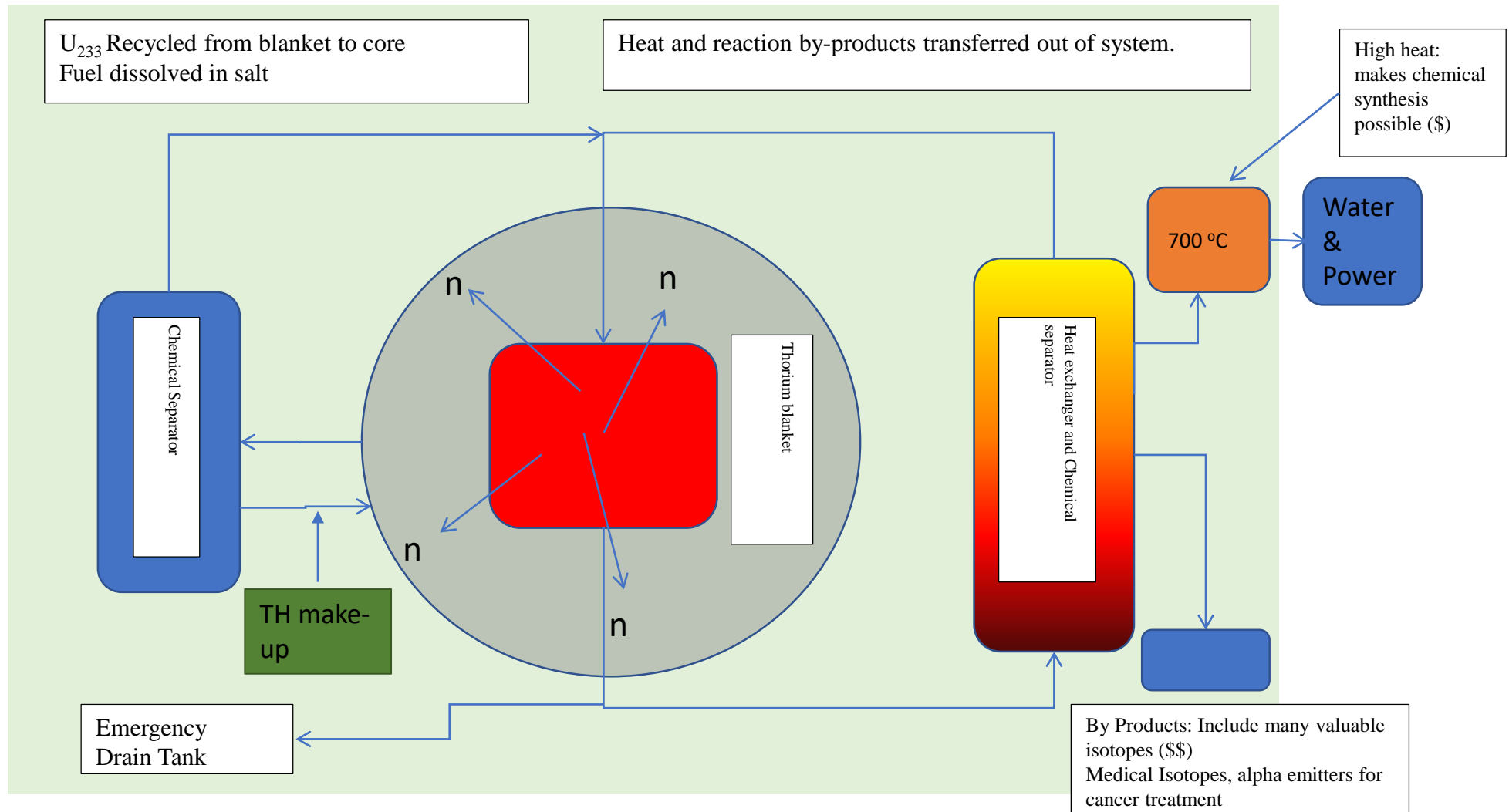


# Thorium/Uranium233 Breeder (energy/kg of fuel)



How much fuel to satisfy the US Electricity Demand from 2018?  
 $4.2 \times 10^{12}$  KWH/Yr  $\times$  1 KG/9  $\times 10^6$  KWH  $\times$  1 T/4,400 KG = 106 T of fuel  
This could be carried in 7 railroad cars  
A large coal plant uses 14,000 Tons of coal per day or 140 RR cars!

# Thorium Breeder Reactor: the thousand-year energy supply



# 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.)

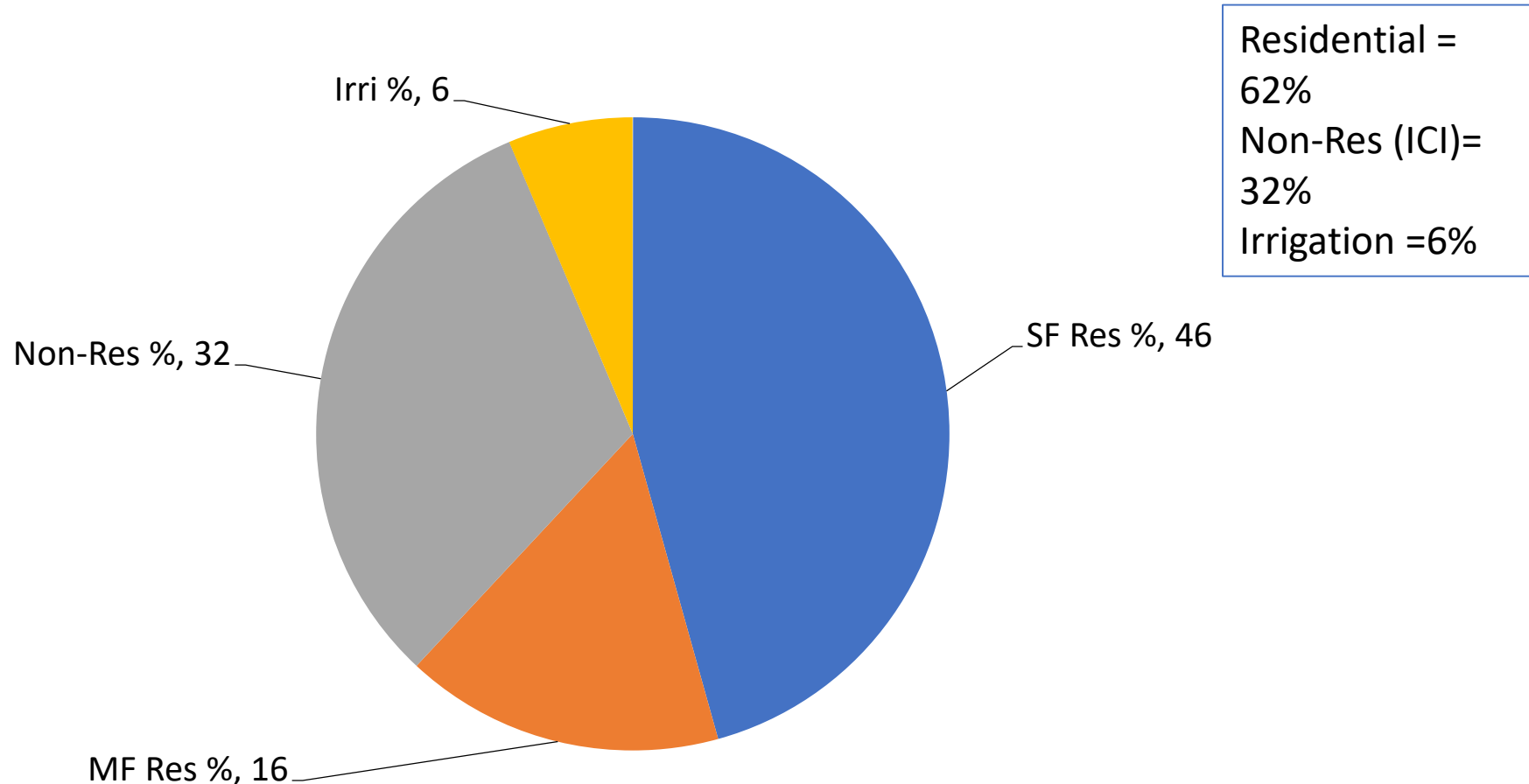
In areas west of the 100<sup>th</sup> meridian it takes ~ the same amount of water for landscapes/gardens.

Parks and open space irrigation adds 10% of residential

ICI requires 50% of residential demands.

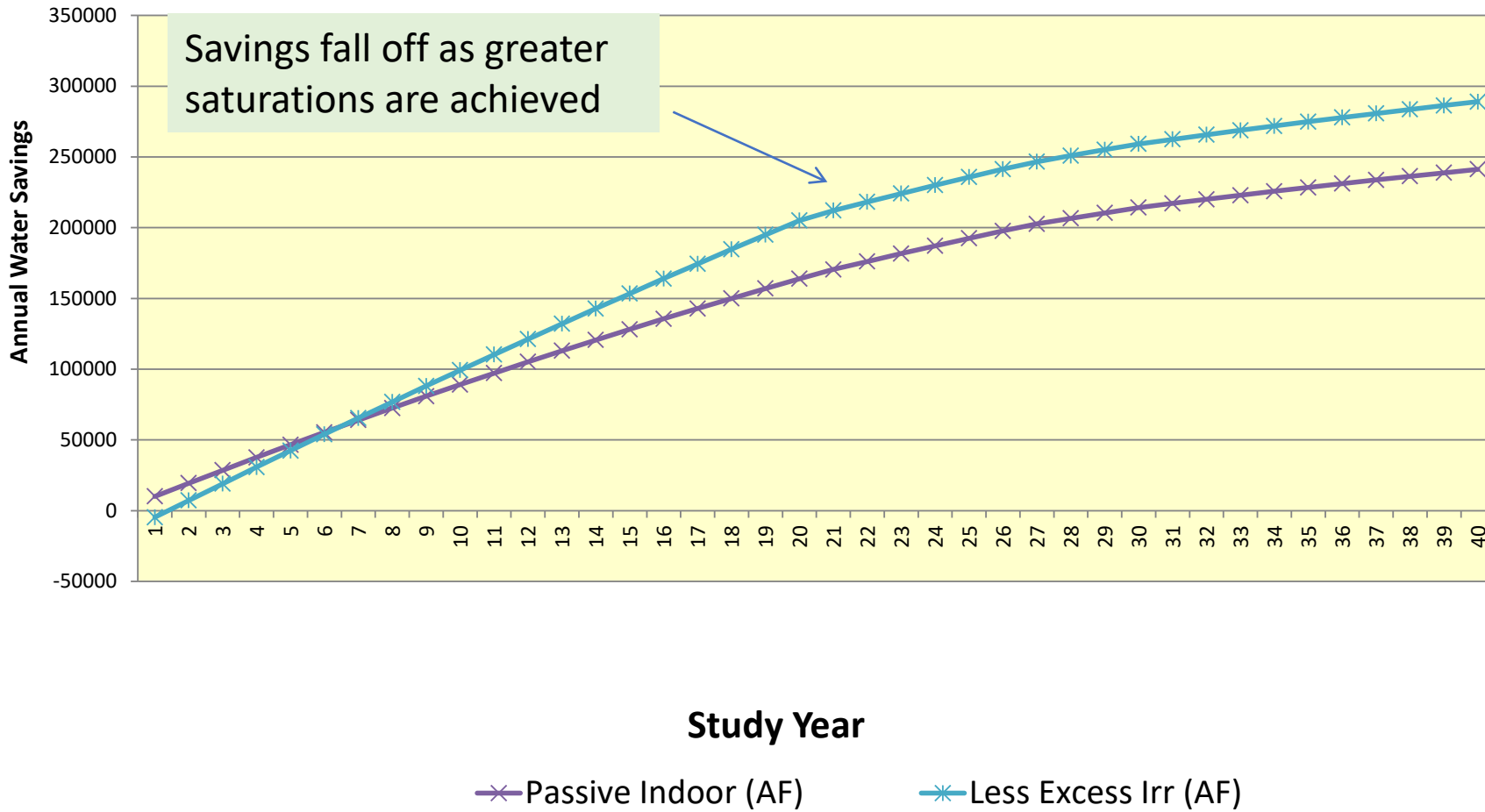
This sets a minimum amount of water required for a city with a good quality of life.

# Breakdown of 26 Municipal Systems



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.

## Annual Savings from Conservation Showing effects of Demand Hardening



## Thermal Distillation of water allows saline or contaminated supplies to be made available for use

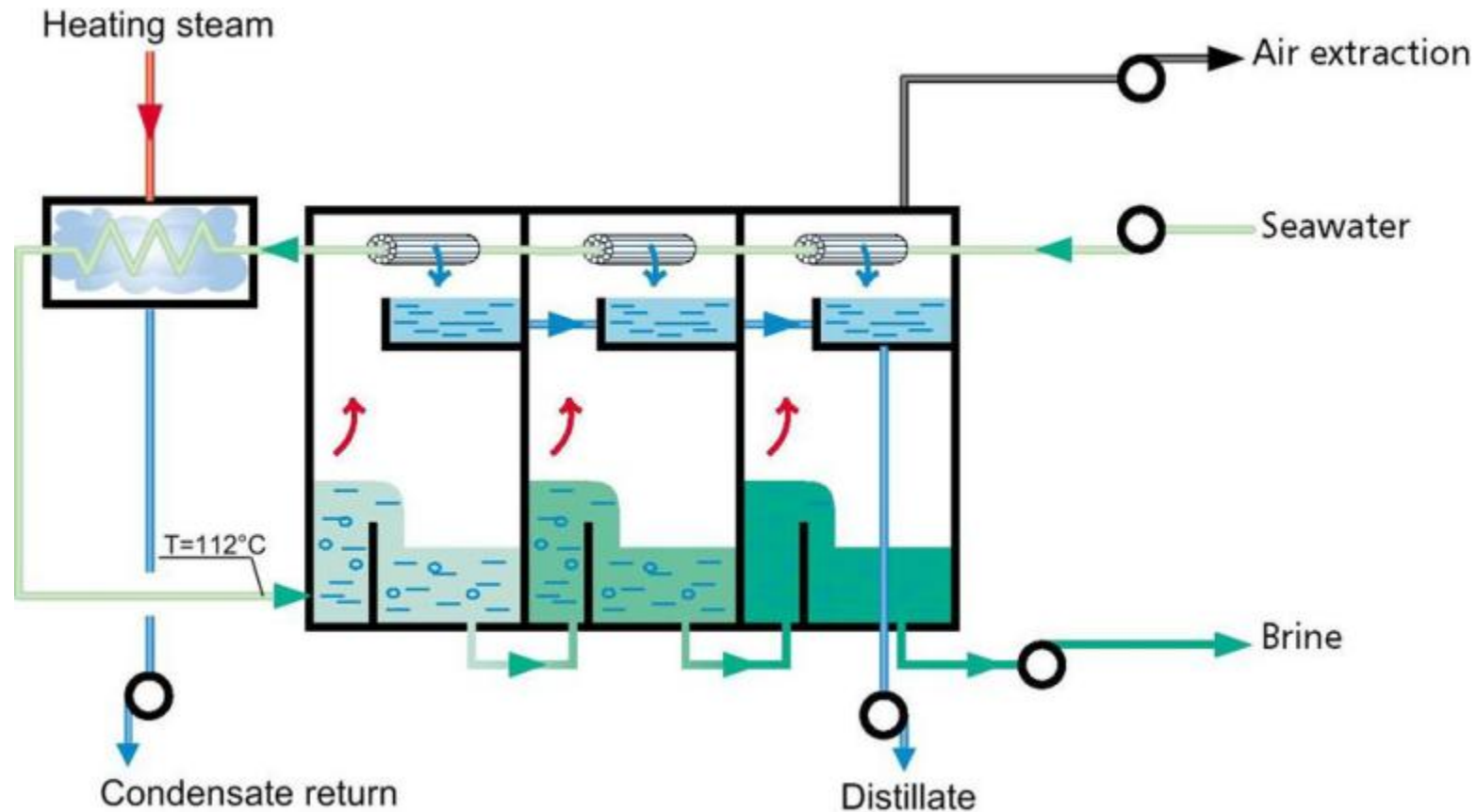
“The lure of cogeneration is quite simply to try to use the heat from burning fuel for two purposes: first to turn turbines to make electricity, secondly to condense in a desalination plant to make water.”

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.

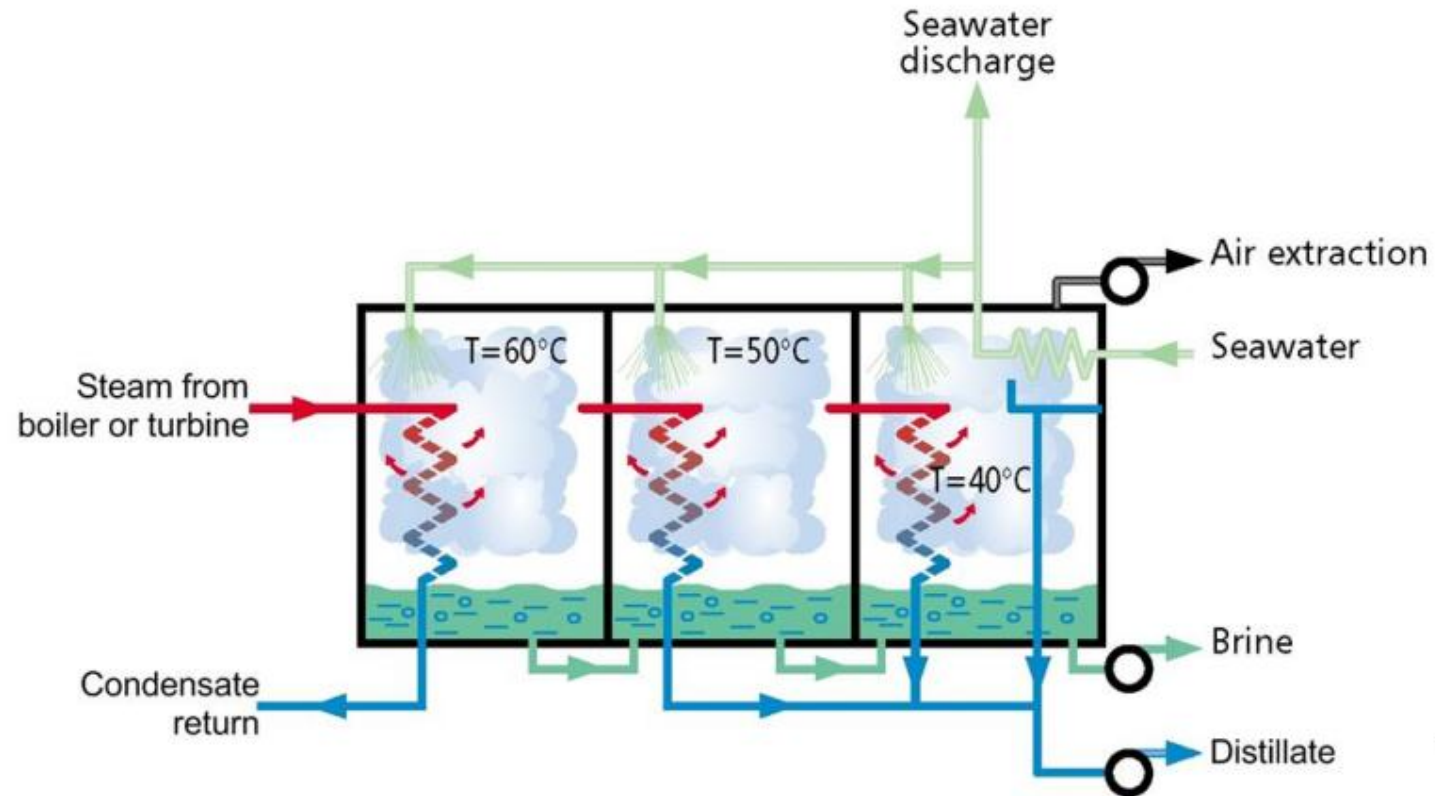
Output rated on MGD of product water/MW of installed thermal capacity of plant.

# Multi-Stage Flash Distillation



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

# Multiple Effect Distillation



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



# Conclusions

- Electrical demands in the U.S. are large and will continue to grow as more EV's are brought on line, and more other uses like space heating are changed from natural gas to electricity.
- New water projects are likely to be bigger users of electricity for pumping and advanced treatment.
- Given the strong desire to decarbonize the electrical system there is no way to maintain a viable energy system that does not include advanced nuclear power.
- Advanced nuclear power plants can be designed to optimize electrical and water production plus providing heat for industrial uses.
- There is no reason why we must have shortages of water or power if we develop advanced molten salt reactors.

# Notes and 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>
  - Nuclear Innovation
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Please contact Bill if you have any questions, comments, or corrections to suggest, or would like more information.

Aquacraft, Inc., 2709 Pine Street. Boulder, CO 80302, 303-859-4997, [bill@aquacraft.com](mailto:bill@aquacraft.com)