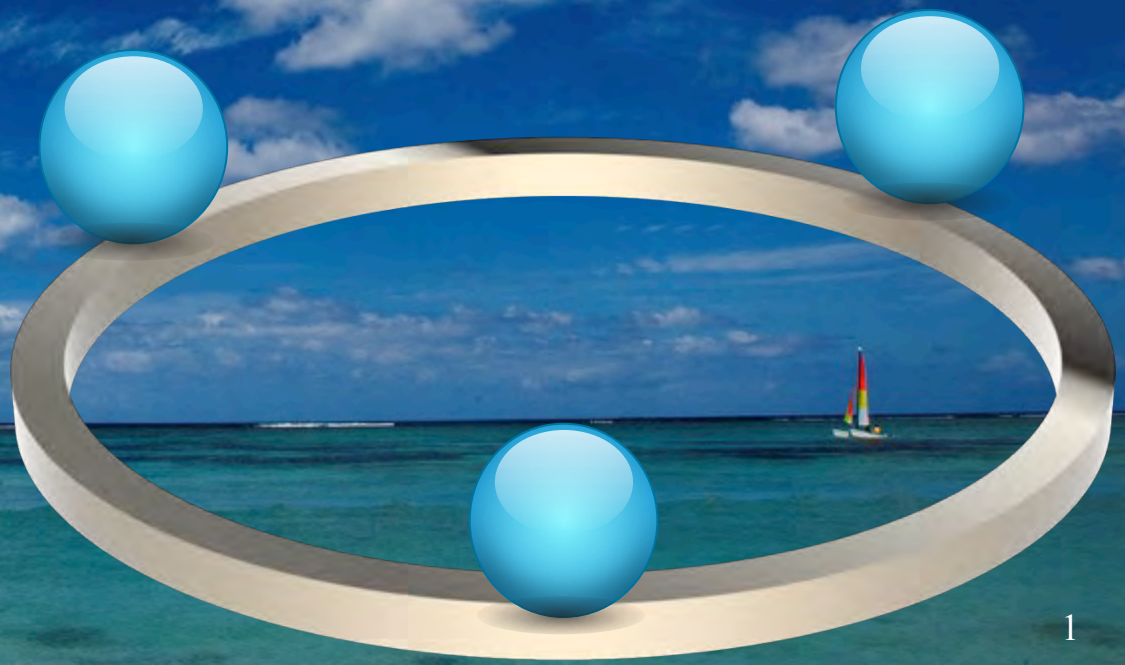
WATER
ENERGY CLIMATE

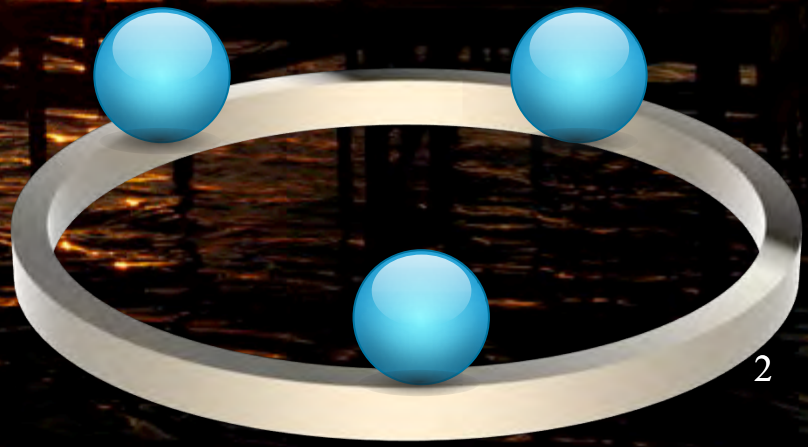


Seychelles

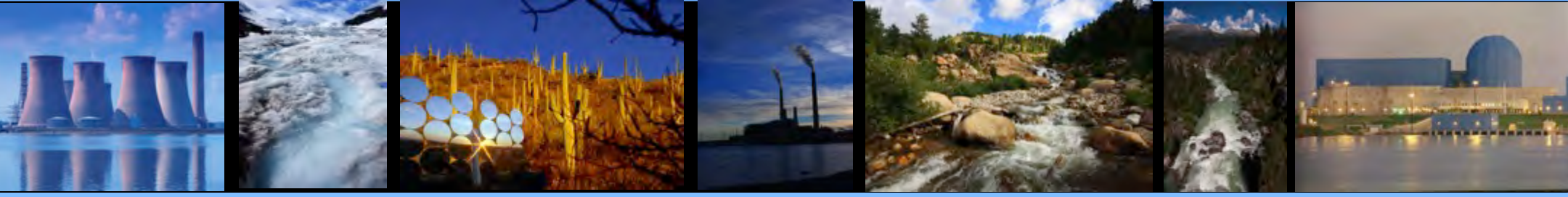
WATER
ENERGY CLIMATE

"Eventually, all things merge into one, and a river runs through it"

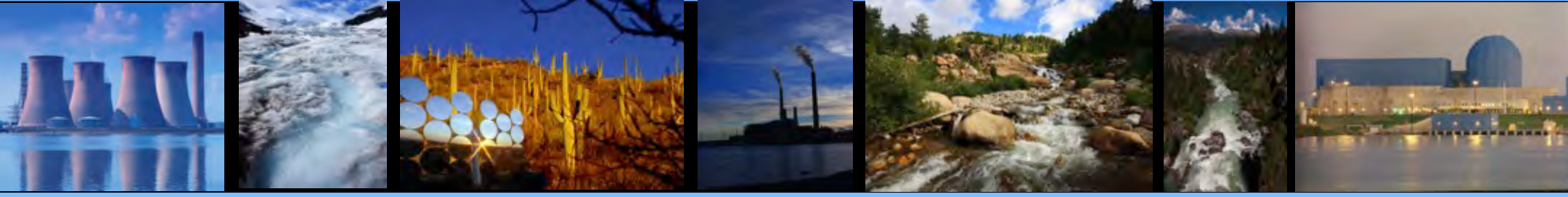
"A River Runs Through it." Norman Maclean



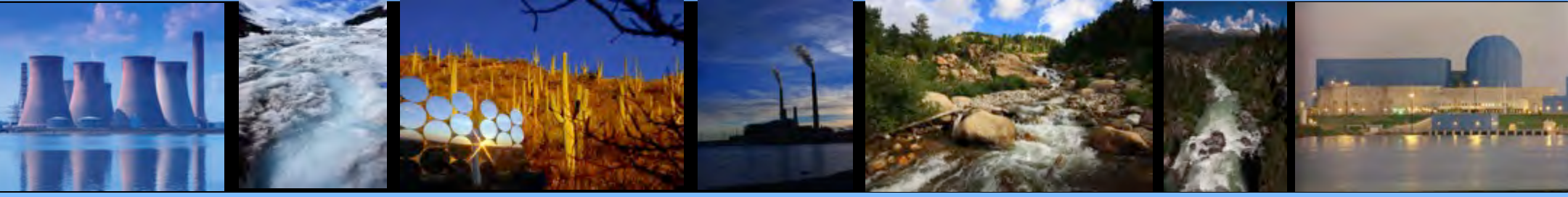
Sunset, Mauritius

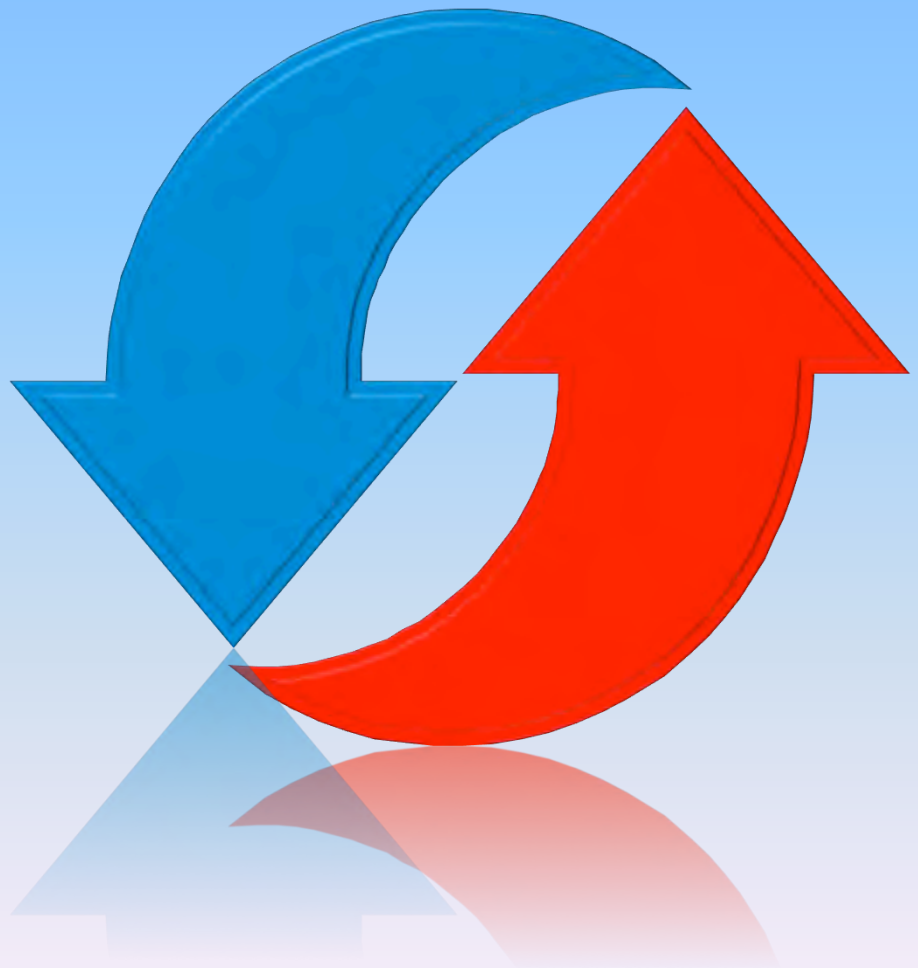


- ***Climate Institute***
- ***Chairman of the Arctic Climate Action Registry Steering Committee***
- ***Spent over 13 months North of the Arctic Circle or in Antarctica.***
- ***Firm believer that Ocean Acidification is a problem of equal magnitude to Climate Change***



- ***I firmly believe we must phase out fossil fuels.***

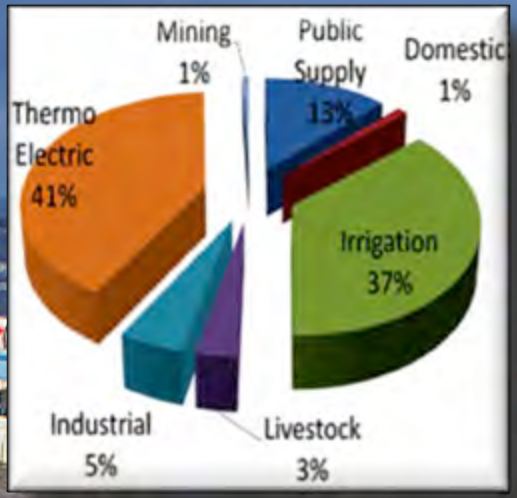




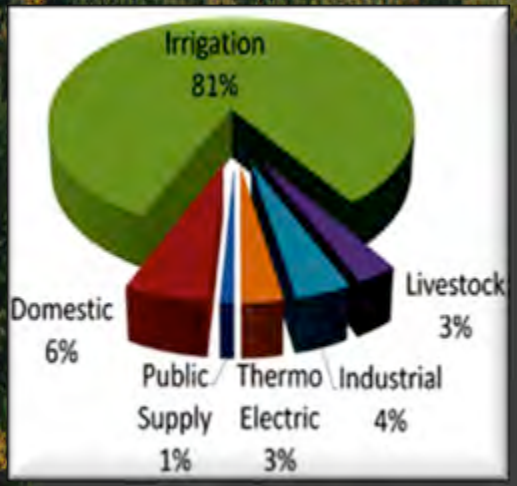
WATER COMPANIES ARE THE LARGEST USERS OF ELECTRICITY

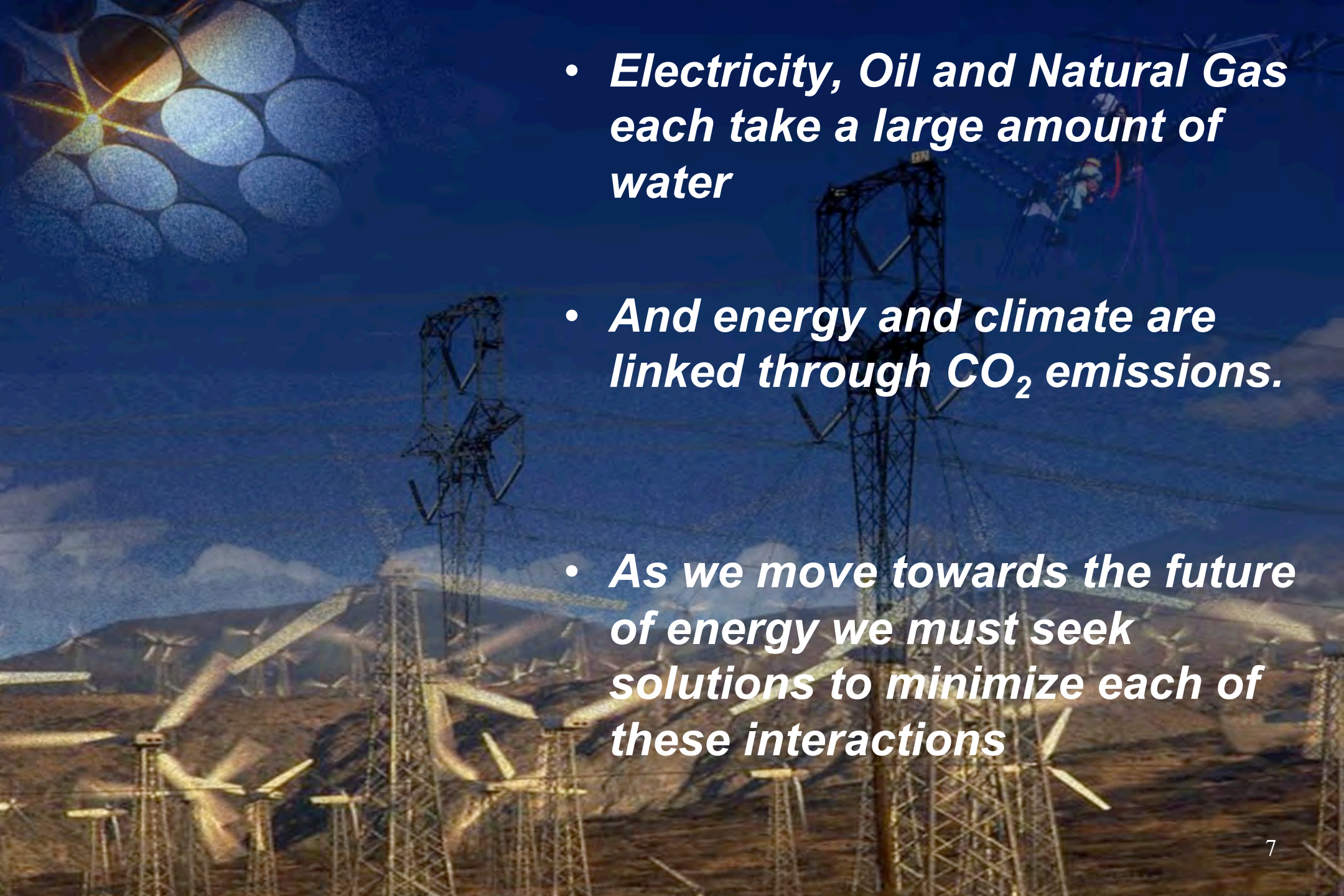
ELECTRIC COMPANIES ARE THE LARGEST USERS OF WATER

Water use



Water consumption



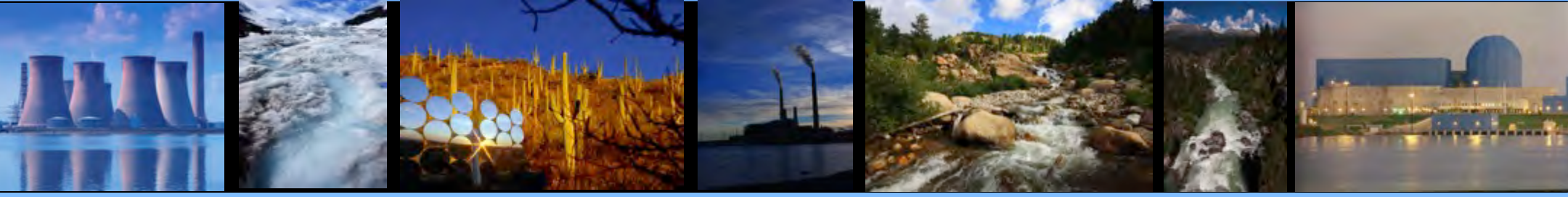


- ***Electricity, Oil and Natural Gas each take a large amount of water***
- ***And energy and climate are linked through CO_2 emissions.***
- ***As we move towards the future of energy we must seek solutions to minimize each of these interactions***

WHY DO POWER PLANTS USE WATER?

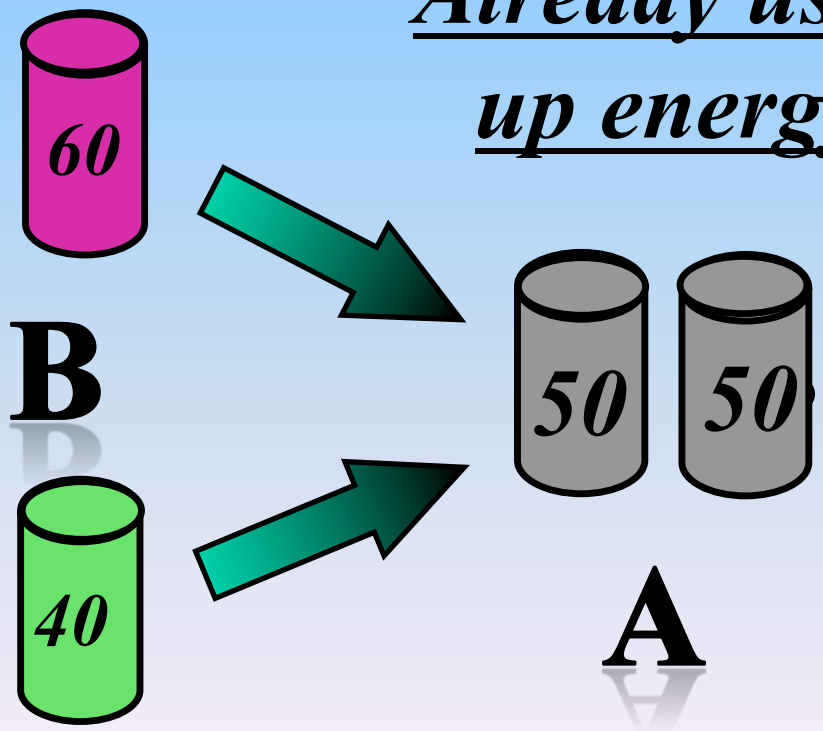
WE ARE WASTEFUL

BUT THERE'S A GOOD REASON FOR IT



ENTROPY

Already used up energy



If system "B" does decay to "A" the ability to extract work from the energy expended in separating them originally is lost to the system forever

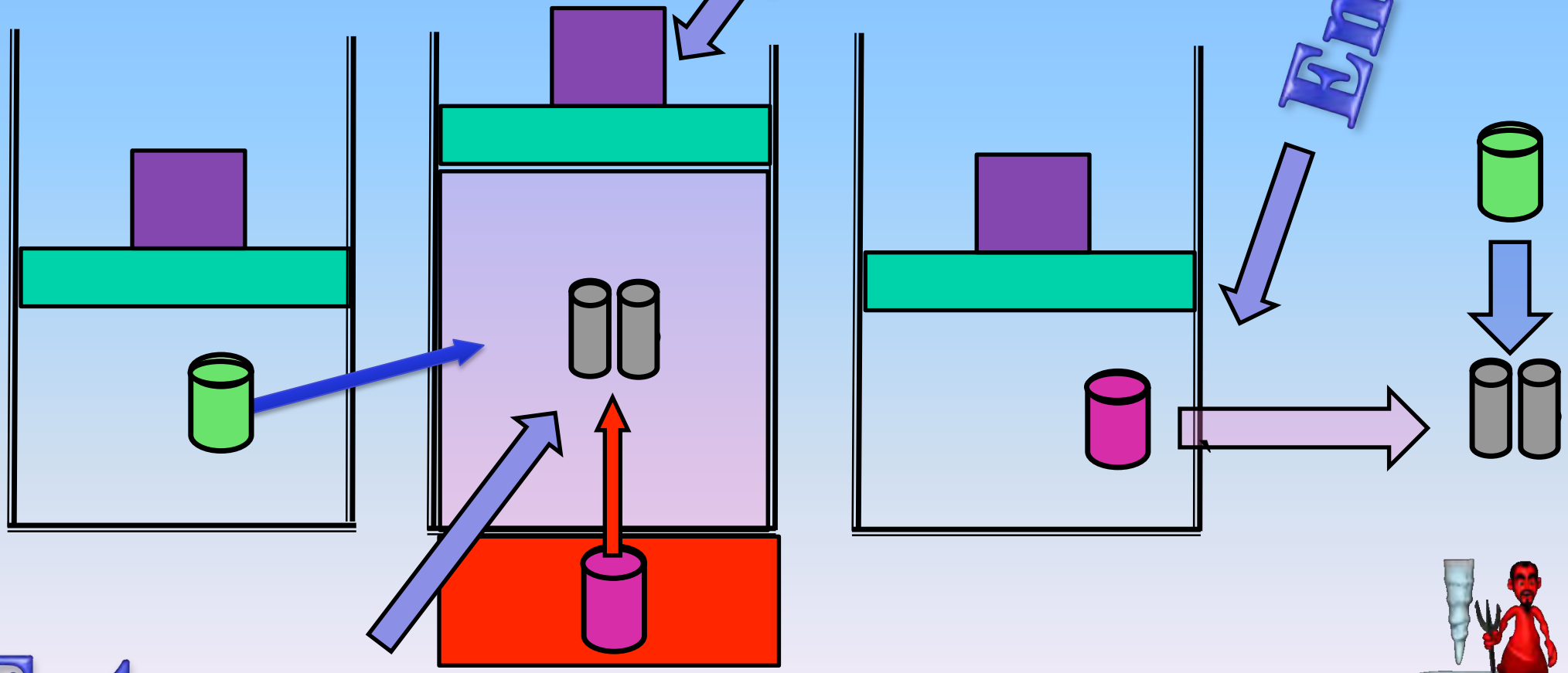
Assume it took 10 units of energy to separate them once the temperature equalized we would forever lose the ability to use that energy

The energy is still there, it is just not in useable form.

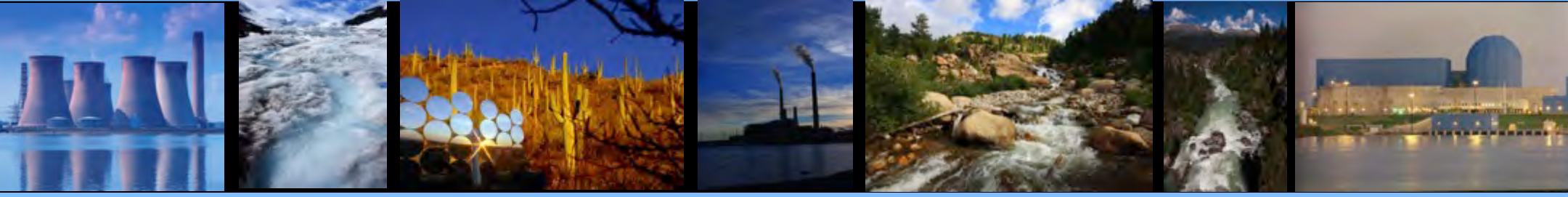
$$\frac{PV}{T} = C$$

Exergy

Entropy



Entropy



1960°F

WASTE

70°F

STEAM
1,000°F

Energy can neither be created nor destroyed

Thermodynamic Efficiency

- The maximum efficiency of any thermal power plant is

$$Efficiency_{Max} = \frac{T_{IN} - T_{OUT}}{T_{in}}$$

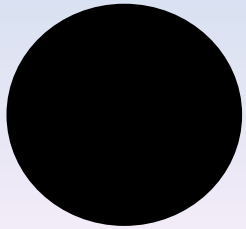
- Where T_{in} = the input temperature
- And, T_{out} = the output temperature.
- For instance where the earth's temperature is 70^0F (529^0K)and the steam temperature is 900^0F (1359^0K).
  Then the maximum efficiency is
- (1359-529)/1359 =830/1359 = 61%

MAXIMUM EFFICIENCY

- *RRH (1000^0K)*

- *RH (800^0K)*

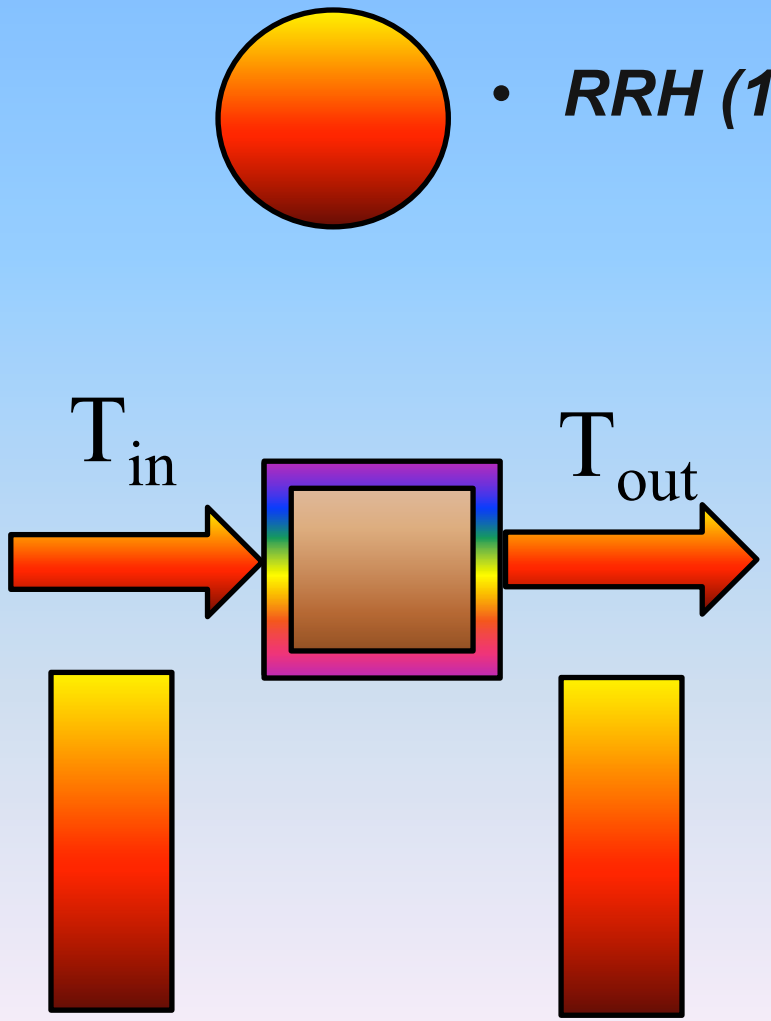
- *Earth (500^0K)*



- *RRRRRRRC (0^0K)*

- *Consider four Worlds.*
- *Assume you have a container with a certain amount of heat at 1000^0K and Mr. Spock beams you to each of the Worlds in turn with as many perfect Machines as you wish*

1000^0K World

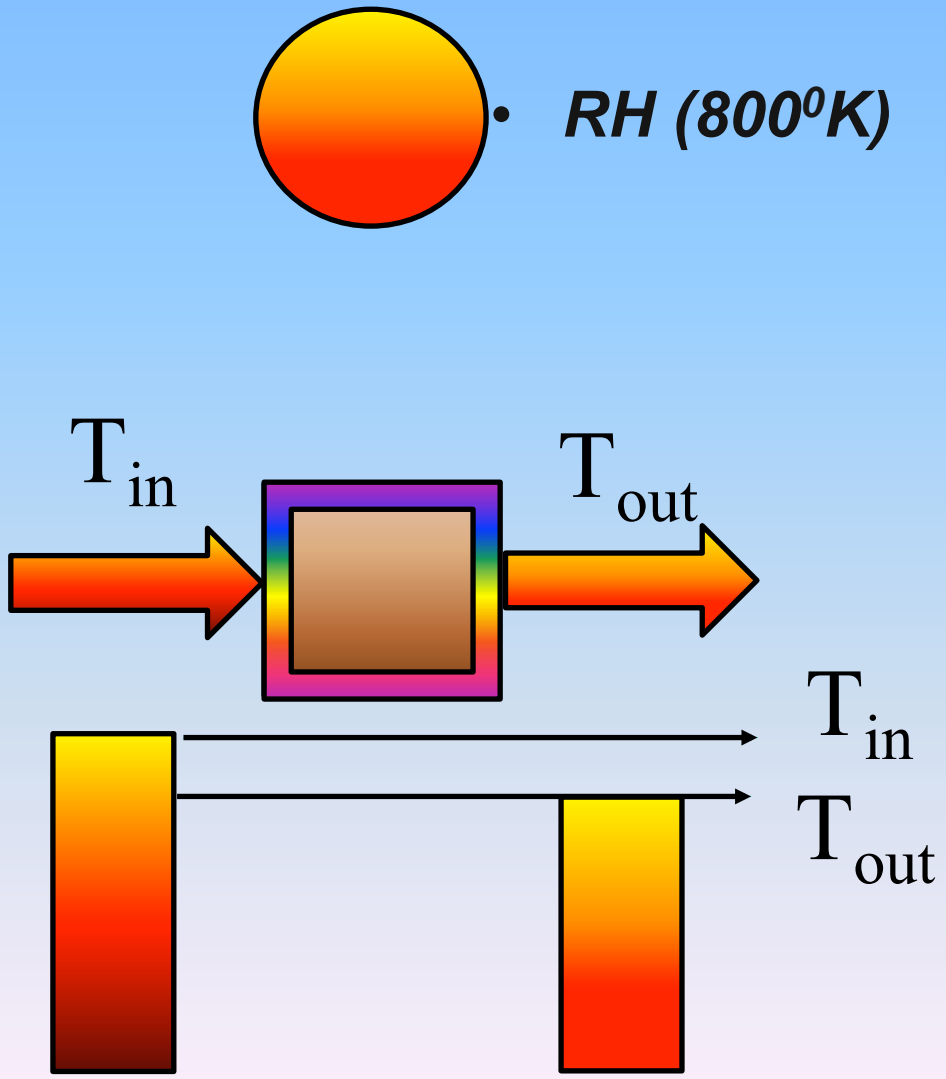


- RRH (1000^0K)

- On the 1000^0K world you machines will not work as your input and output temperatures are the same.

$$Efficiency_{Max} = \frac{T_{IN} - T_{OUT}}{T_{in}}$$

800^0K World

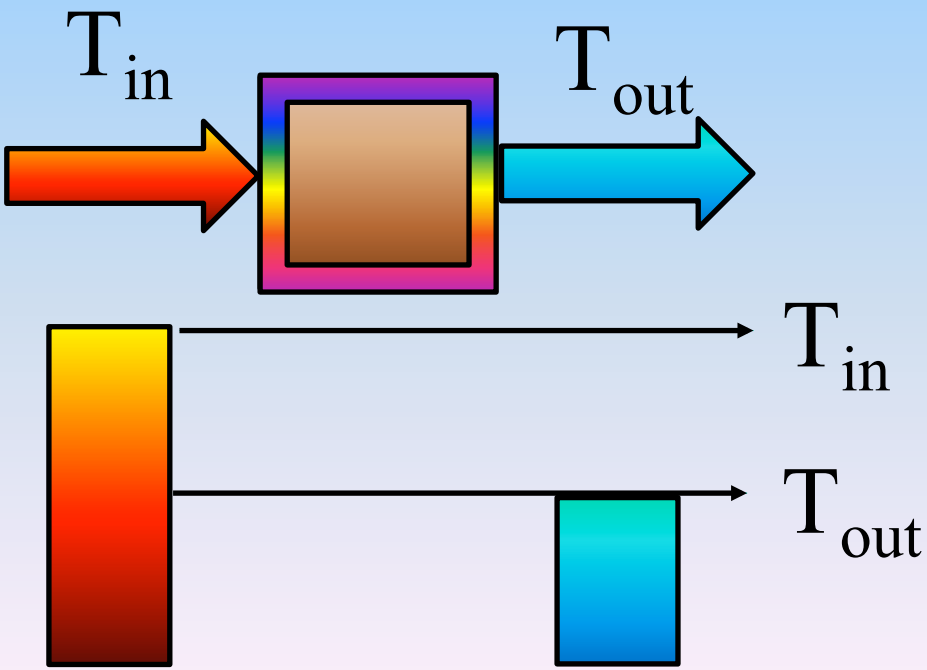


- On the 800^0K world you machines will work until your output reaches 800^0K and then no more work can be extracted.

$$Efficiency_{Max} = \frac{T_{IN} - T_{OUT}}{T_{in}}$$

Earth 500^0K World

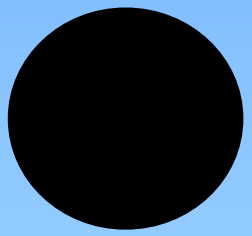
- *Earth (500^0K)*



- *On Earth your machines will work until your out put temperature reaches 500^0K and then no more work can be extracted.*

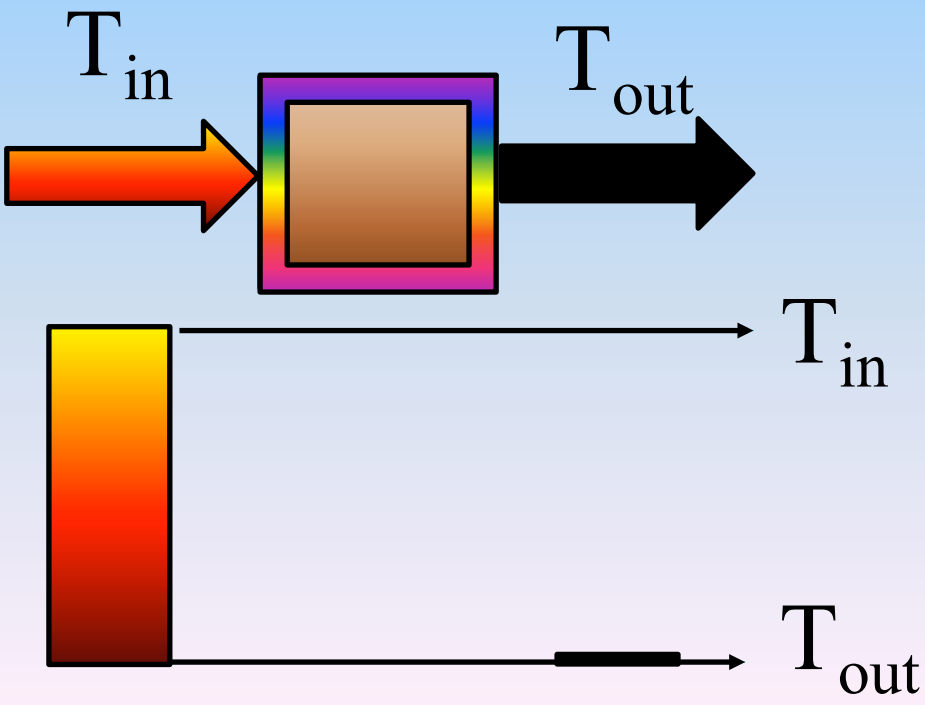
$$Efficiency_{Max} = \frac{T_{IN} - T_{OUT}}{T_{in}}$$

0^0K World

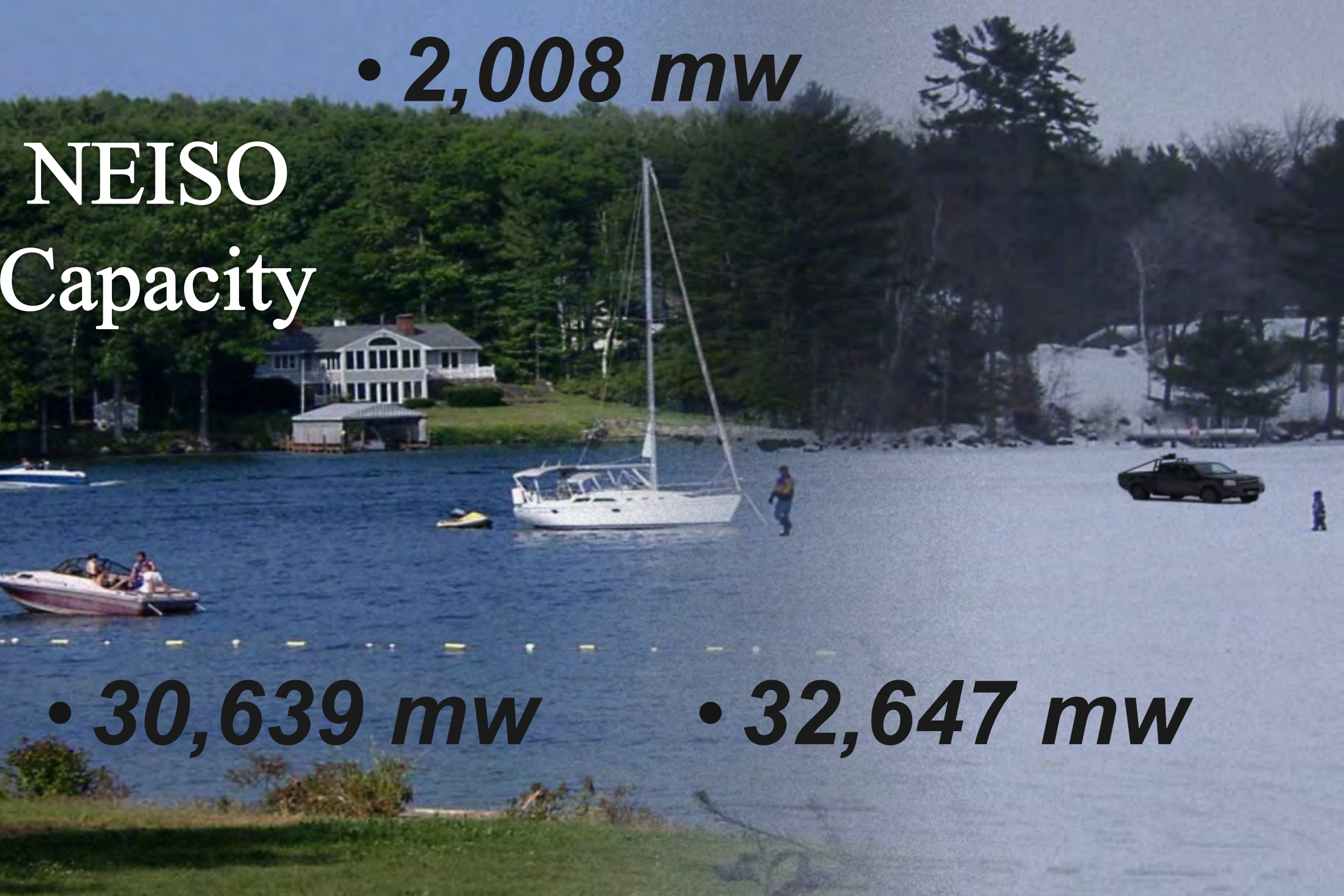


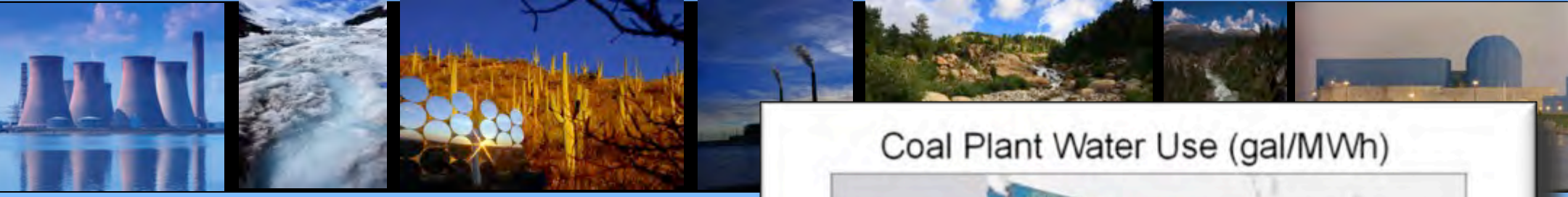
- *RRRRRRRC (0^0K)*

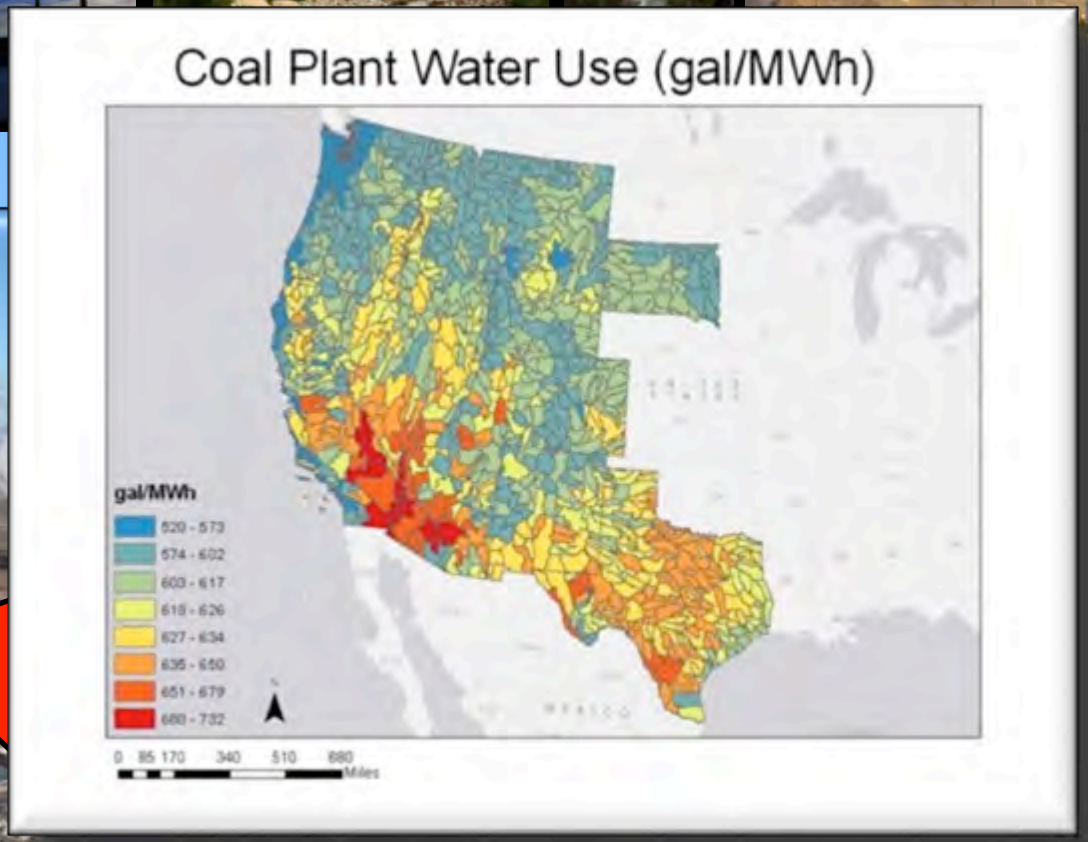
- *On the 0^0K World all of the heat can be converted to work*



$$Efficiency_{Max} = \frac{T_{IN} - T_{OUT}}{T_{in}}$$


• 2,008 mw
NEISO
Capacity
• 30,639 mw
• 32,647 mw




Coal Plant Water Use (gal/MWh)
gal/MWh
520 - 573
574 - 602
603 - 617
618 - 626
627 - 634
635 - 650
651 - 679
680 - 732
0 85 170 340 510 680
Miles

2,008

ELECTRICITY VS. WASTE

1,000

390

610

POWER PLANT EFFICIENCY

	Efficiency	Energy in	Elec Out	Waste Heat
• *1960's Coal units*	*34%*	*100*	*34*	*66*
• *Modern coal units*	*40%*	*100*	*40*	*60*
• *Simple cycle gas*	*38%*	*100*	*38*	*62*
• *Combined cycle gas*	*60%*	*100*	*60*	*40*

1960's

Modern

LM6000

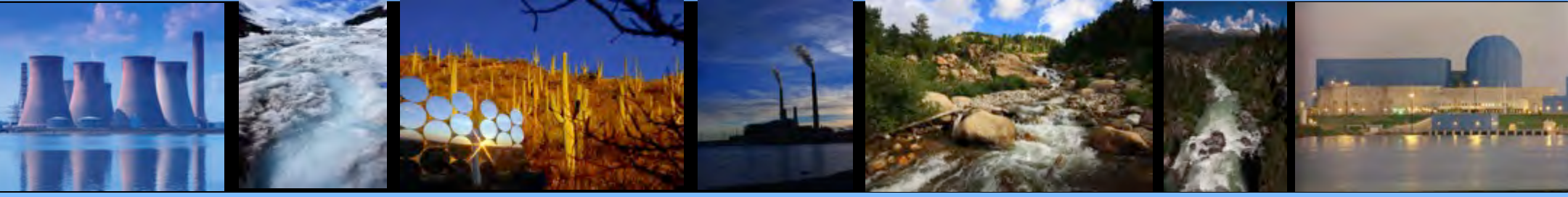
HRSG

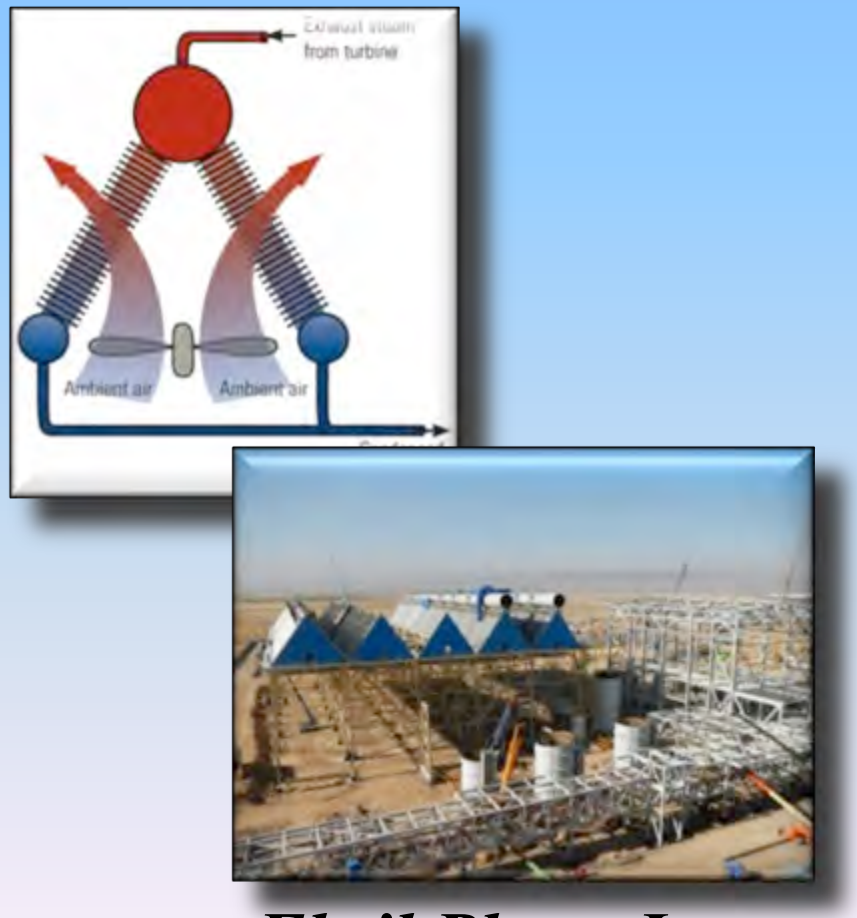
BUT WHERE DOES THE WATER COME IN ?

Geothermal
Iceland

WE USE THE WATER TO GET RID OF THE WASTE HEAT

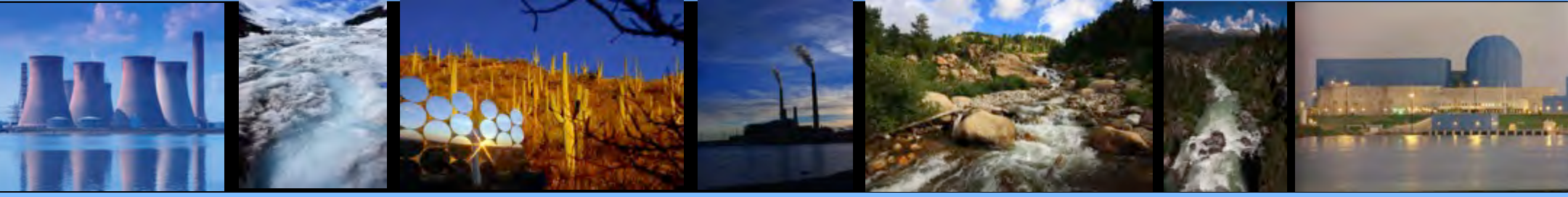
Super Critical Coal, China





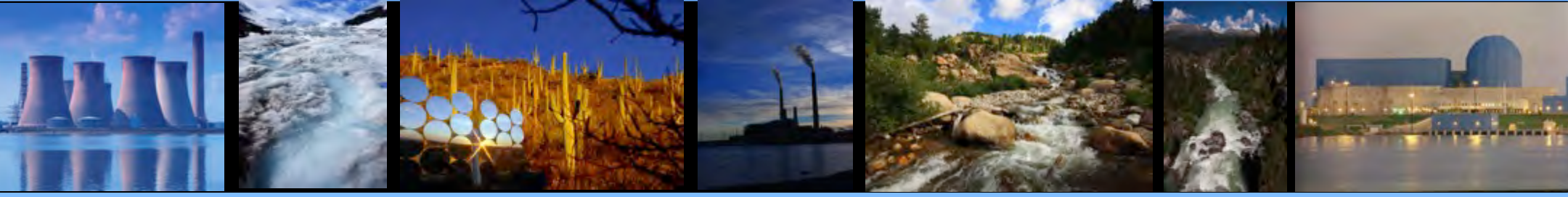
Ebril Plant, Iraq

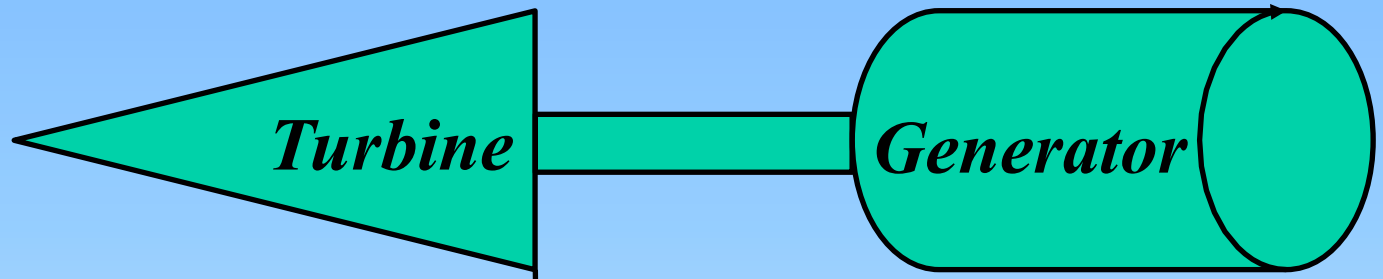
- *We need something that can be discharged to the environment.*
- *That narrows it down to water and air.*
- *It takes one calorie to heat one gram of water one degree centigrade.*
- *But it only takes 0.24 calories to heat air a comparable amount.*
- *Thus, all other things equal it would take four times the weight of air to cool the plant.*



ALL OTHER THINGS ARE NOT EQUAL

- *It takes 1 calorie/gram to heat water*
- *But 540 calories/gram, to turn it to steam.*
- *Rather than use 540 grams we can use one.*
- *But it requires <u>using</u> water through evaporation not just withdrawing it.*
- *Air cooling cannot take advantage of the Heat of Vaporization*





540 cal/gram

Low temperature
Low Pressure
Steam

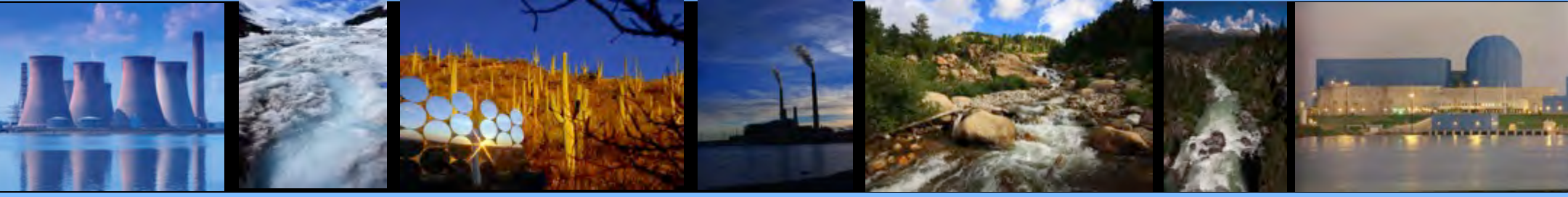
"Cool" Water

Water

"Warm" Water

Δ_T~40^{0}F

Once-through cooling



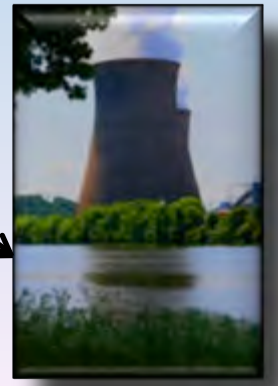
STEAM

~3% EVAPORATED

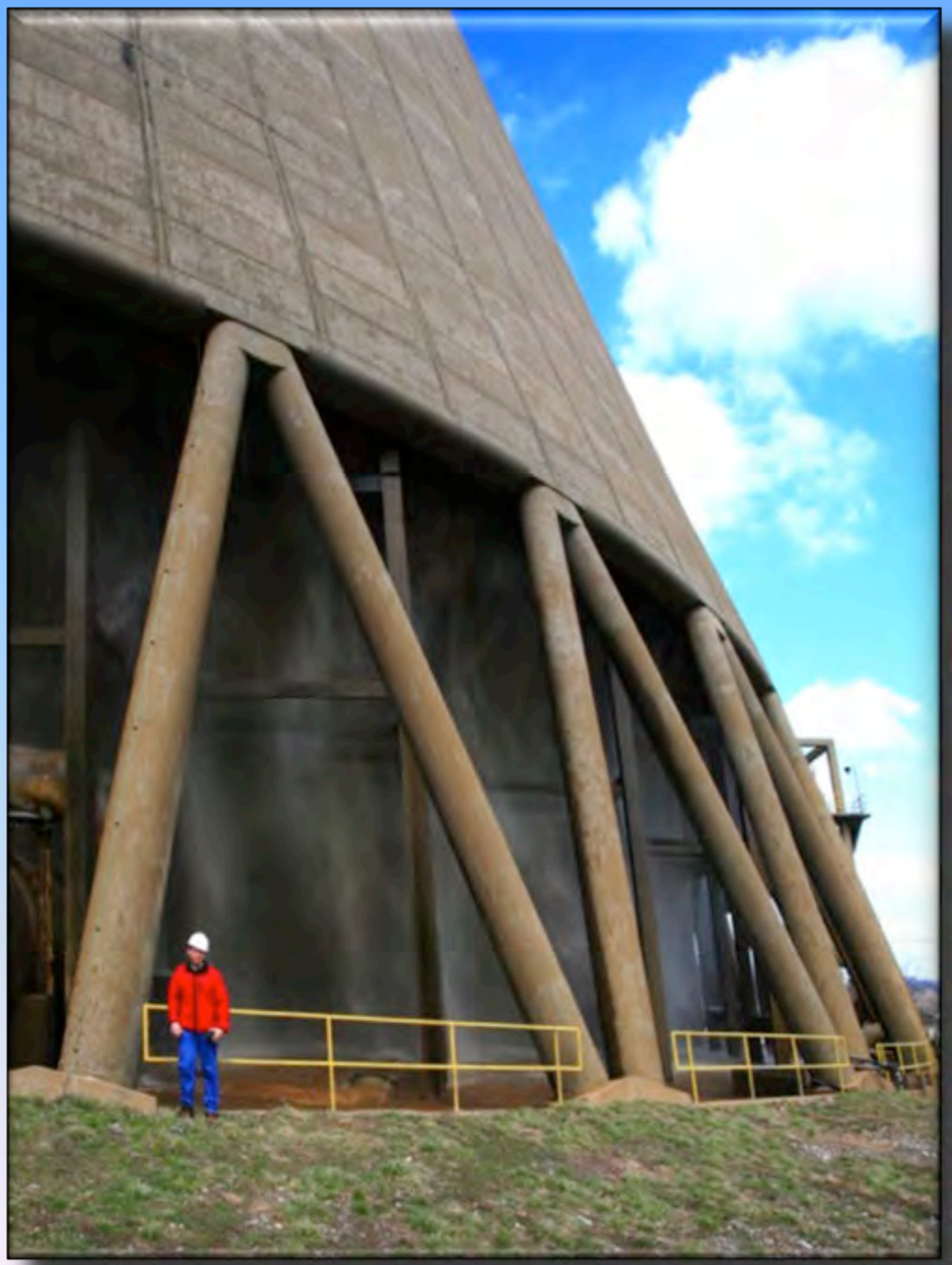
540 cal/gram

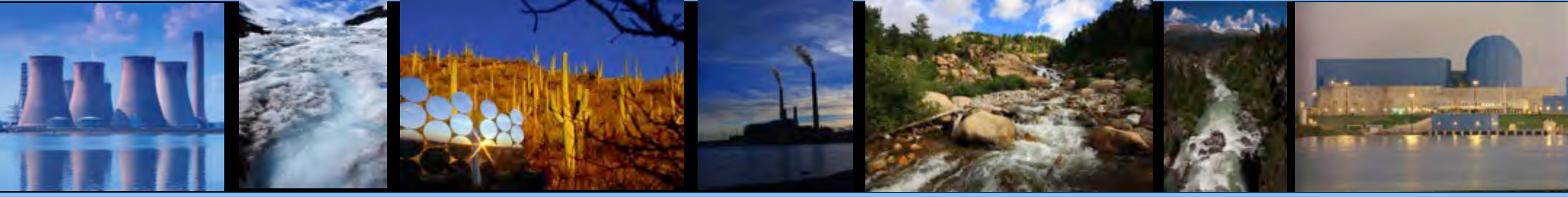
"Warm" Water

"Cool" Water

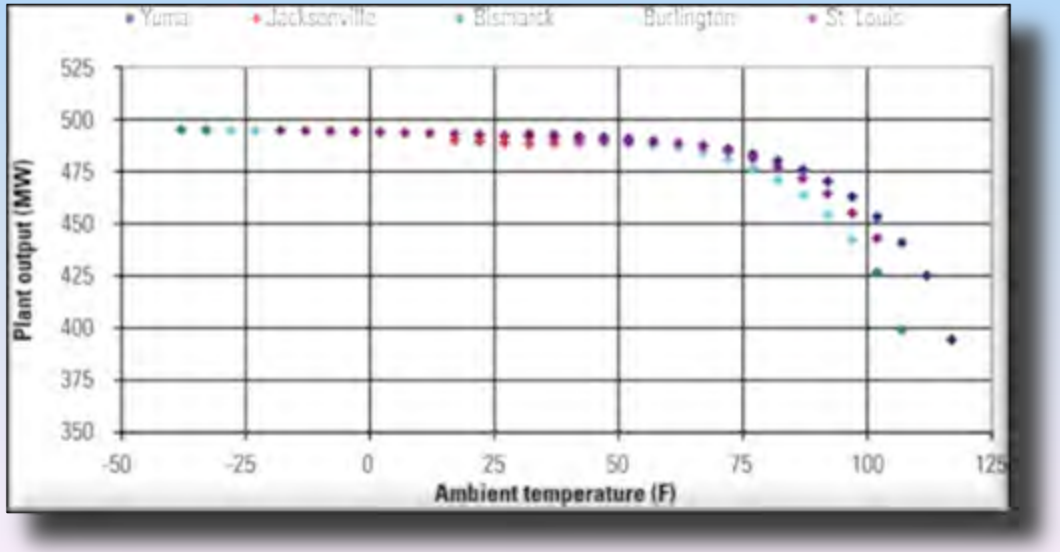


"Cool" Water



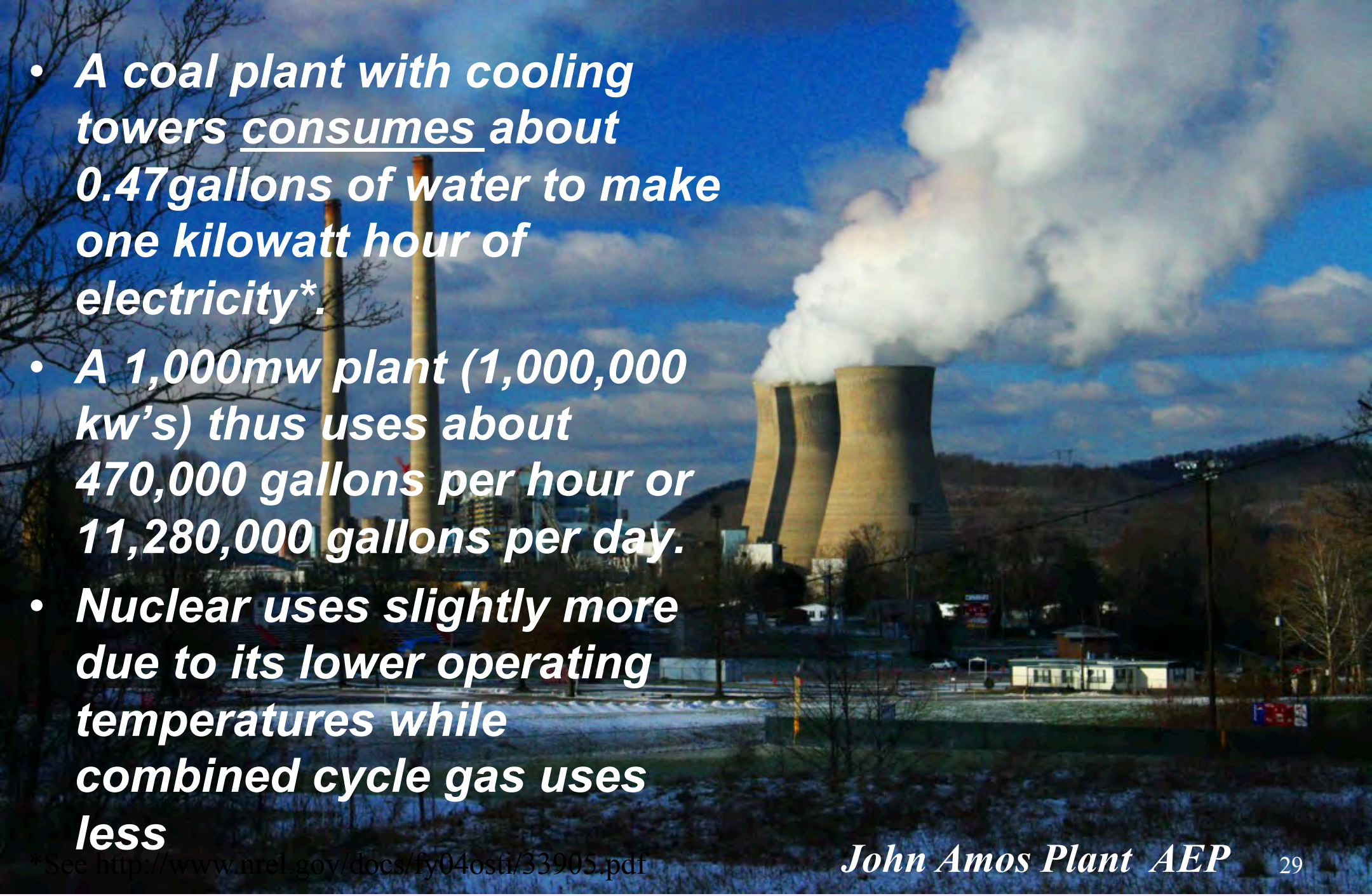


coal-fired Zhangshan



AIR COOLED VS. WATER COOLED

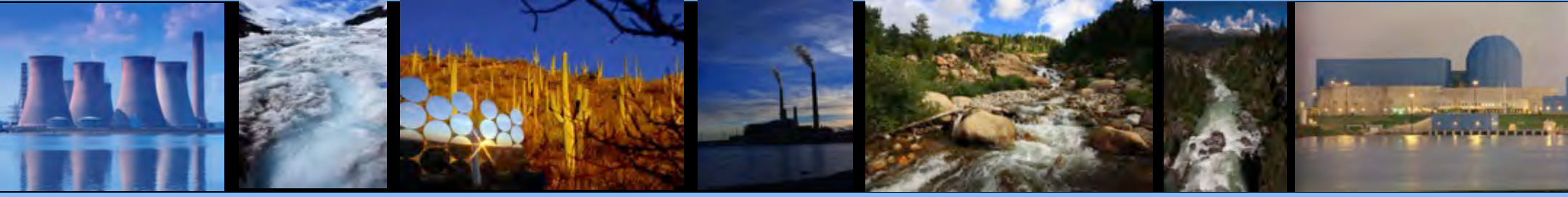
- *Given two identical power plants the air-cooled plant will be about 7% less efficient than the water cooled plant.*
- *This means*
  - *More fuel*
  - *More CO_2*
  - *More heat discharge (but to the air)*



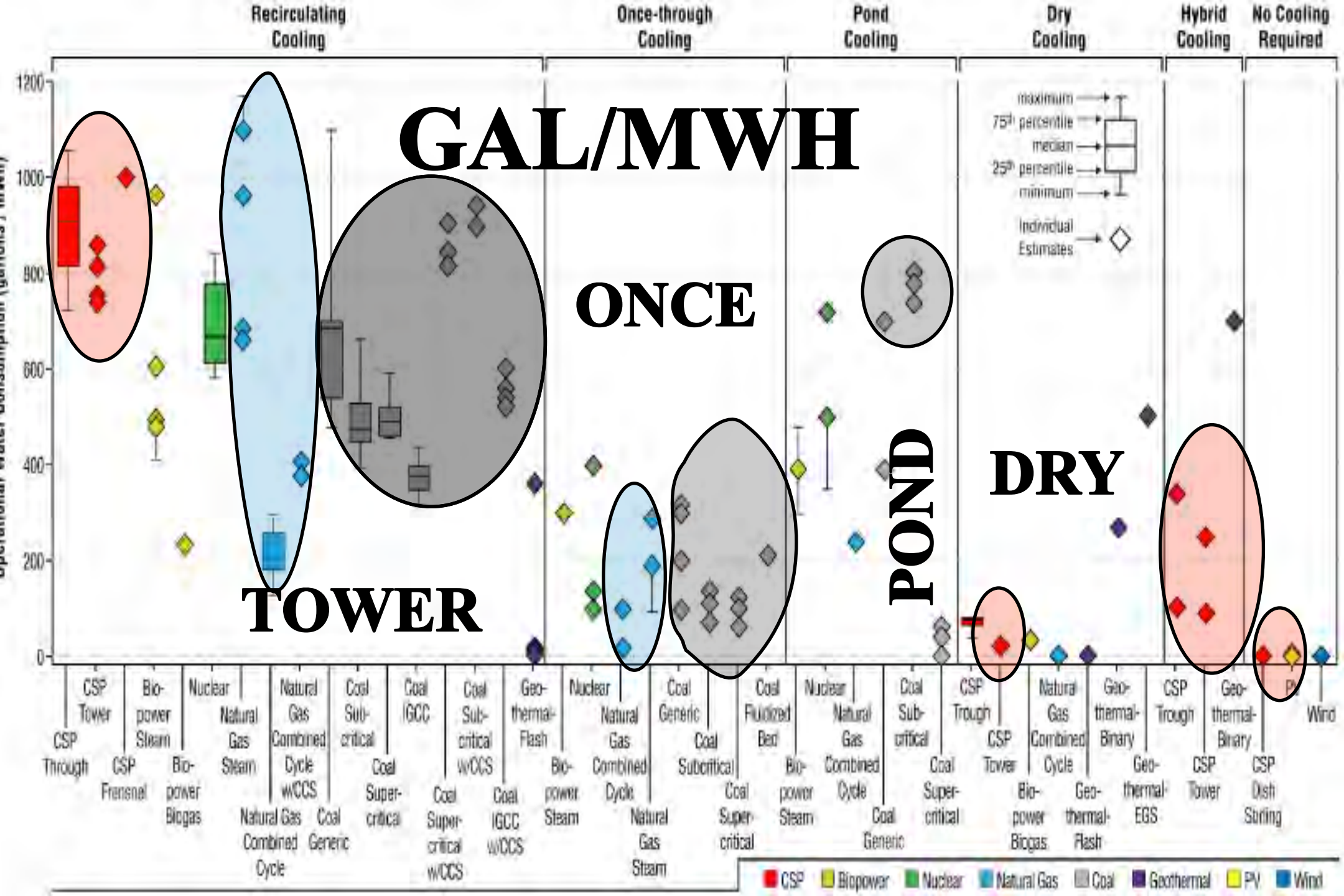
- *A coal plant with cooling towers consumes about 0.47gallons of water to make one kilowatt hour of electricity*.*
- *A 1,000mw plant (1,000,000 kw's) thus uses about 470,000 gallons per hour or 11,280,000 gallons per day.*
- *Nuclear uses slightly more due to its lower operating temperatures while combined cycle gas uses less*

*See http://www.nrel.gov/docs/fy04osti/33905.pdf

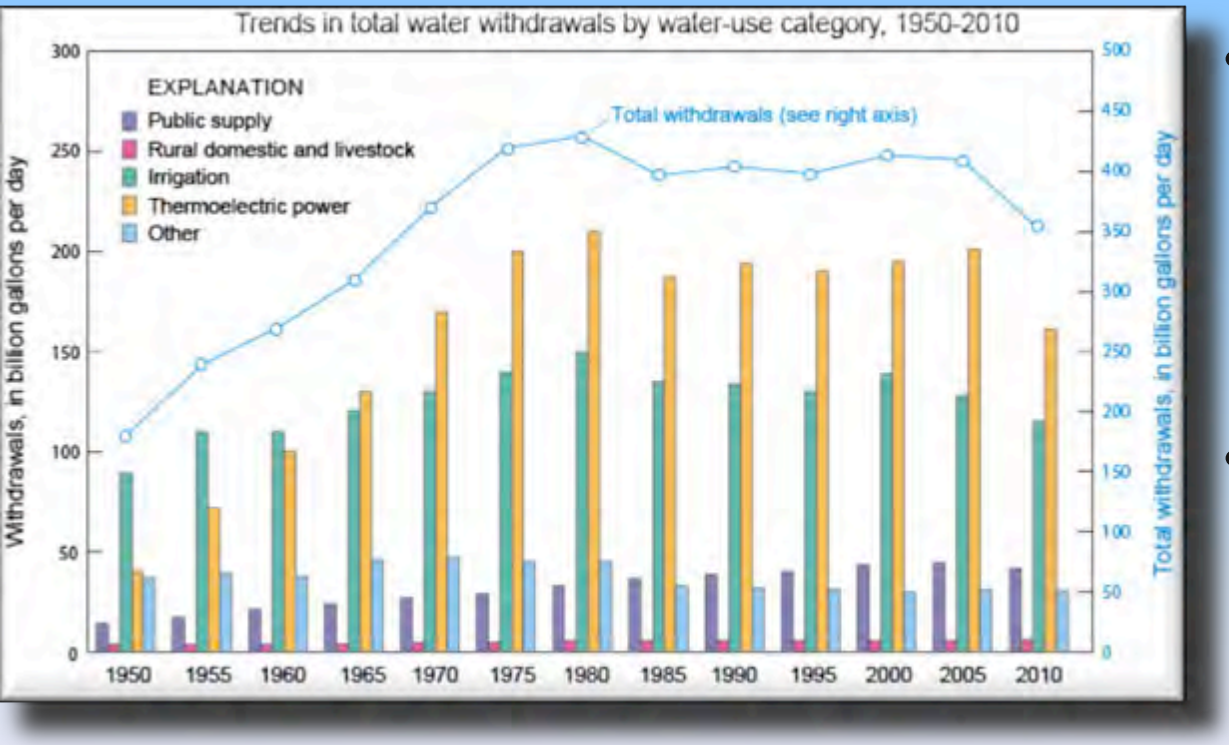
John Amos Plant AEP



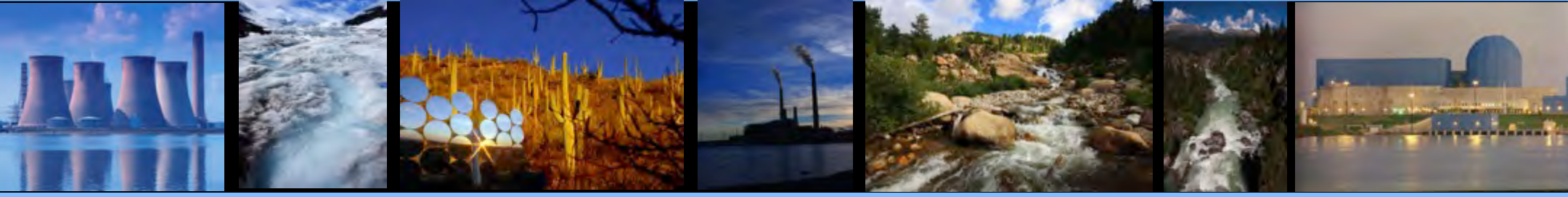
	Usage	Withdrawals	Temp.
ONCE THROUGH	~0	100%	Δ_T~40^{0}F
COOLING TOWERS	~3%	5%	Δ_T~0^{0}F


Recirculating Cooling
Once-through Cooling
Pond Cooling
Dry Cooling
Hybrid Cooling
No Cooling Required
GAL/MWH
TOWER
ONCE
POND
DRY
maximum
75th percentile
median
25th percentile
minimum
Individual Estimates
1200
1000
800
600
400
200
0
CSP Through
CSP Tower
CSP Fresnel
Bio-power Steam
Bio-power Biogas
Nuclear
Natural Gas Steam
Natural Gas Combined Cycle
Natural Gas Combined Cycle wCCS
Coal Generic
Coal Sub-critical
Coal Super-critical
Coal IGCC
Coal Super-critical wCCS
Coal Sub-critical wCCS
Coal IGCC wCCS
Geo-thermal-Flash
Bio-power Steam
Nuclear
Natural Gas Combined Cycle
Natural Gas Steam
Coal Generic
Coal Subcritical
Coal Super-critical
Coal Fluidized Bed
Bio-power Steam
Nuclear
Natural Gas Combined Cycle
Coal Generic
Coal Sub-critical
Coal Super-critical
CSP Trough
CSP Tower
Bio-power Biogas
Natural Gas Combined Cycle
Geo-thermal-Flash
Geo-thermal-EGS
CSP Trough
CSP Tower
Geo-thermal-Binary
CSP Dish Stirling
PV
Wind
CSP
Biopower
Nuclear
Natural Gas
Coal
Geothermal
PV
Wind

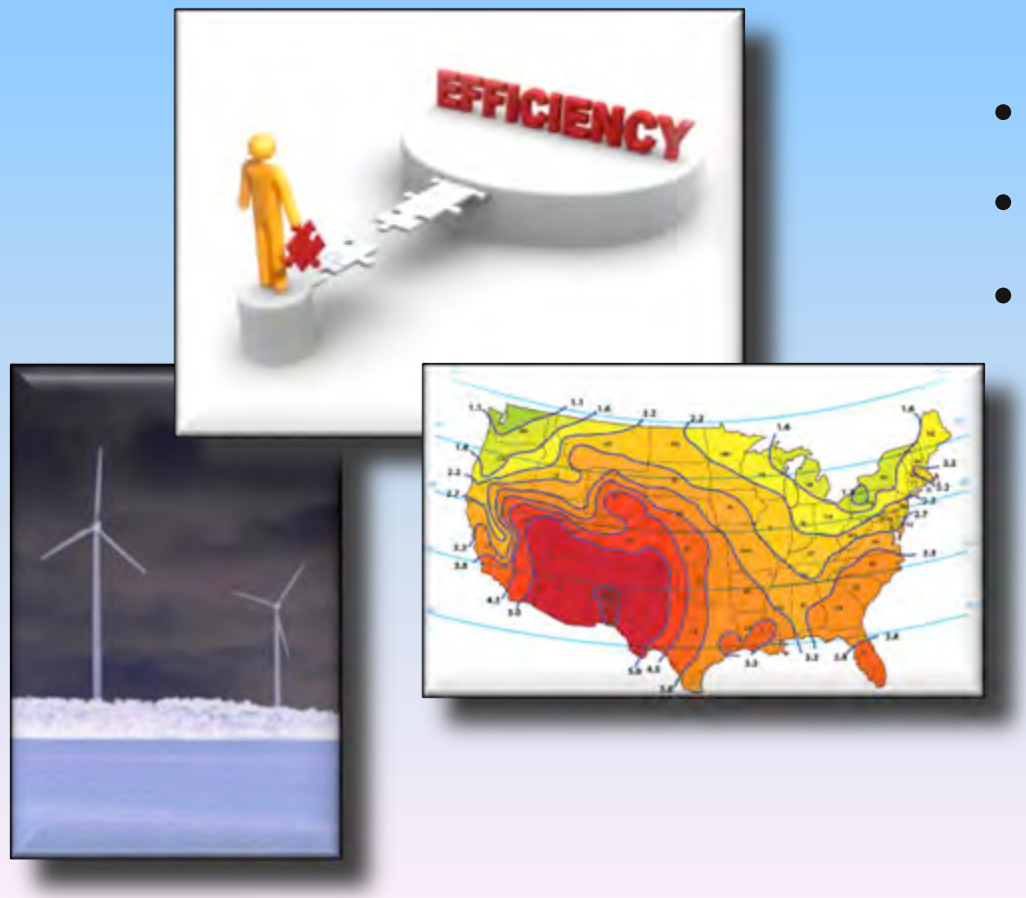
WATER USE IN ELECTRIC PRODUCTION



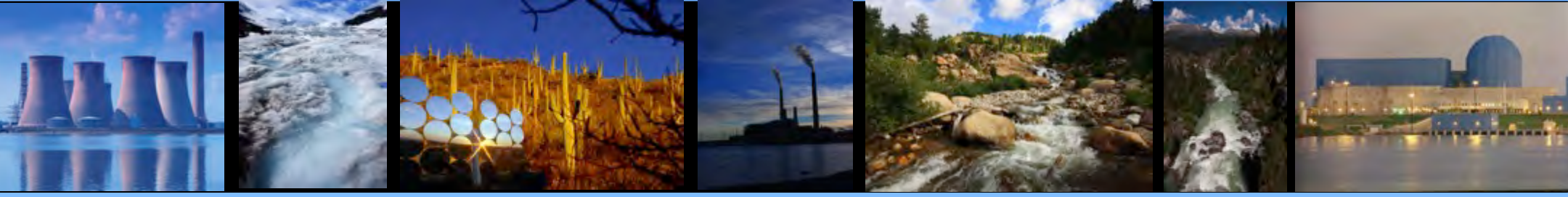
- ***Water withdrawal in electric production has decreased over the last few years due to renewables and greater efficiency.***
- ***Super critical units run at higher temperature and pressure and hence are more efficient.***



HOW DO WE DECREASE USAGE?



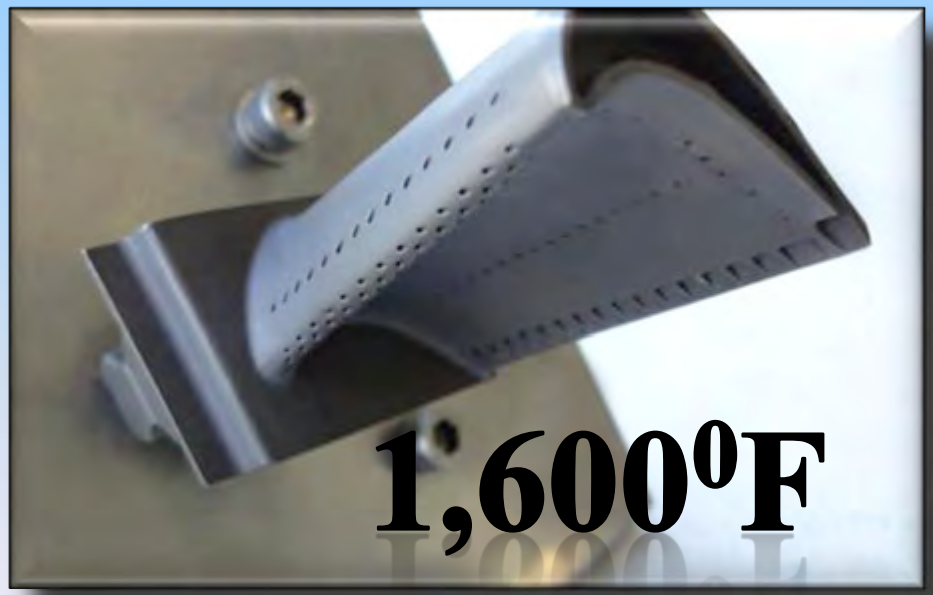
- *Renewables*
- *Gas Turbines*
- *Efficiency is almost always cheaper than generation*
  - *Appliance efficiency standards*
  - *CAFE Standards*
  - *Building Codes*



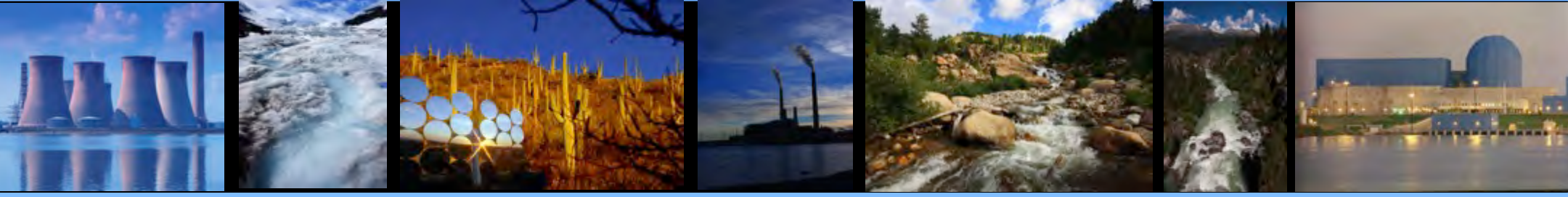
WHAT ARE WE DOING?

$$\frac{T_{IN} - T_{OUT}}{T_{in}}$$

- *You can't do much about outlet temperatures.*
- *We are engaged in a constant search for higher temperatures and pressures.*

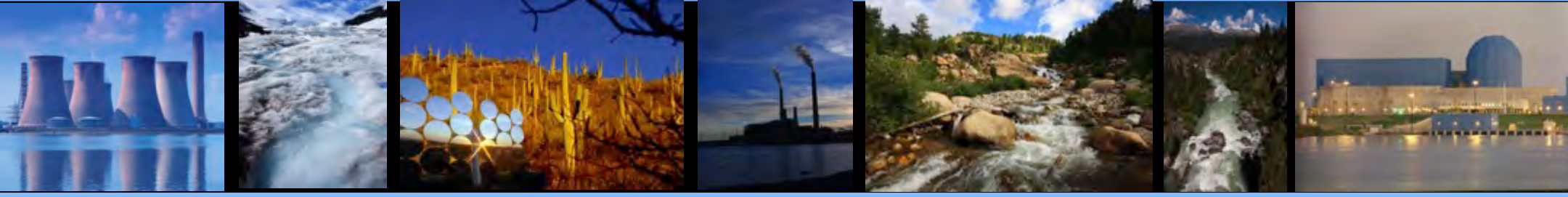


LESS CO_2
LESS FUEL
LESS WATER



WHAT ARE WE DOING?

- *In coal units we are going to ultra supercritical units*
- *Super critical 705^{0}F/3208 psi Ultra Super critical 1100^{0}F*
- *As with gas turbines the main push is in materials science.*



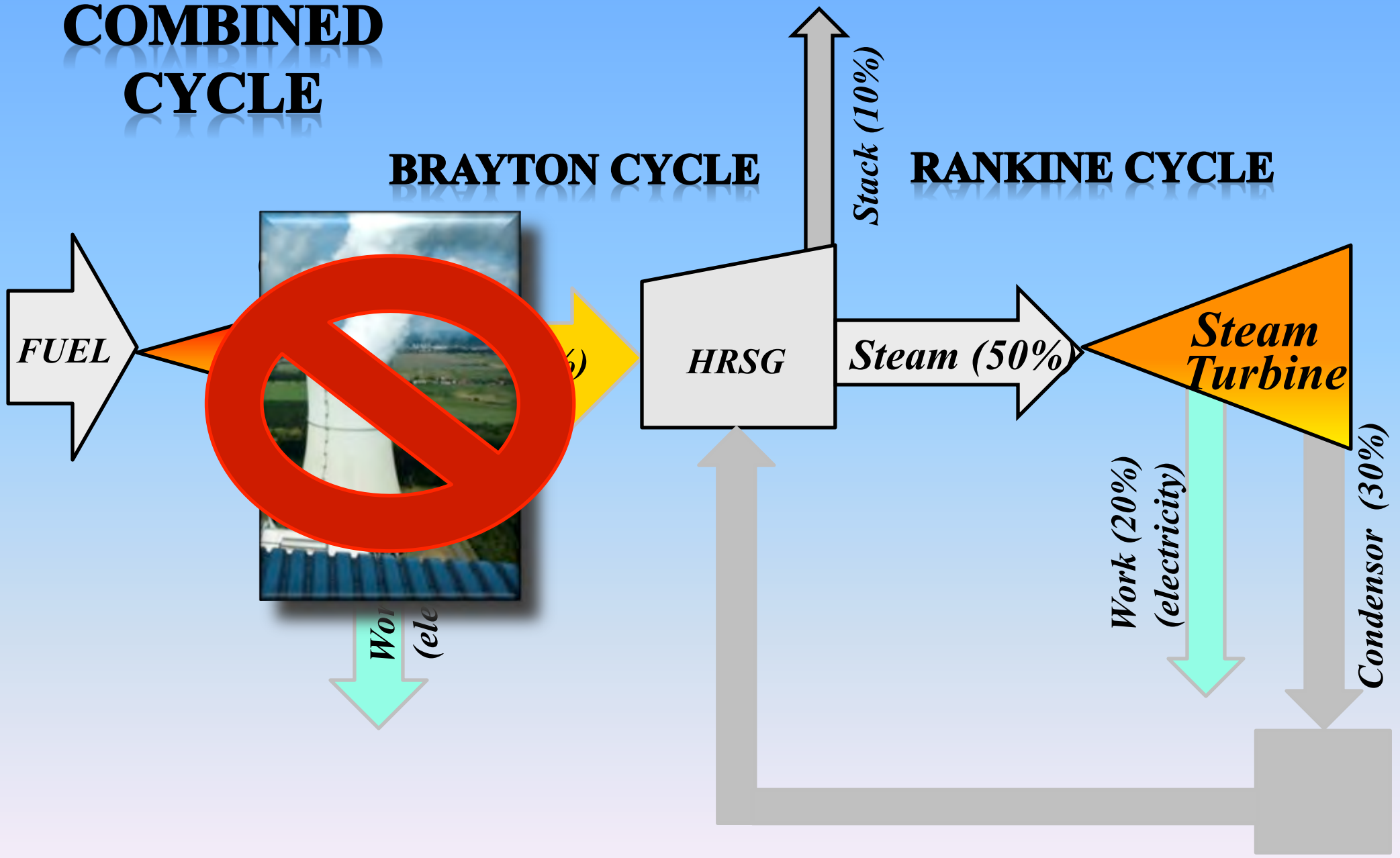
1960^{0}F

WASTE

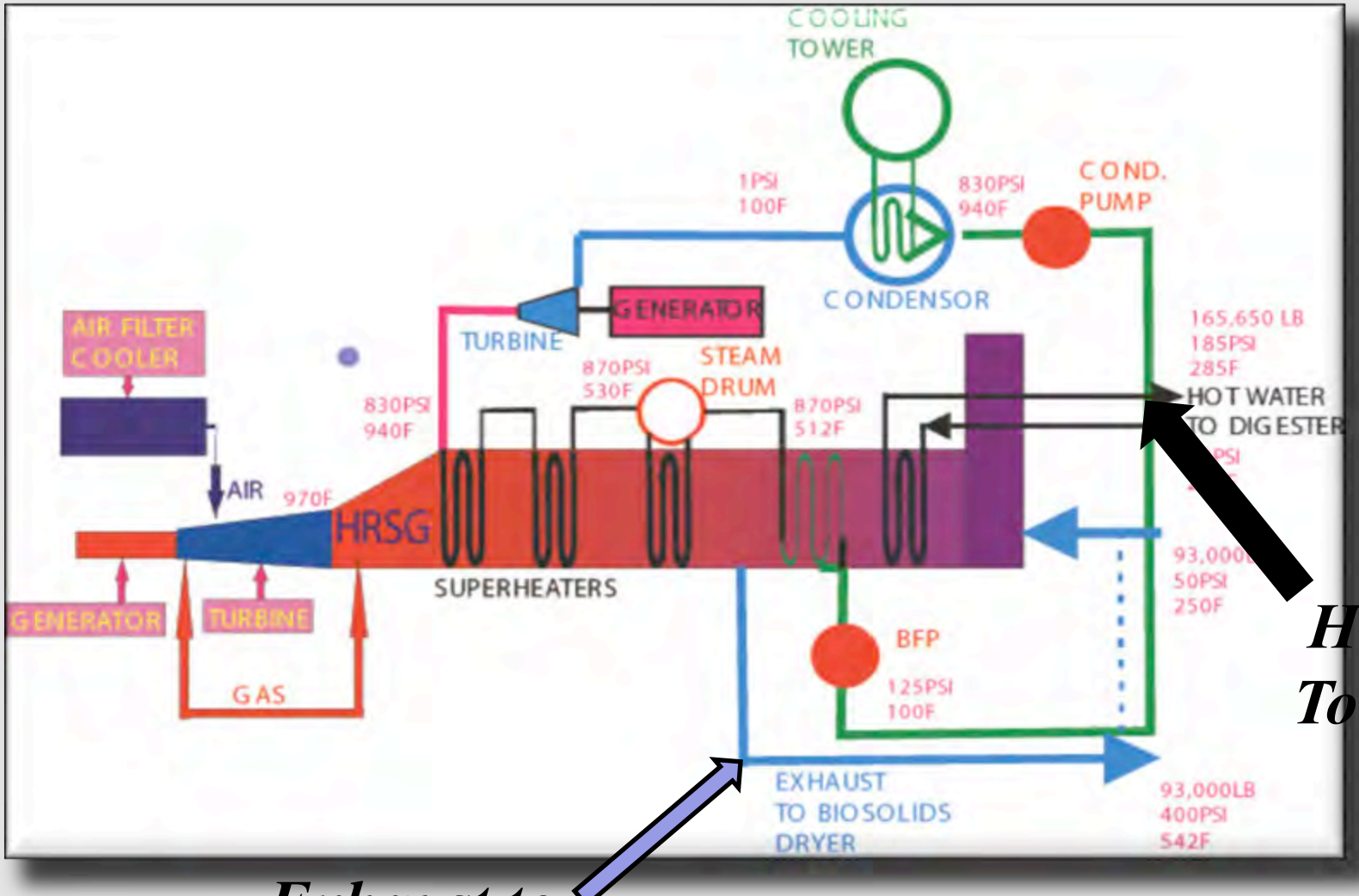
70^{0}F

STEAM
1,000^{0}F

COMBINED CYCLE



COMBINED CYCLE COGEN



Hot Water To Digester

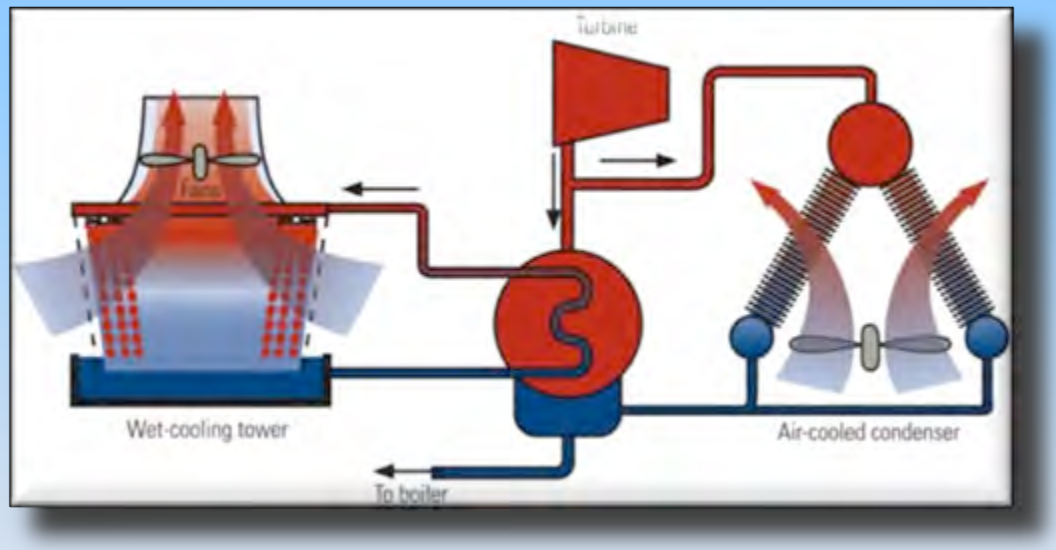
Exhaust to Biosolids dryer

HSRG

HYBRID COOLING SYSTEMS

coal-fired Zhangshan

Southern Calif. Edison



SOLAR AND WIND

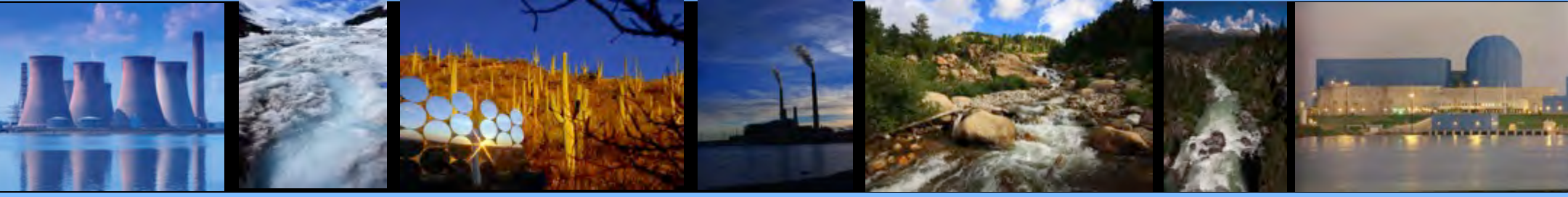
- ***Photovoltaic Solar and wind do not use water.***
- ***Concentrated Solar does as it heats a liquid and needs a heat sink just like any other thermal plant.***
- ***These water savings should be included in any cost benefit analysis especially in the Southwest.***

UNCONVENTIONAL WATER SOURCES

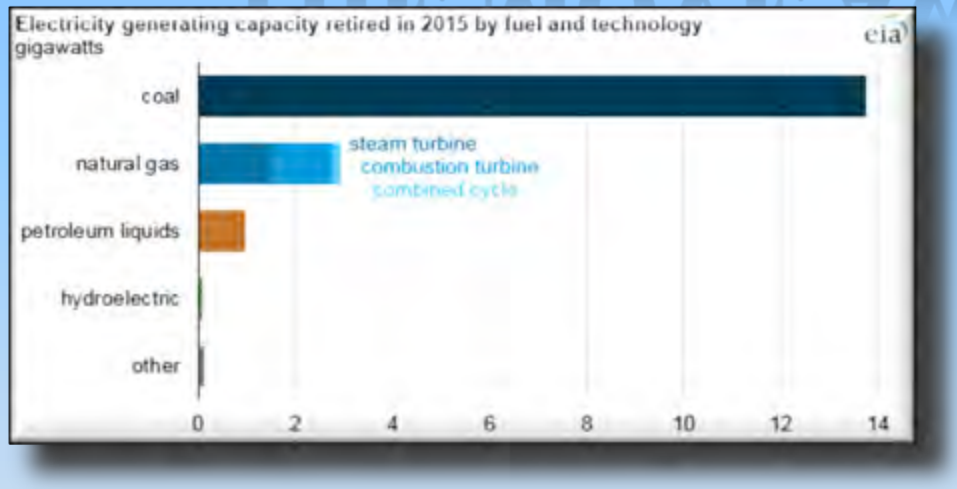
- *Seawater and brackish water from coastal areas (for cooling towers)*
- *High-salinity groundwater*
- *Mine water and produced water from oil and gas wells*
- *Agricultural runoff*
- *Storm water*

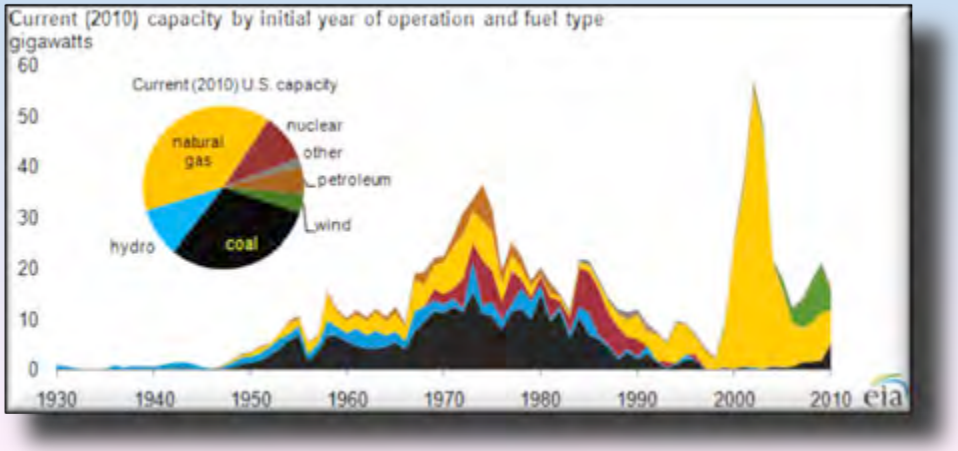
- *Backup water systems*
- *Different materials*
- *Water transport*

Palo Verde



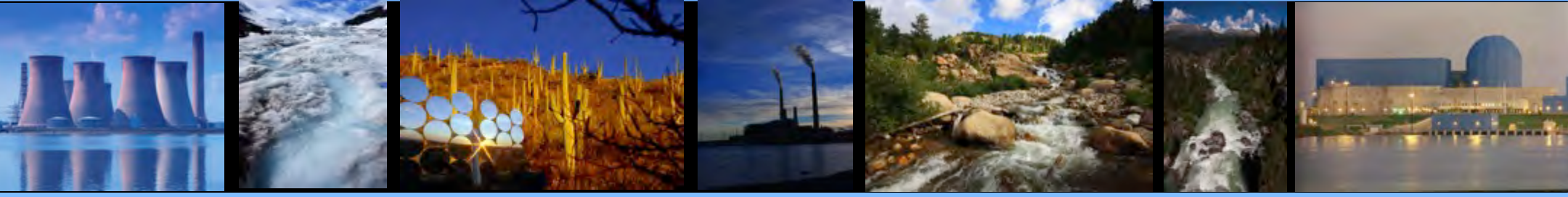
THE MOVE AWAY FROM COAL





- *EOL*
- *Gas Price*
- *Regulatory Exhaustion*
  - *PM_{10}, 316(b), NOX, SOX, MATS*
- *Climate Change,*

Longwall Mine, WV

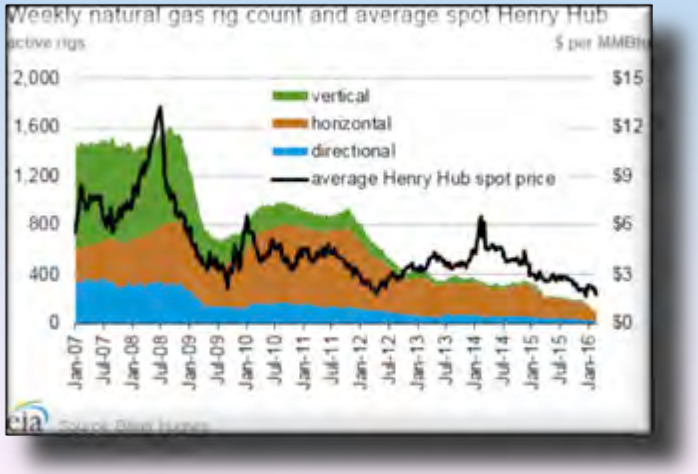


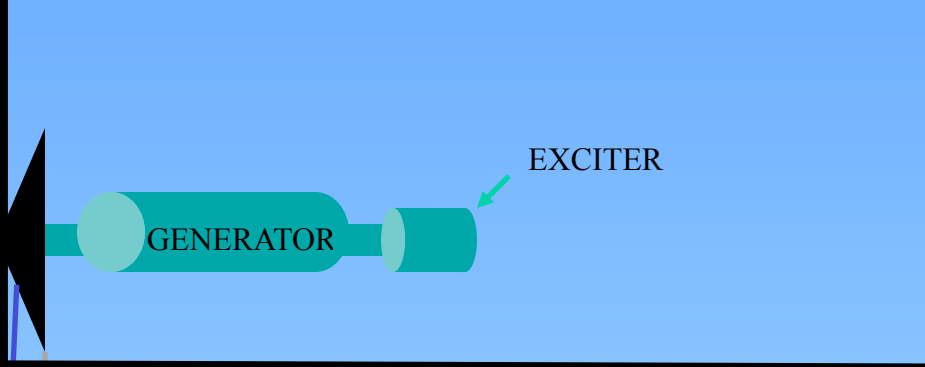
THE MOVE TO GAS

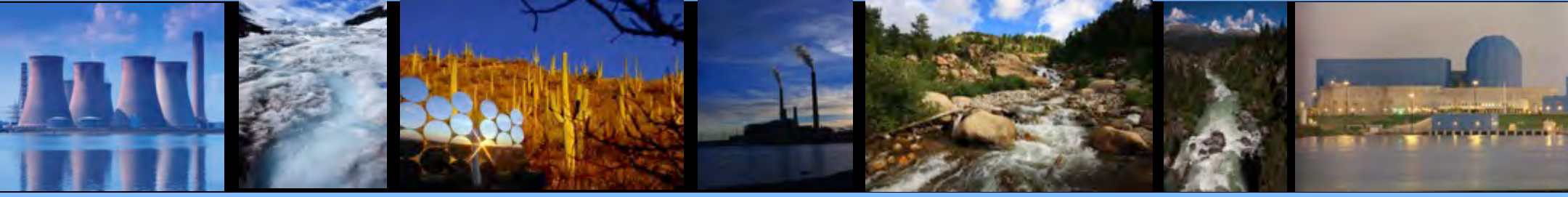
Efficiency <u>PLUS</u>

Simple

Cheap fuel

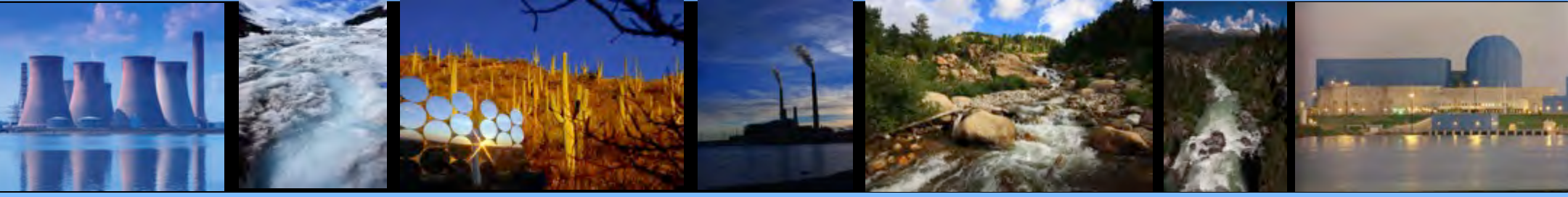



EXCITER
GENERATOR



THE TRANSITION TO RENEWABLES

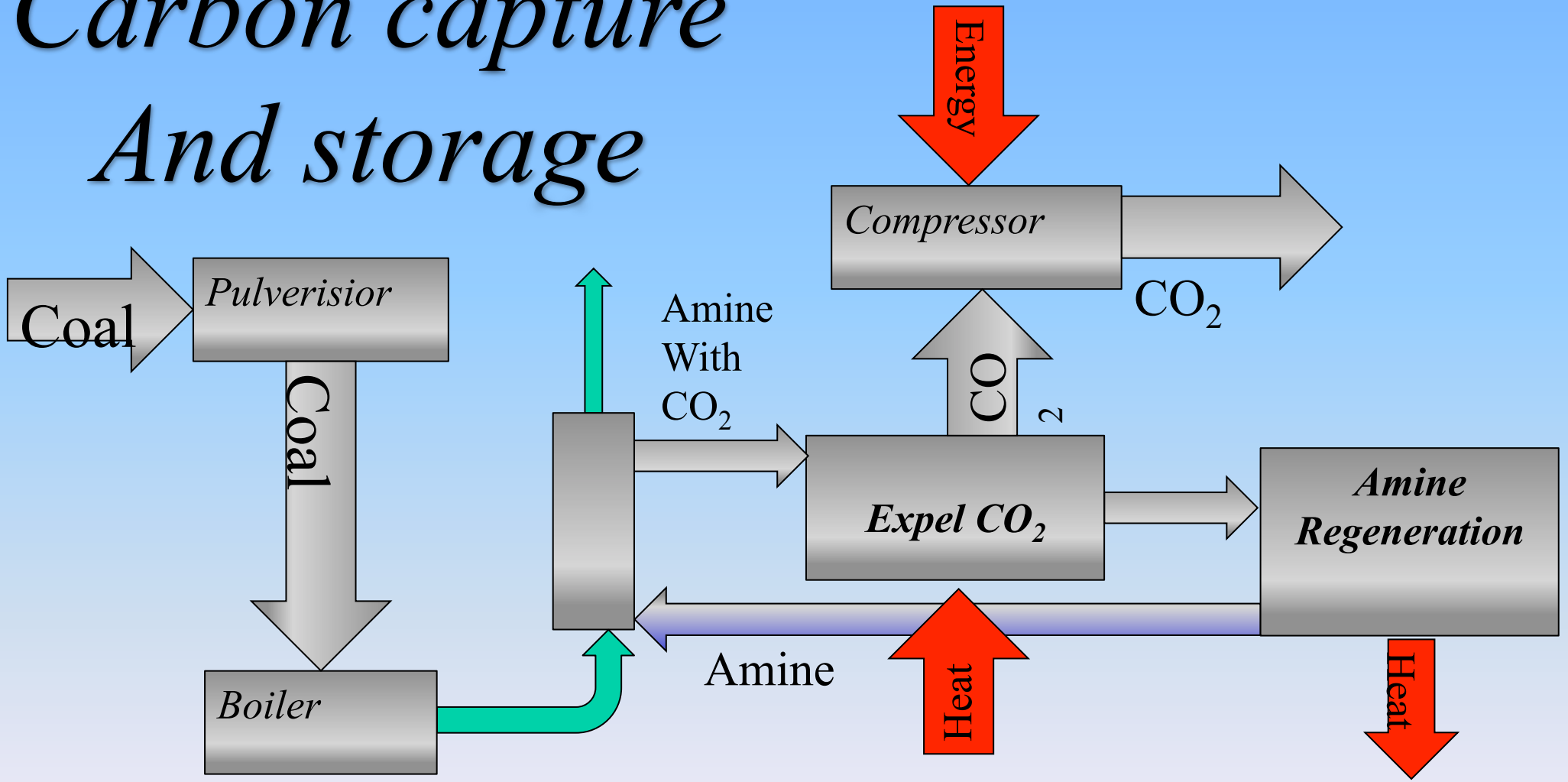
- ***Low Natural Gas Prices prices will hinder the transition from fossil fuel to renewables***
- ***But renewables have substantial costs above energy costs (Germany, Ontario)***

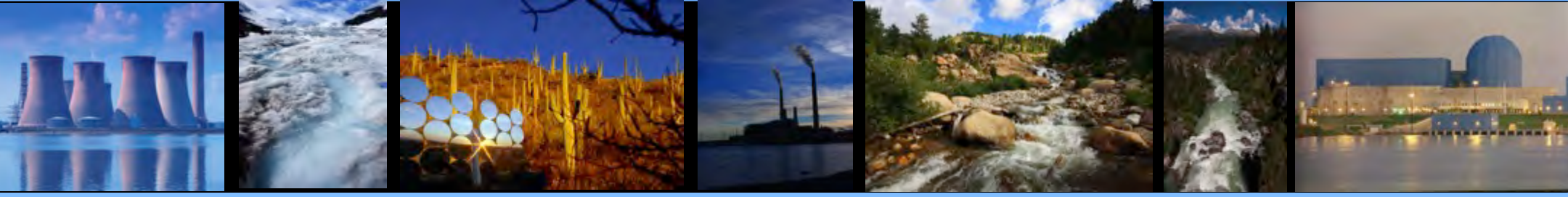


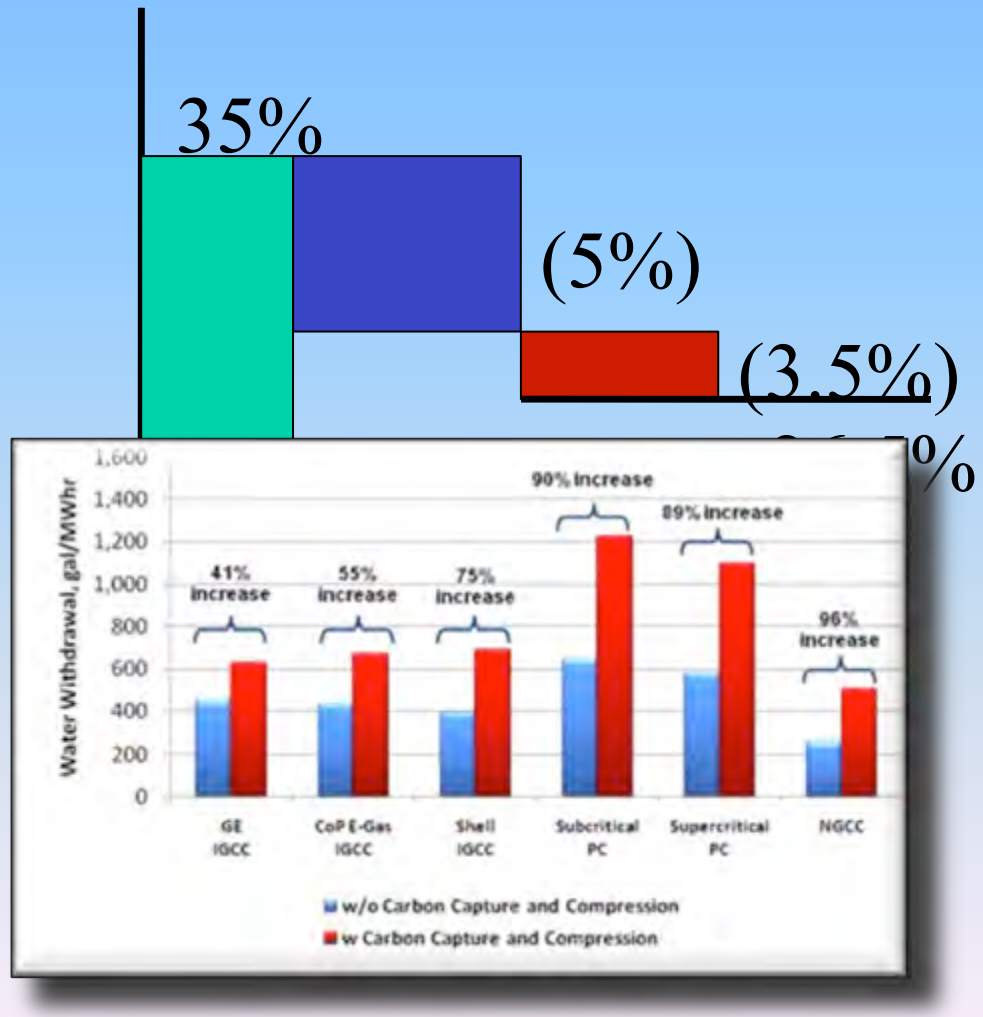
CARBON CAPTURE AND STORAGE

- *Carbon Capture and Storage will increase water and fuel use.*
- *In most CCS plans the CCS Unit takes 25-30% of the plant output to operate.*
- *Thus plants require more fuel and water and have more heat pollution as output.*
- *So the balance is between lower CO_2 and lower heat, water and fuel.*

Carbon capture And storage



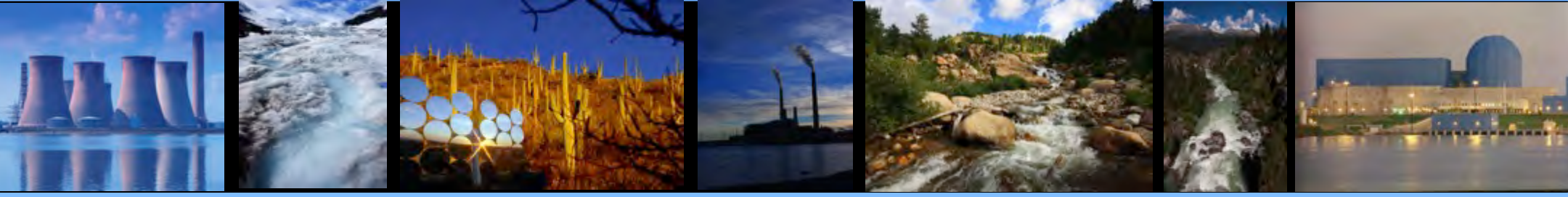


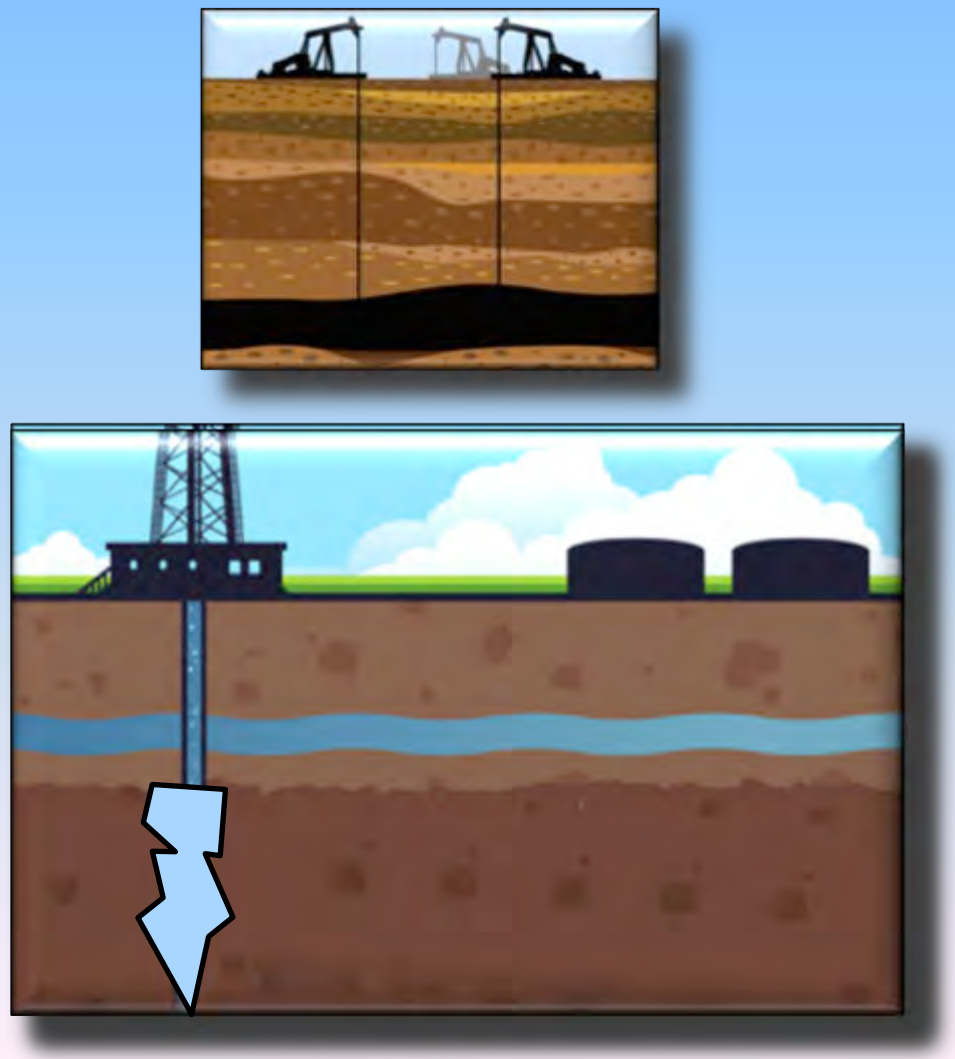


- *Base Efficiency*
- *Amine Heating / Regeneration*
- *Compression*
- *To produce the same out put requires about a 35% increase in plant size and an increase in coal burned of 70,000 pounds per hour (from 500,000 for a 500 MW Plant)*
- *Lower efficiency implies more waste heat and correspondingly more cooling water.*

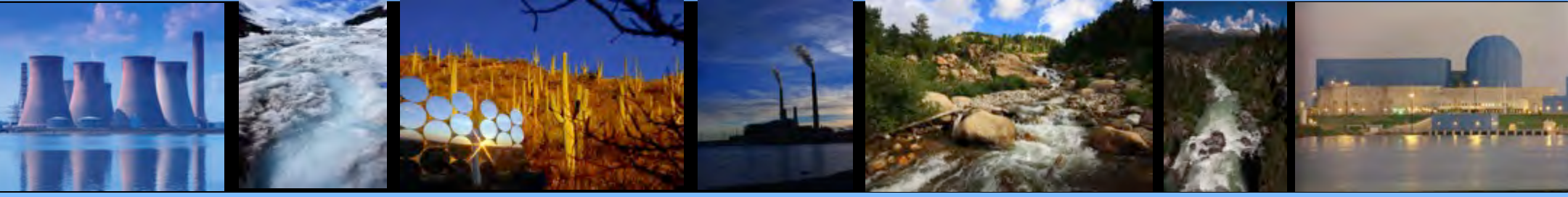
OIL AND GAS

FRACKING



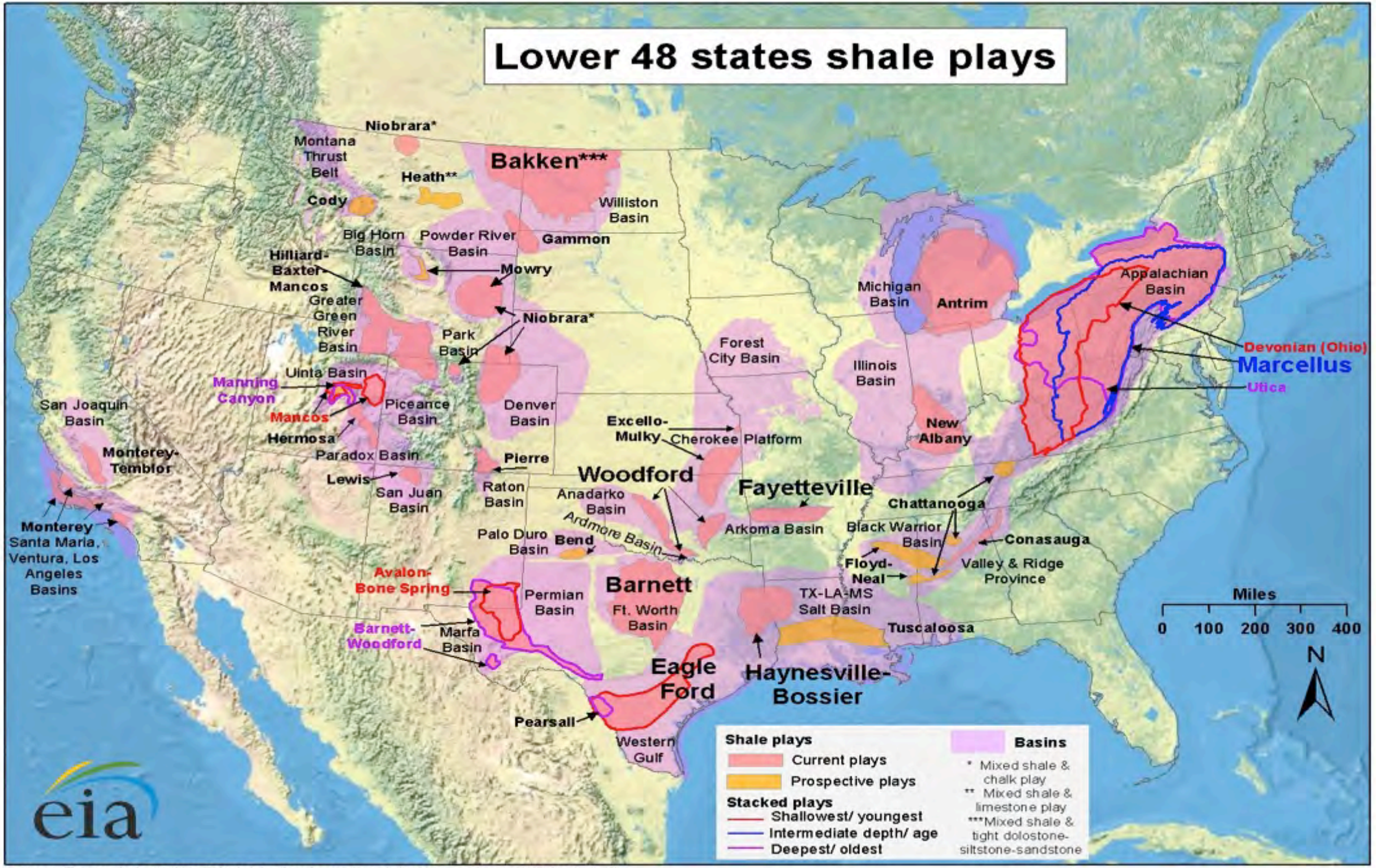


- ***Fracking (Fracturing) is the injection of high pressure liquids to break up the hydrocarbon bearing rocks to permit extraction.***
- ***Fracking has been around for years, it is not new technology.***
- ***What has changed is drilling technology.***
- ***Directional drilling has given us the ability to follow the seam for thousands of feet.***

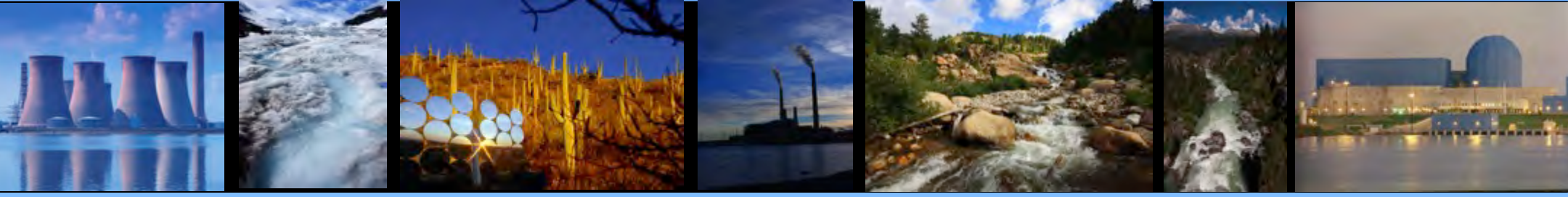


Fracking injects a mixture of water, chemicals and "proppants" into the well.

Proppants are tiny fragments (they can be very fine sand) that keep the cracks in the rocks open after the pressure is released.



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

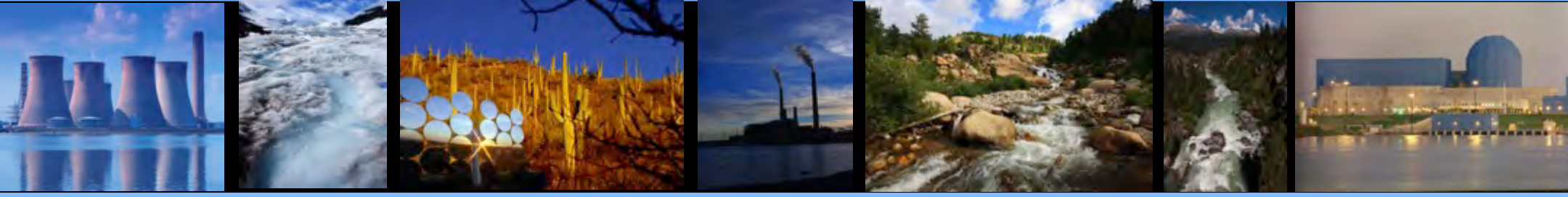


WHY ARE WE STILL DRILLING FOR GAS ?

WE AREN'T

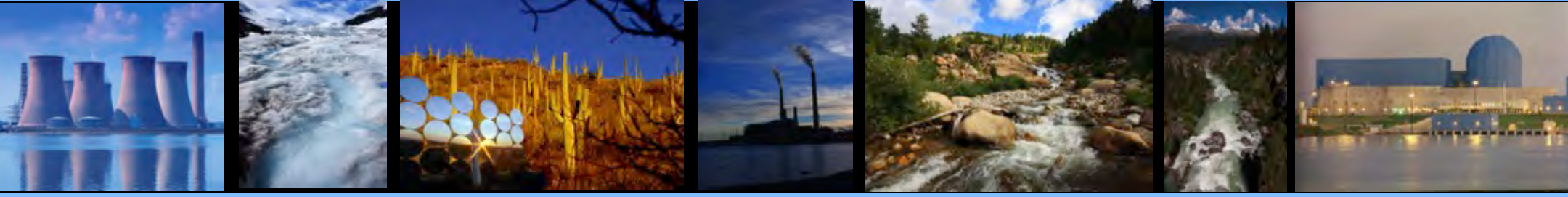
Noble Energy

- *"Hold by Production" clauses*
- *Most gas produced today is associated gas*
- *Gas drilling has already been reduced*
- *Most believe we will become a net oil exporter*
- *Fracked wells have a very high IFR leading to a quick payback.*
- *We don't have the transportation costs that others do.*



GALLONS PER FRACK JOB

• *Marcellus Shale*	*PA*	*4.5*	*million gallons*
• *Sandstone,*	*CO*	*2.7*	*million gallons*
• *Barnett Shale*	*TX,*	*2.8*	*million gallons*
• *Eagle Ford Shale*	*TX,*	*4.3*	*million gallons*
• *Haynesville Shale*	*TX*	*5.7*	*million gallons*
• *Bakken Formation*	*ND,*	*1.5*	*million gallons*
• *Horn River Shale*	*BC*	*15.8*	*million gallons*

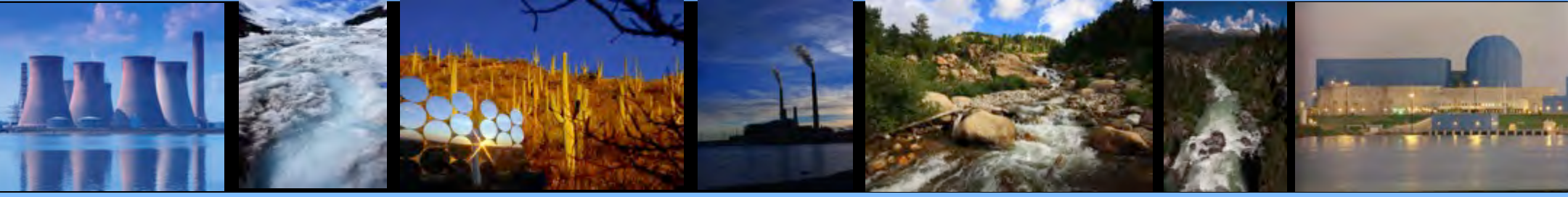


FRACKING

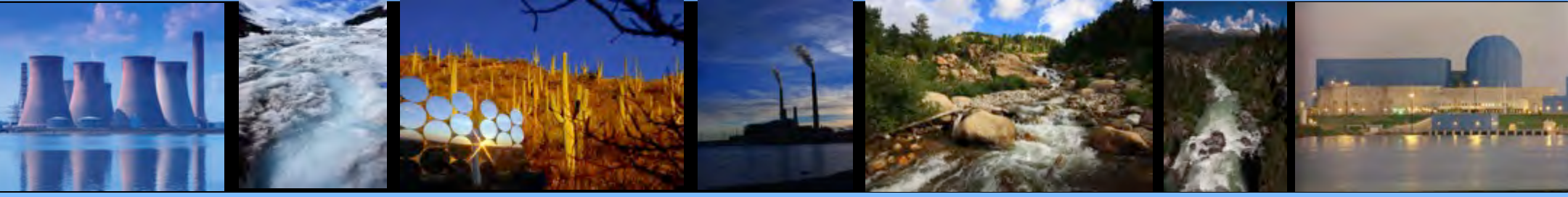
- ***Frack water uses less than 1% of U.S. total water consumption and, according to a Duke University study, is less water intensive than coal mining on a per BTU basis.***

Fracking
Patina Oil and Gas
DJ Basin, Colorado

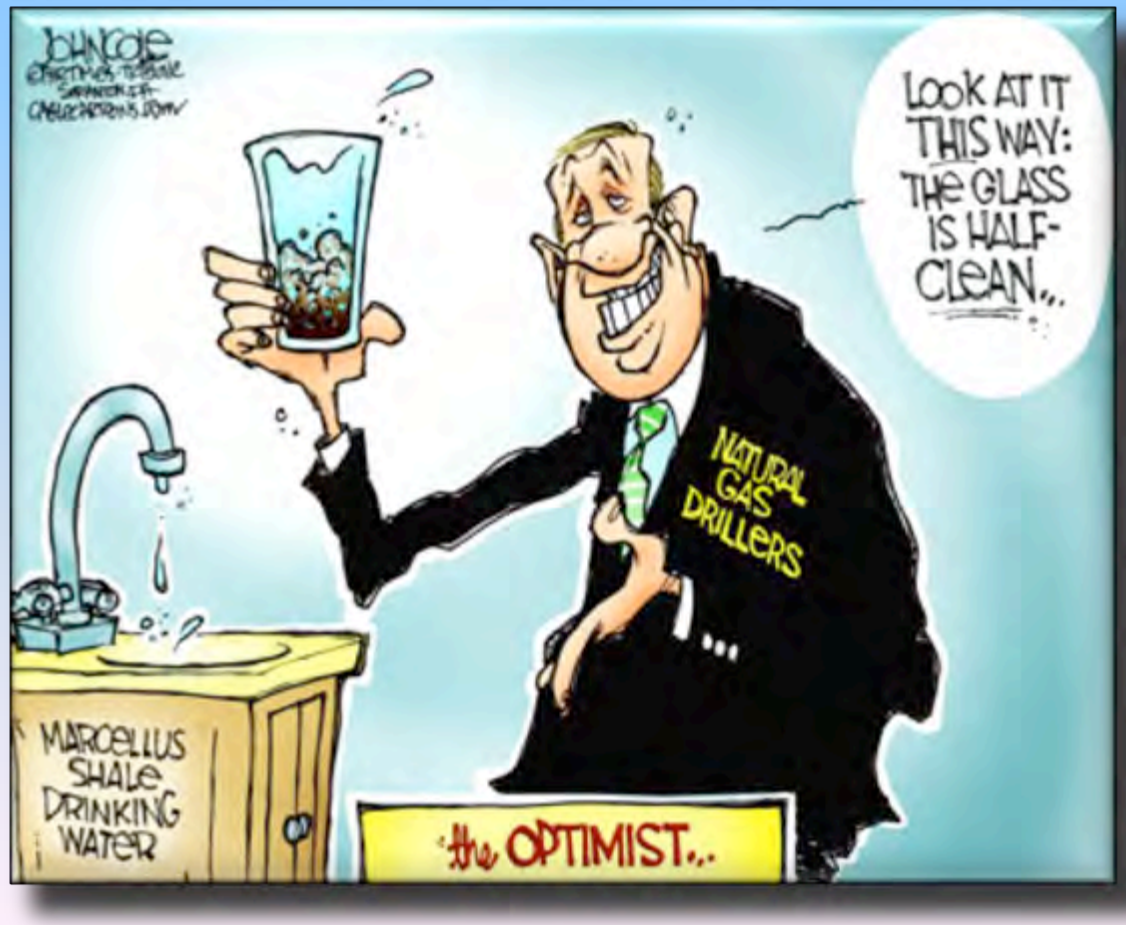
- ***A major concern with fracking is wastewater.***
- ***Seawater has about 20,000 mg/l TDS.***
- ***Frack water has 40,000-450,000 TDS many of which are hazardous.***



- *Many feel that oil and gas drilling release huge quantities of methane one of worst greenhouse gases.*
- *Others point out however that natural gas plants emit less CO_2 than coal plants to compensate.*
- *The amount of methane emitted by oil and gas drilling is controversial.*

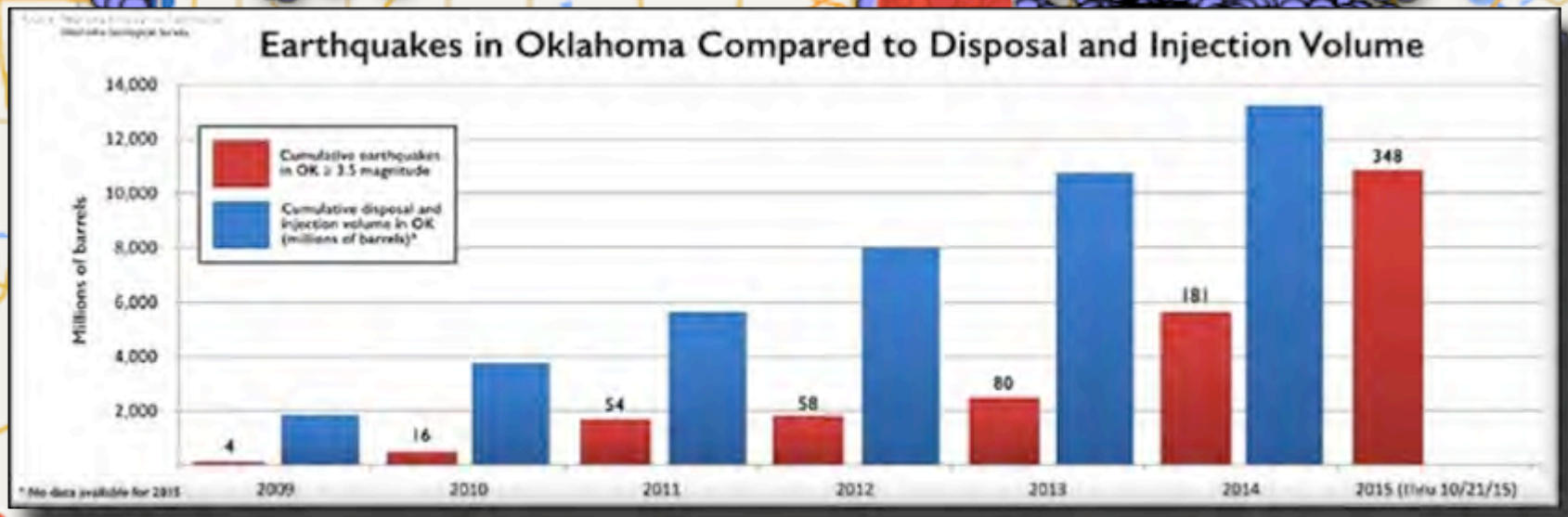


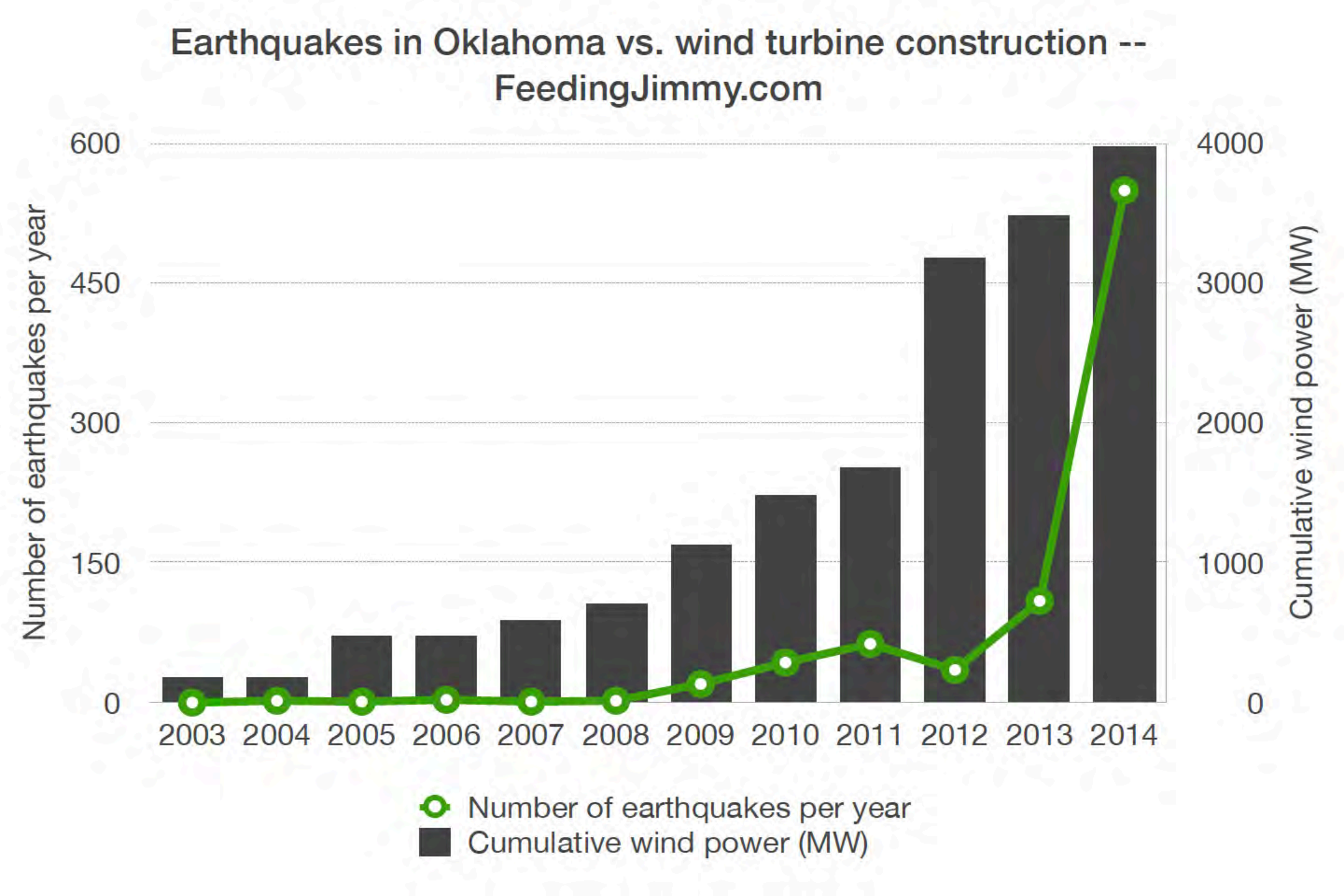
POLLUTION FROM FRACKING

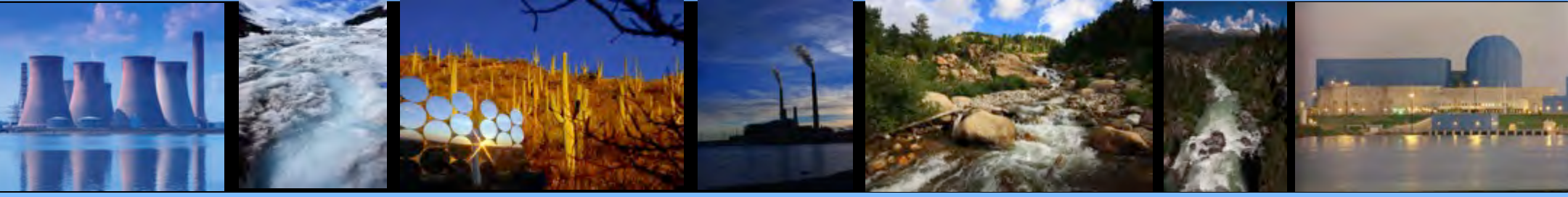


- ***Fracking has also been implicated in causing pollution in water wells.***
- ***Opponents point out cases where methane and frack chemicals have been found in groundwater from water wells.***

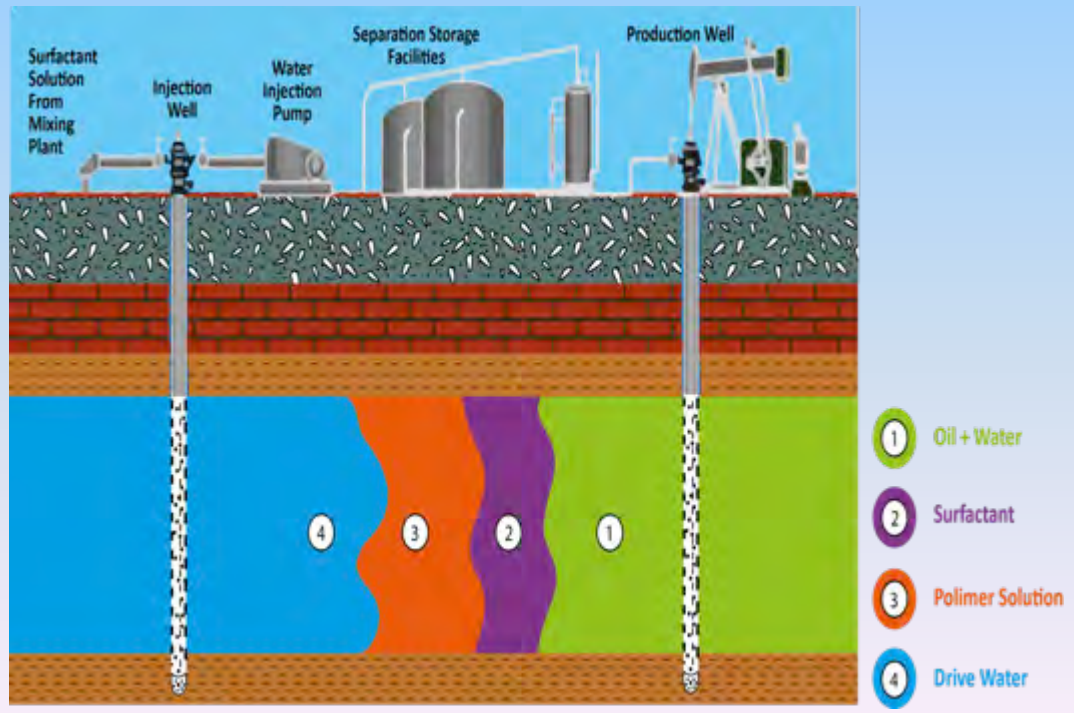
Produced Water



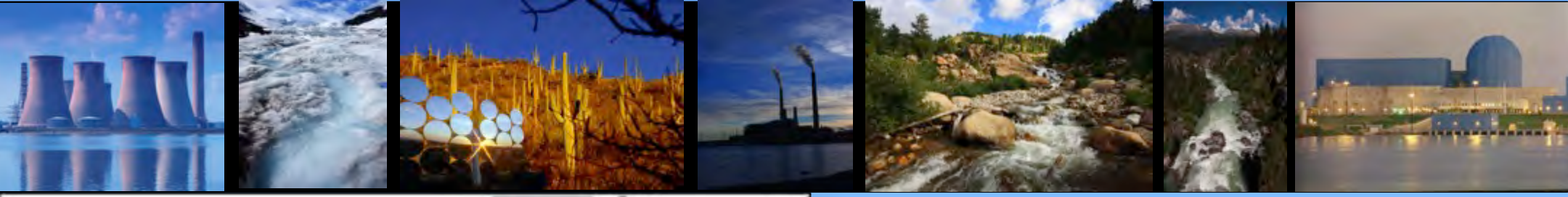

Earthquakes in Oklahoma vs. wind turbine construction -- FeedingJimmy.com
600
450
300
150
0
Number of earthquakes per year
4000
3000
2000
1000
0
Cumulative wind power (MW)
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Number of earthquakes per year
Cumulative wind power (MW)

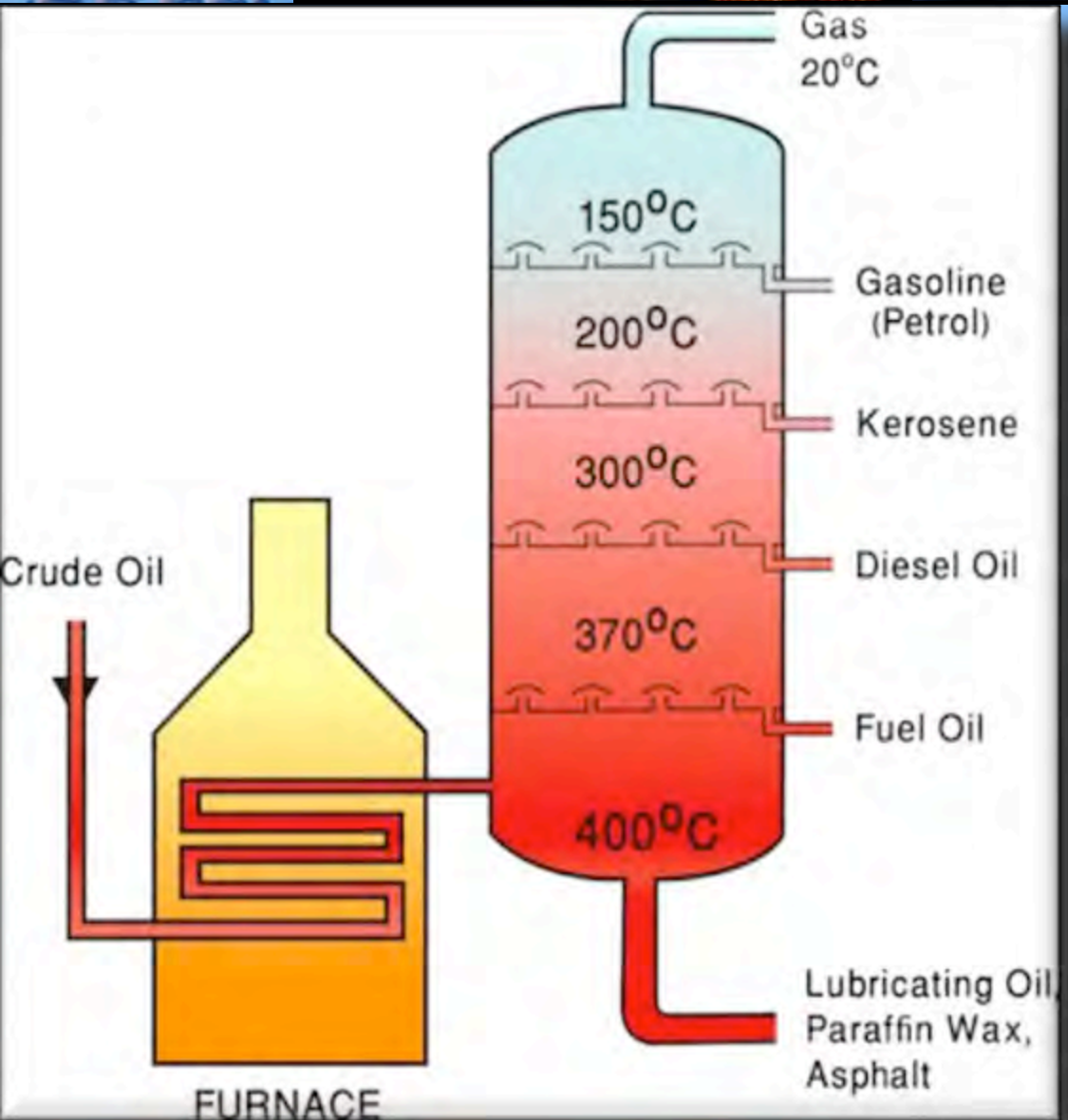


ENHANCED OIL RECOVERY



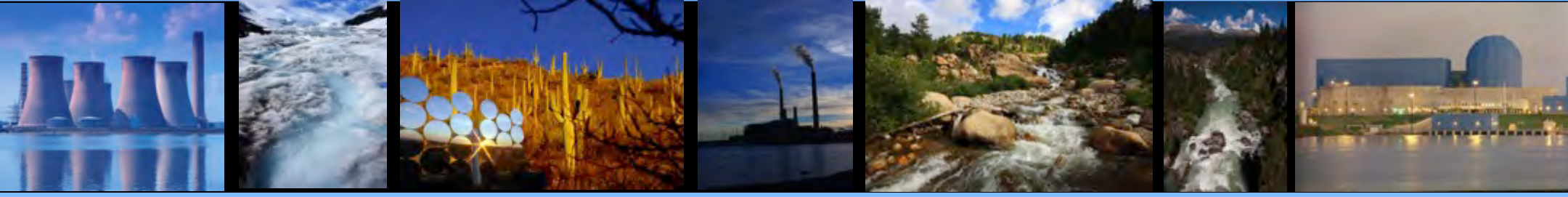
- ***Conventional drilling also uses water for Enhanced Oil recover (EOR)***
- ***Water and chemicals are pumped underground to force oil to the surface***





Refineries use about 1 to 2.5 gallons of water for every gallon of product. In the United States, which refines nearly 800 million gallons of petroleum products per day we consumes about 1 to 2 billion gallons of water each day to produce fuel (USDOE, 2006).

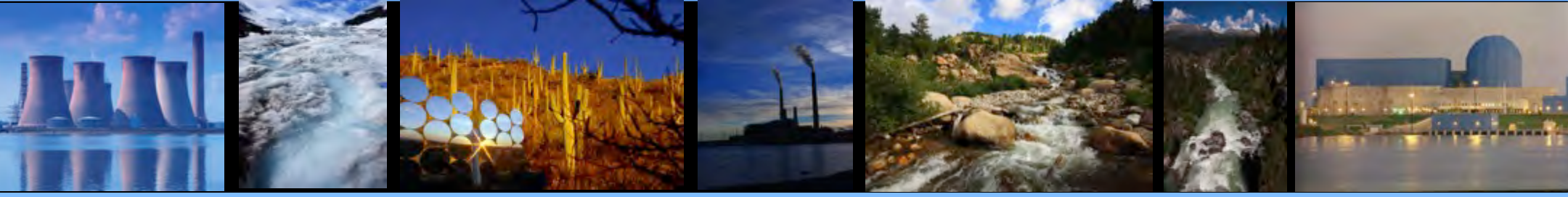
BIOFUELS



- *Producing one liter of ethanol from sugarcane takes nearly 3,500 liters of irrigation water in India,*
- *but just 90 liters of irrigation water in Brazil.*
- *In China, it takes 2,400 liters of irrigation for maize to yield a liter of ethanol.*
- *Irrigation of corn for biofeedstock production withdraws about 2 BGD*
- *(Source DOE).*

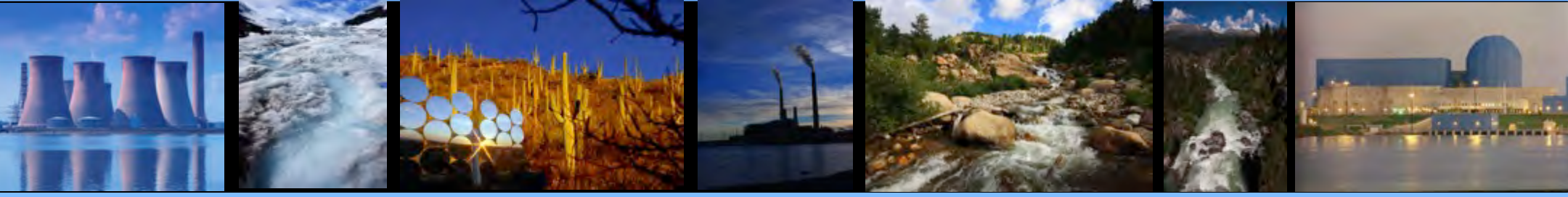
Fuels Production Water Intensity (gal/mile).

	Consumption		Withdrawal	
	Extraction/ Growing	Processing/ Refining	Extraction/ Growing	Processing/ Refining
Gasoline from Liquid Petroleum	0–0.25	0.05–.1	0–0.25	0.6
Diesel from Liquid Petroleum	0–0.18	0.04–0.09	0–0.18	0.4
E85 from Irrigated Corn Grain	3.0–84	0.1–0.3	6.7–110	0.3–0.4
E85 from Non-Irrigated Corn Grain	0.004–0.006	0.1–0.3	0.08–0.1	0.3–0.4
E85 from Irrigated Corn Stover	2.4–45	0.2–0.3	5.2–64	0.35
E85 from Non-Irrigated Corn Stover	0.003	0.24–0.25	0.7	0.35
Biodiesel from Irrigated Soy	0.6–24	0.002–0.01	1.1–26.2	0.007–0.03
Biodiesel from Non-Irrigated Soy	0.002–0.01	0.002–0.01	0.01	0.007–0.03



BIOFUELS VS. FRACKING

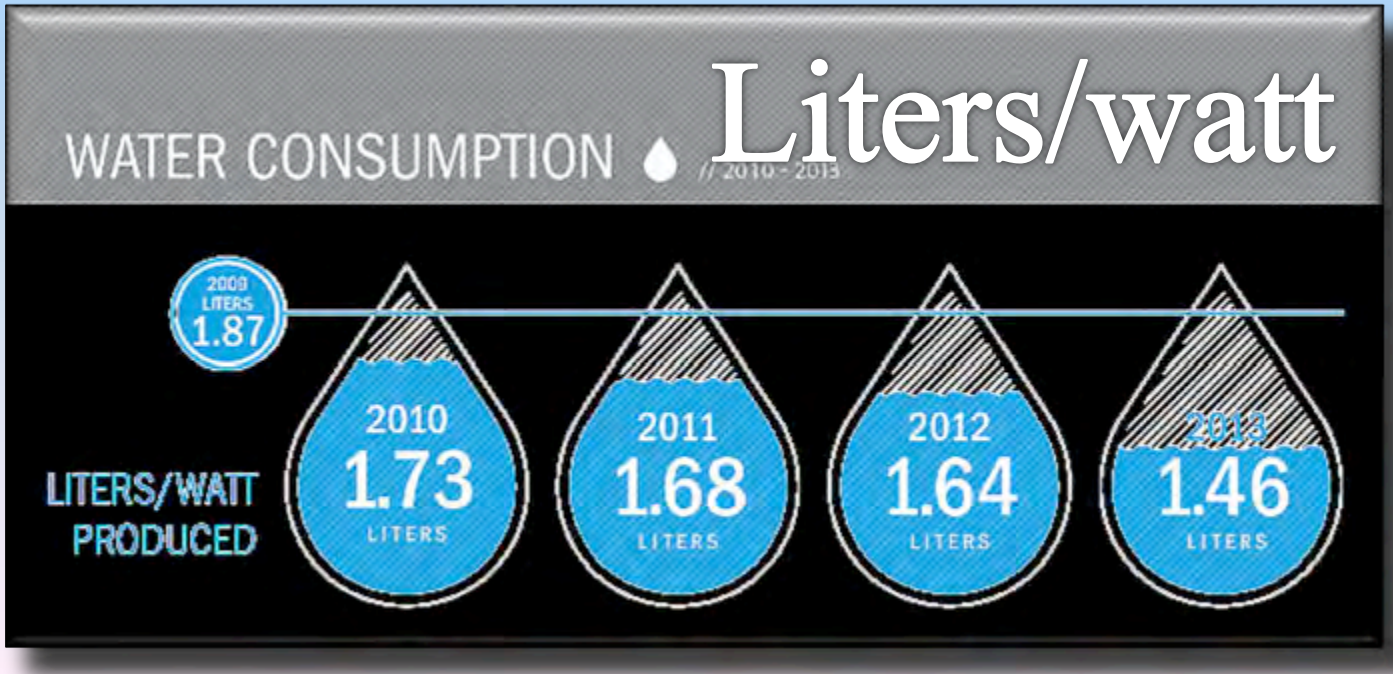
- ***Biofuels require water just as EOR, coal processing and fracking require water.***
- ***Frack fluids consume about (0.2 BG/D DOE WENR) vs. 2.0BG/D for U.S. biofuels***



Water Used in Producing Solar

First Solar

Liters/watt	1.46
Gal/Liter	3.857
gal/watt	0.379
Gal/kw	378.541
Days/Year	330
Hrs/Day	8
Hrs/Year	2,640
Years	10
KWH	26,400
Gal/KWH	0.014



Land Use in Solar

DOE 8.9Acres per mw

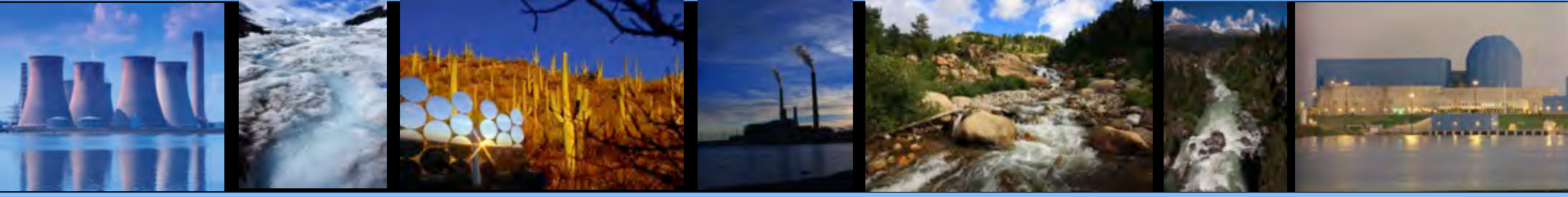
1,000 mw=139 square miles

= 11miles X 11miles

Rooftop.

Mine Tailings

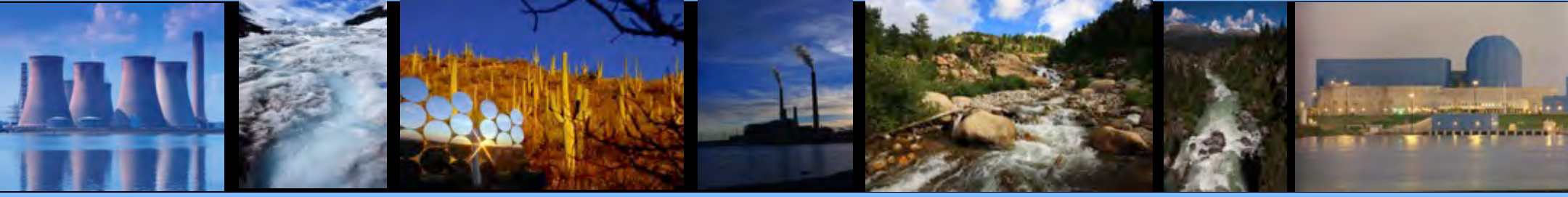
Interstate Medians



ELECTRICITY USE IN WATER

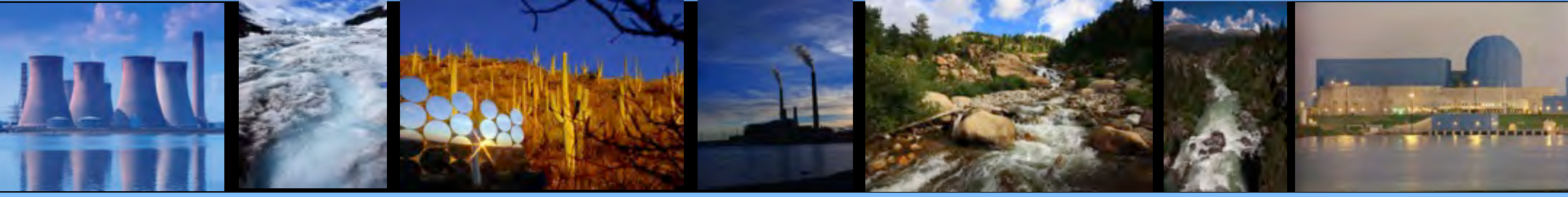
Central Arizona Project
Picacho Pumping Plant

- ***As the electric industry is the largest water user in the United States it only seems fair that the water industry is the largest user of electricity consuming about 13% of the nation's electricity.*** [71]
- ***Water related energy use in California consumes 19% of the state's electricity***
- ***The main use is pumping***

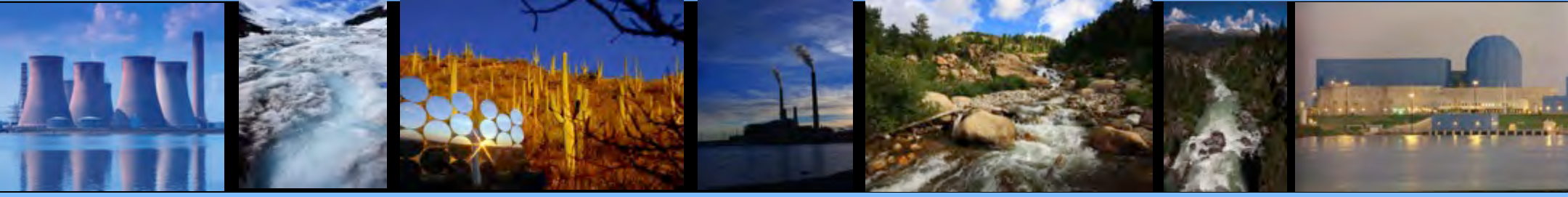


NON REVENUE WATER

- *In the United States about 20% of water is "non-revenue" water.*
- *The main determinant of NRW is system age, Eastern utilities have far higher NRW than Western Utilities.*
- *City of Philadelphia FY2012*
  - *Total 237.1 mg/d*
  - *Billed 152.6 mg/d*
  - *NRW 84.5 mg/d*



- ***In some Eastern water systems over 30% of the water is lost thus 30% of their electricity being wasted.***
- ***Thus at the 20% NRW average the 13% of the U.S. electricity used by these systems results in a waste of 2.6% of the Nations electricity.***
- ***Hard to fix as millions of tiny leaks.***



ELECTRICITY IN WASTEWATER

Wastewater Treatment – Veolia

- ***Use in wastewater treatment is also high***
- ***The energy used in wastewater treatment is about 60% of the energy used in water processing and delivery.***

THE WORLD

Cape Verde

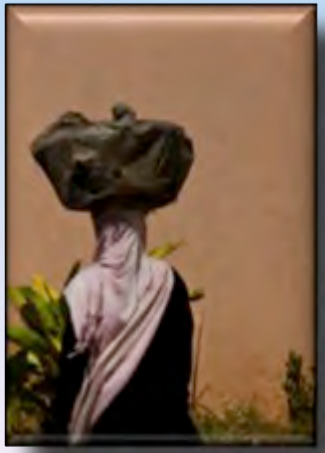
Egypt

Zanzibar

Oman

China

Sri Lanka

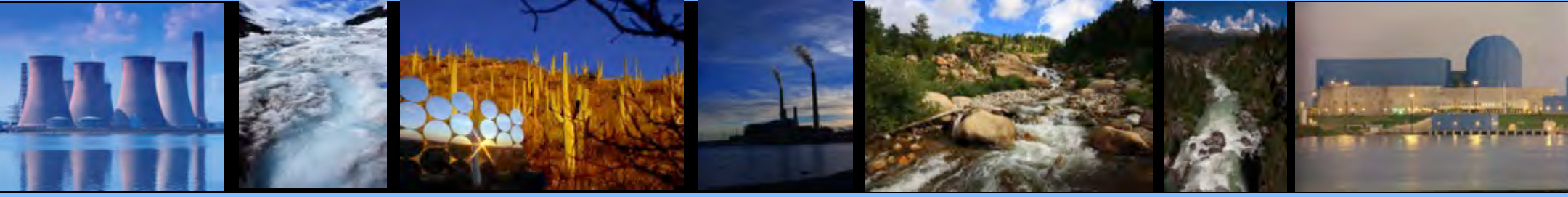


Kenya

India

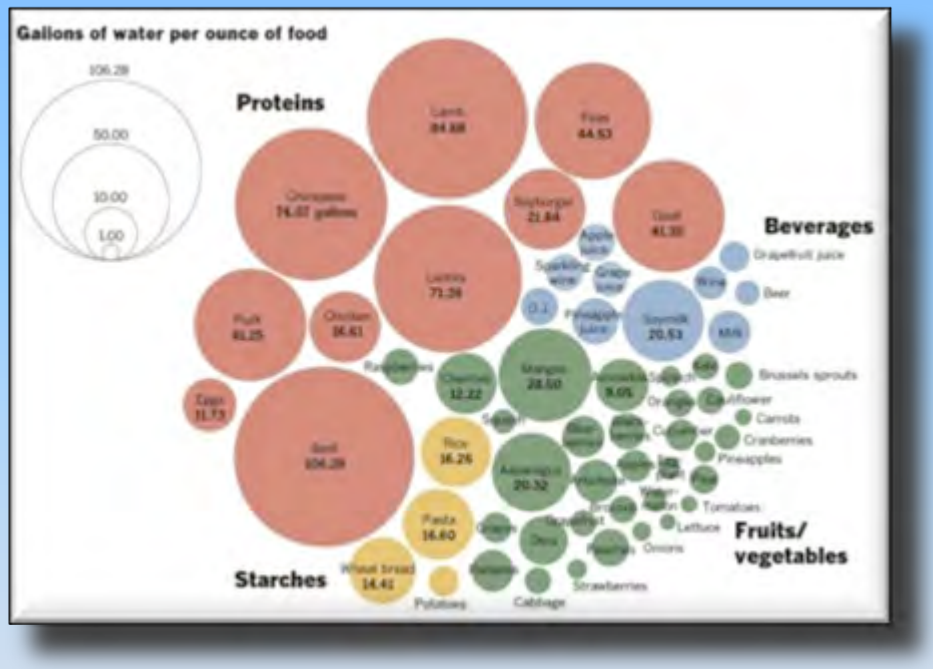
Tibet

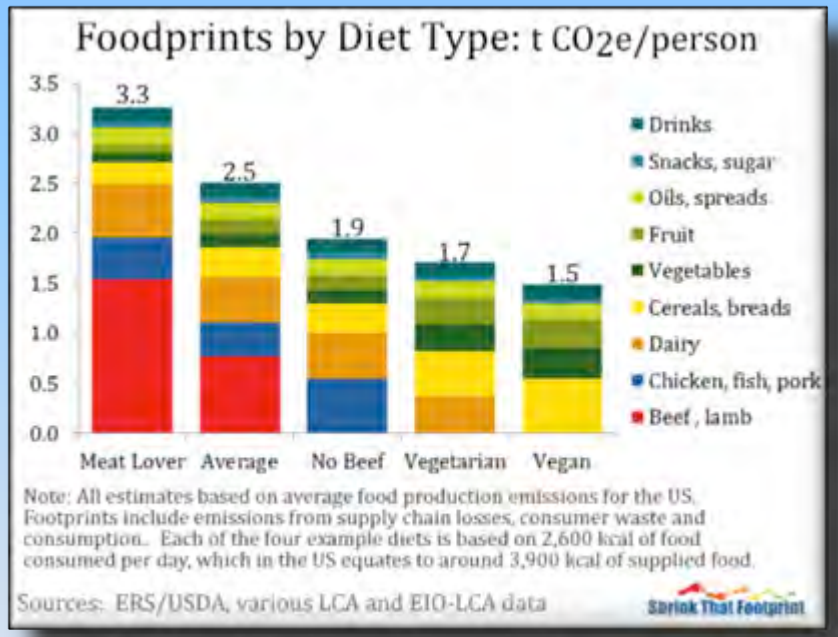
Bhutan



- ***The largest determinants of water use for energy (and energy use for water) in the future will be;***
- ***population growth and,***
- ***people moving up the economic ladder and acquiring;***
- ***energy using devices and,***
- ***different preferences in food***

WATER FOOTPRINT OF FOODS

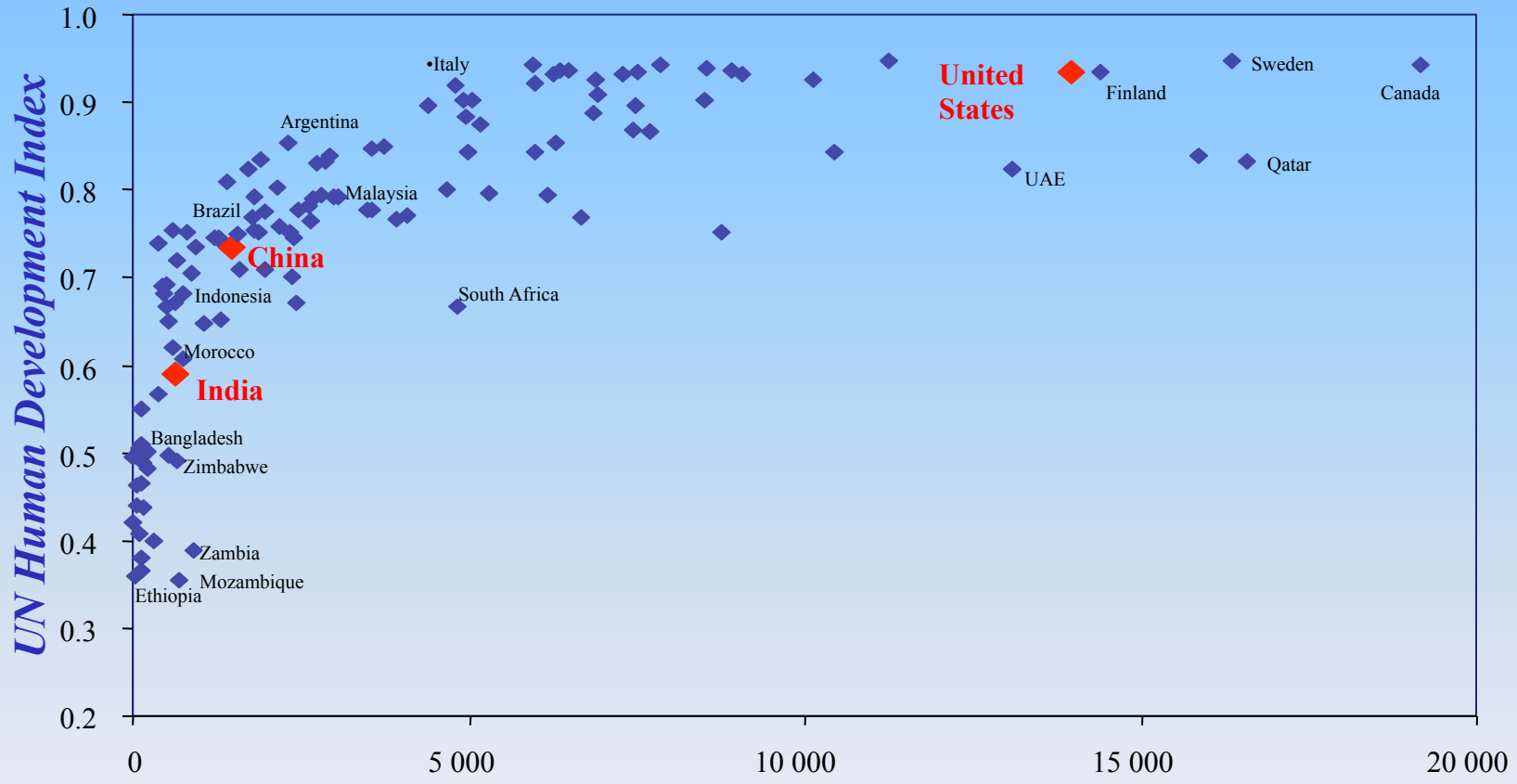




Fertilizer (Energy)

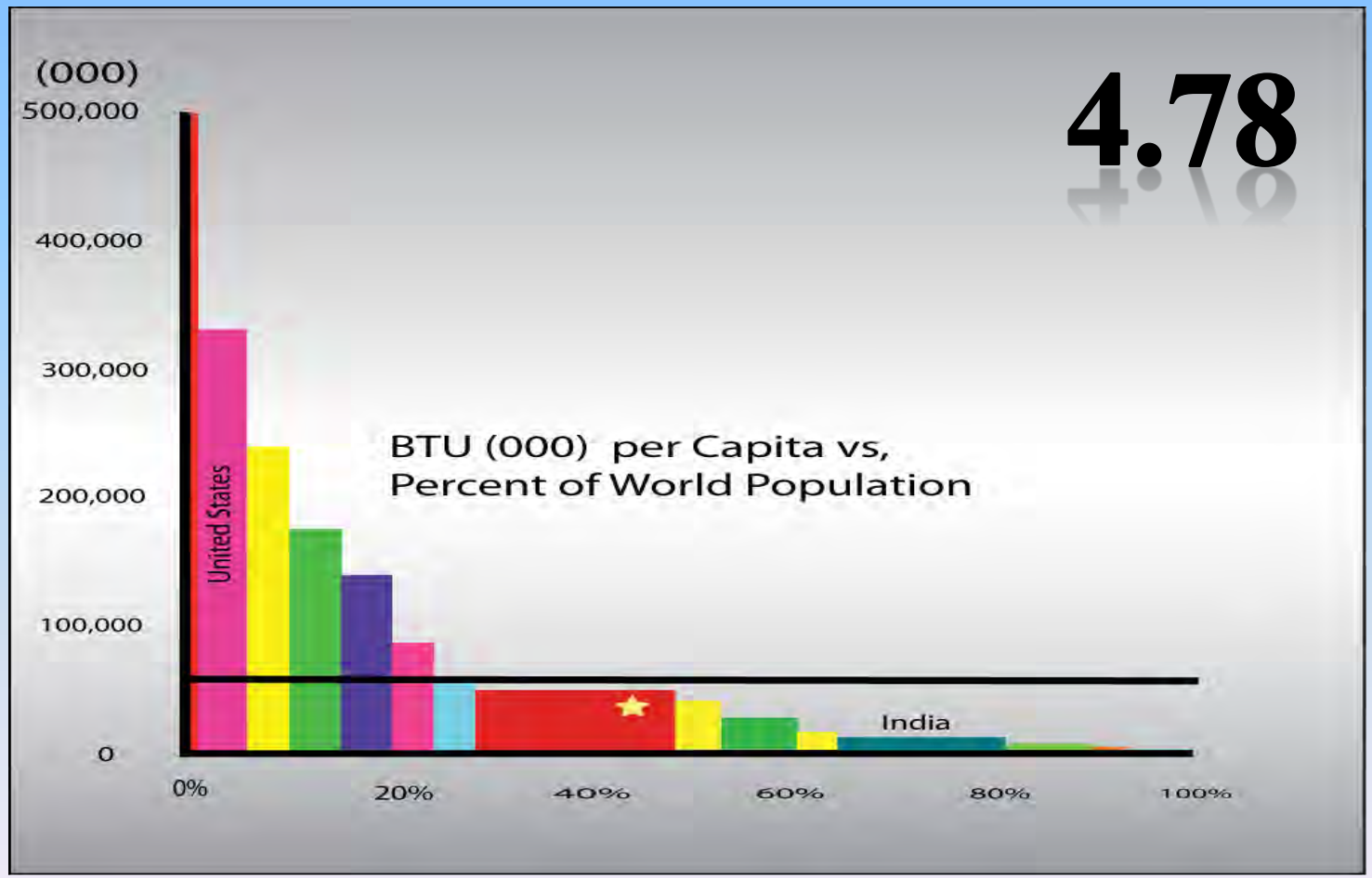
Irrigation

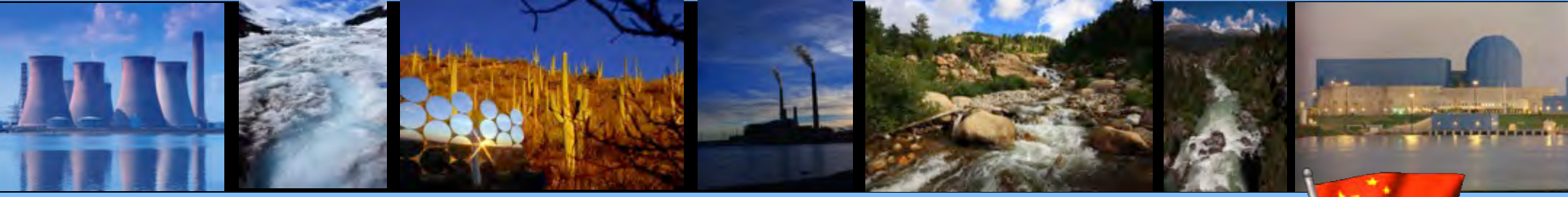
GLOBAL ELECTRICITY USE



Electricity Use

4.78

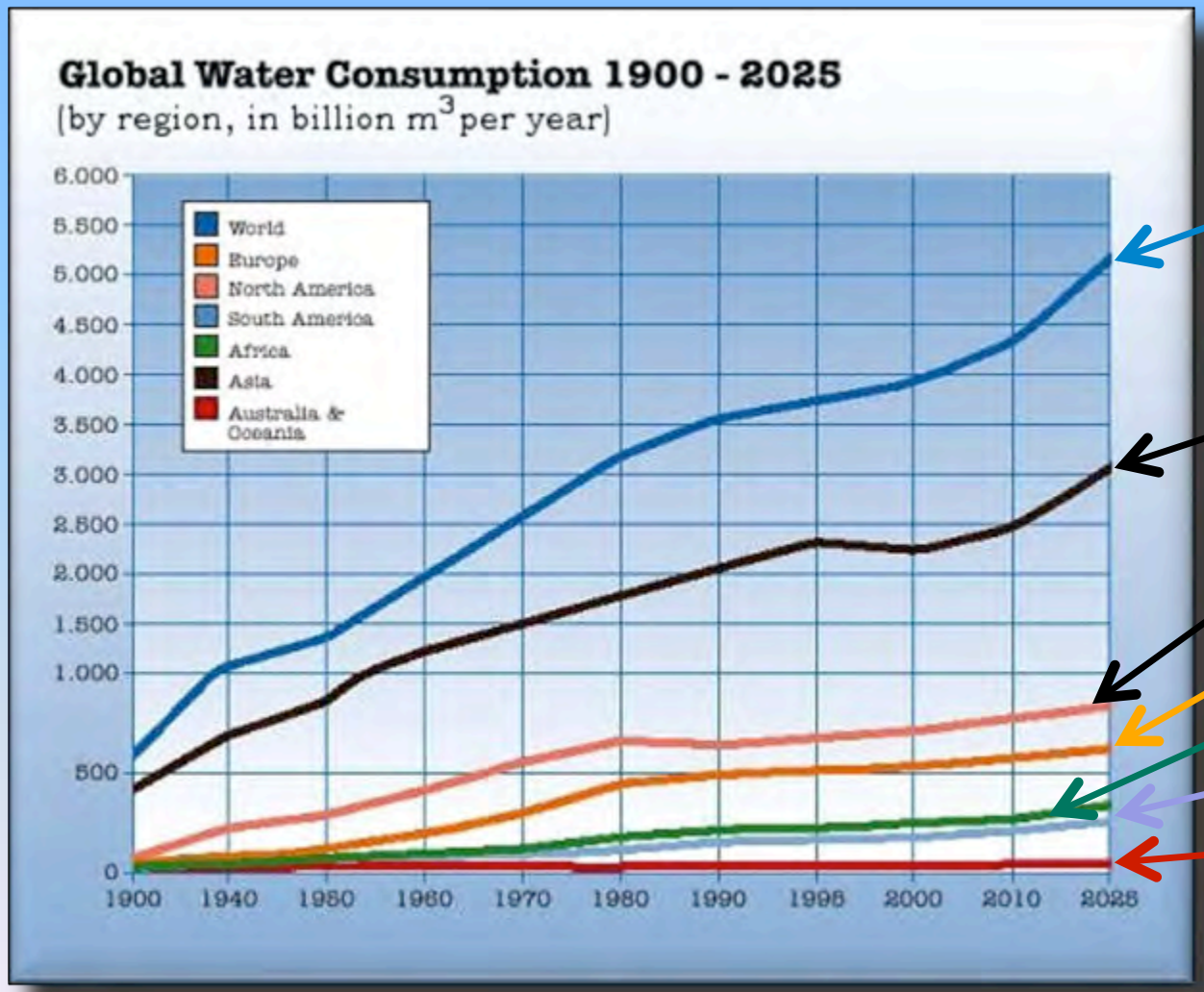

(000)
500,000
400,000
300,000
200,000
100,000
0
United States
BTU (000) per Capita vs,
Percent of World Population
India
0%
20%
40%
60%
80%
100%



- ***Assume China has 130mv/1,000 people***
- ***To get to 200 takes another 70mv/1,000***
- ***Or 70,000mv/million***
- ***Or 70,000,000mv/ billion***
- ***For 1.3 billion people that's 91,000,000 motor vehicles to get up to the level of Iran and Uruguay (but below Bosnia Herzegovina (214))***

Number	Country	Motor vehicles/ 1000
1	San Marino	1,263
2	Monaco	842
3	Liechtenstein	826
4	United States	809
	……	
97	Panama	132
98	China	128
99	Dom. Republic	128

GLOBAL WATER CONSUMPTION
BILLION CUBIC METERS PER YEAR



WORLD

ASIA

N. AMERICA

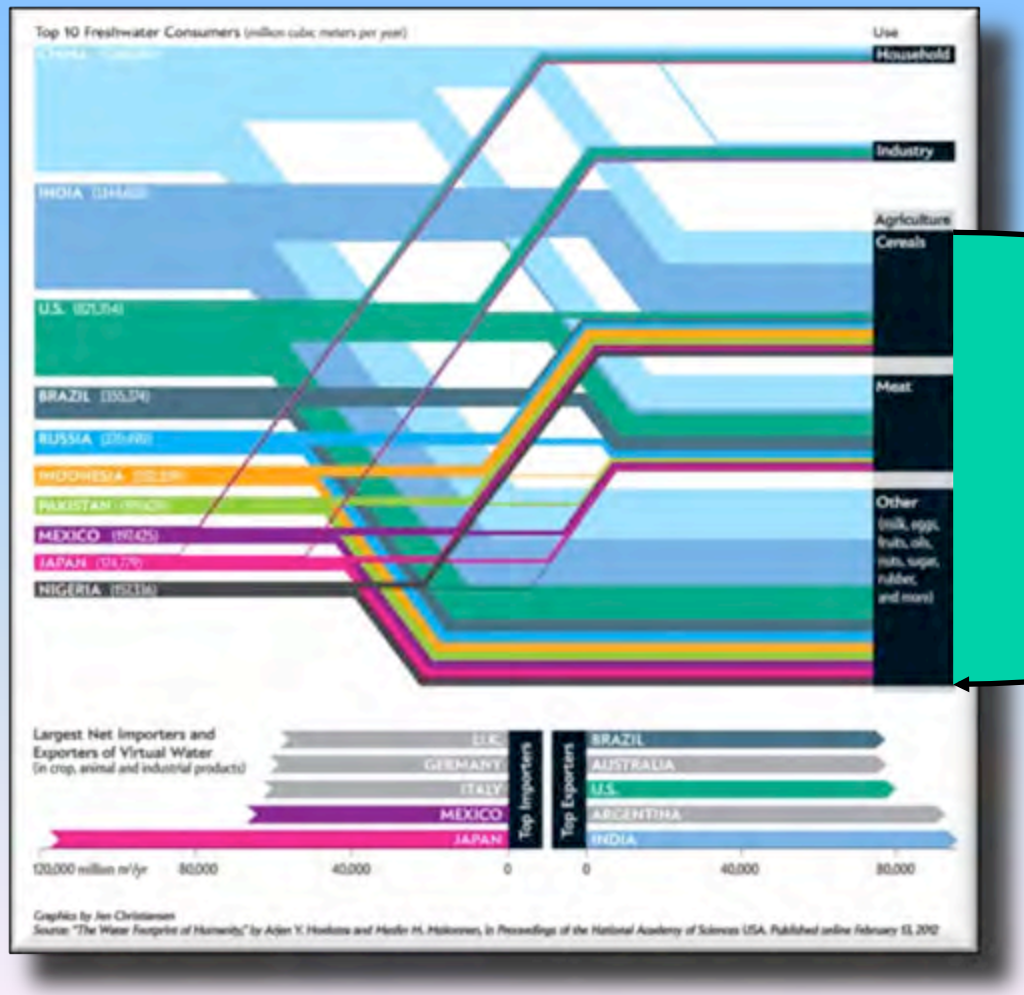
EUROPE

AFRICA

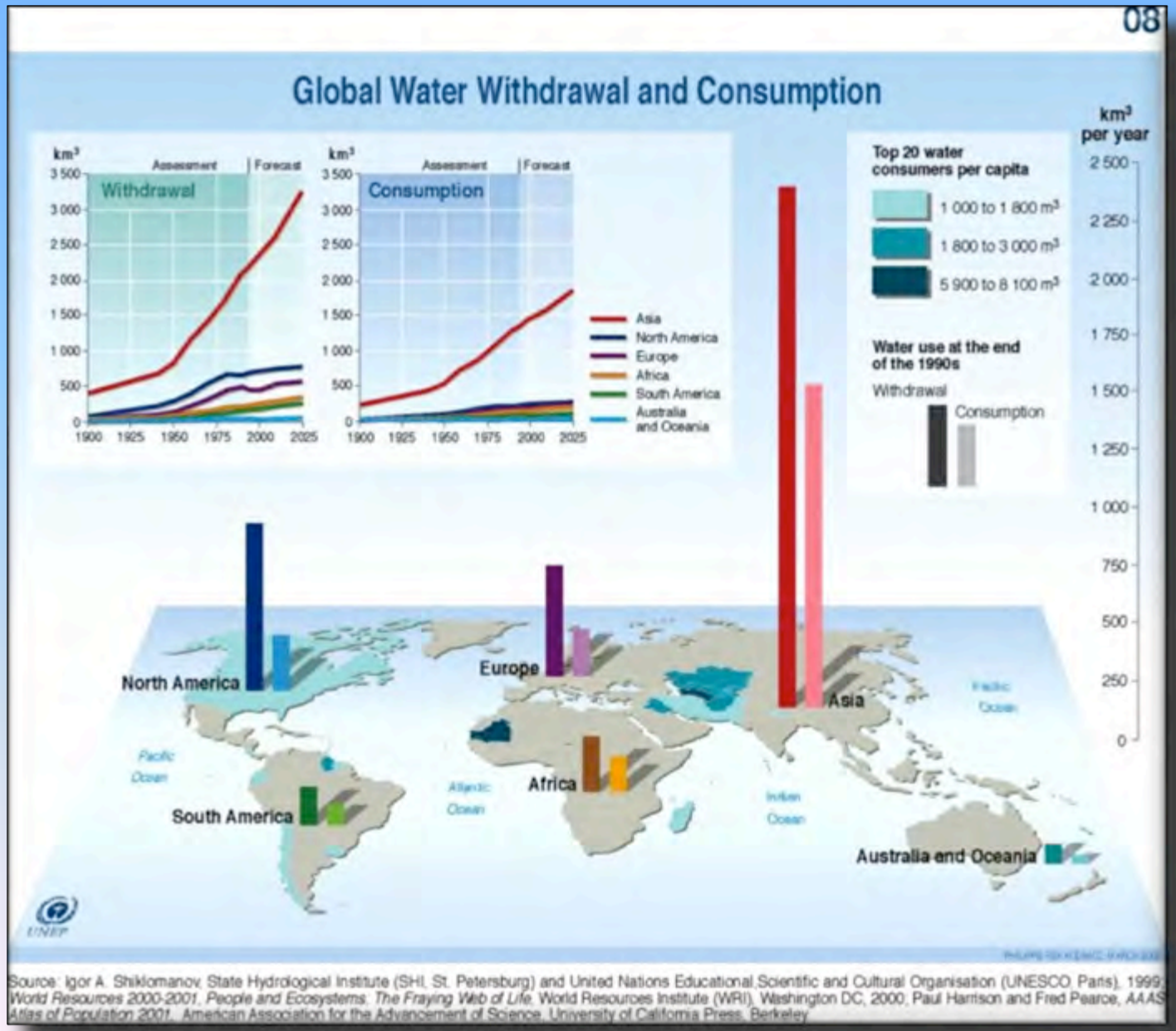
S. AMERICA

OCEANIA

WATER CONSUMPTION BY COUNTRY AND END USE

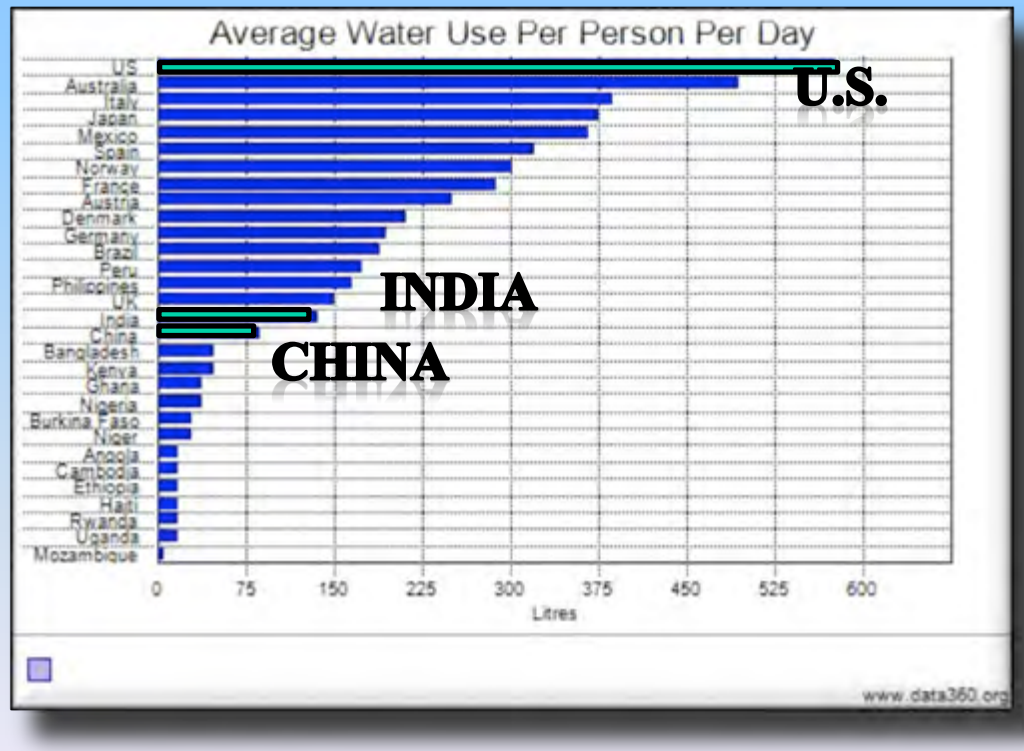


AGRICULTURE FOOD PRODUCTION

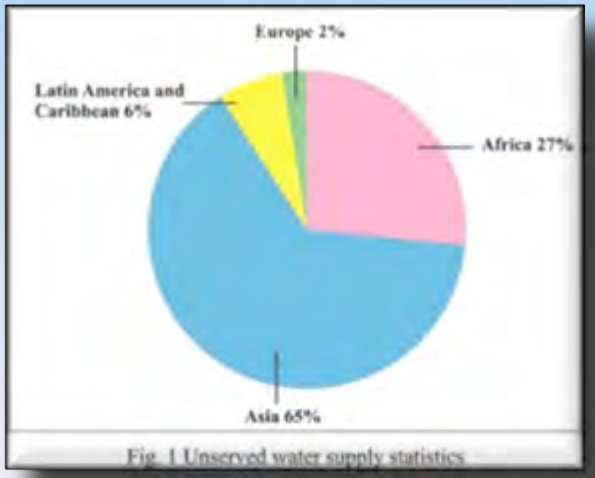


Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999; *World Resources 2000-2001, People and Ecosystems, The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000; Paul Harrison and Fred Pearce, *AAAS Atlas of Population 2001*, American Association for the Advancement of Science, University of California Press, Berkeley

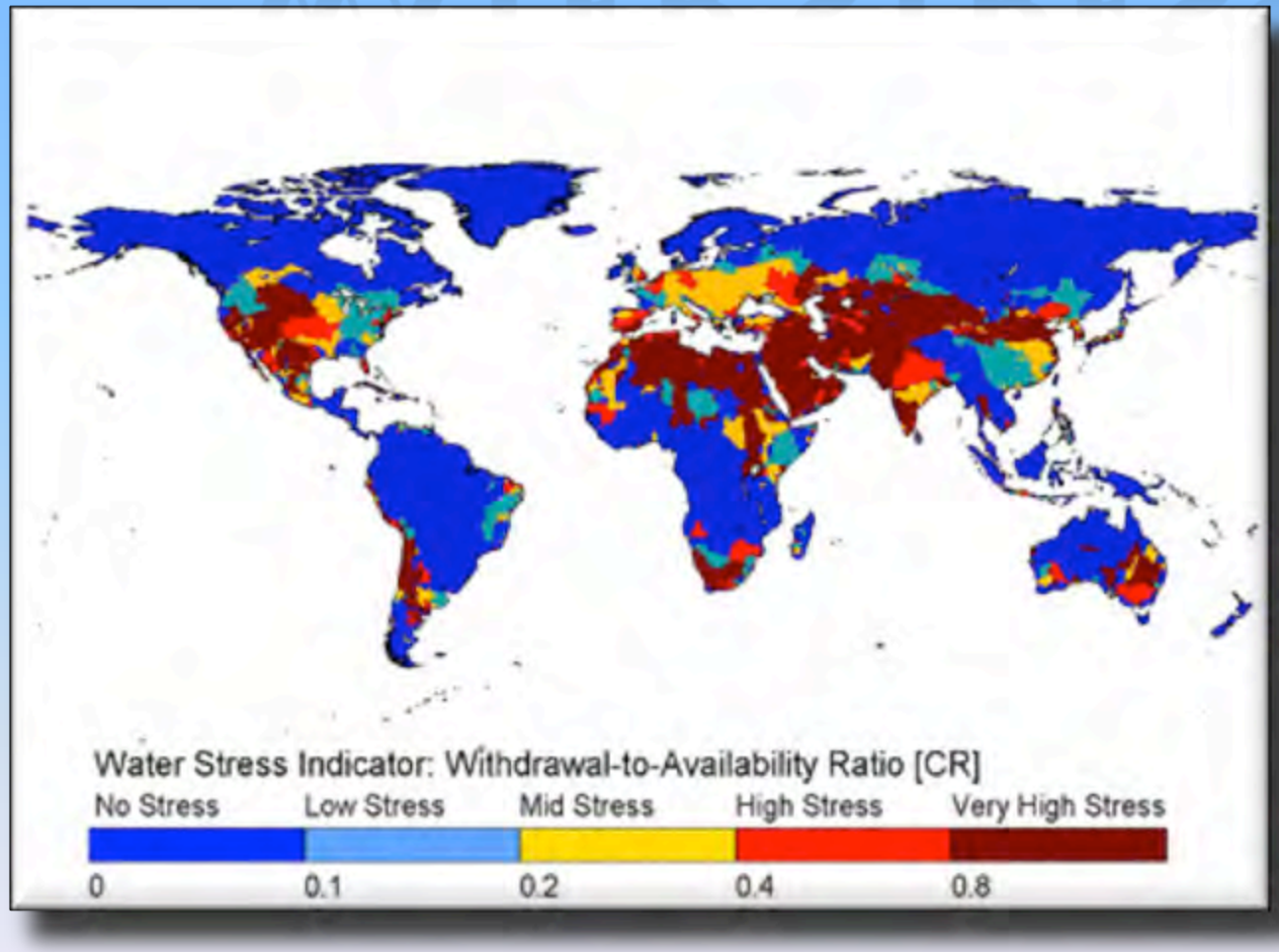
CHINA WATER CONSUMPTION PER CAPITA



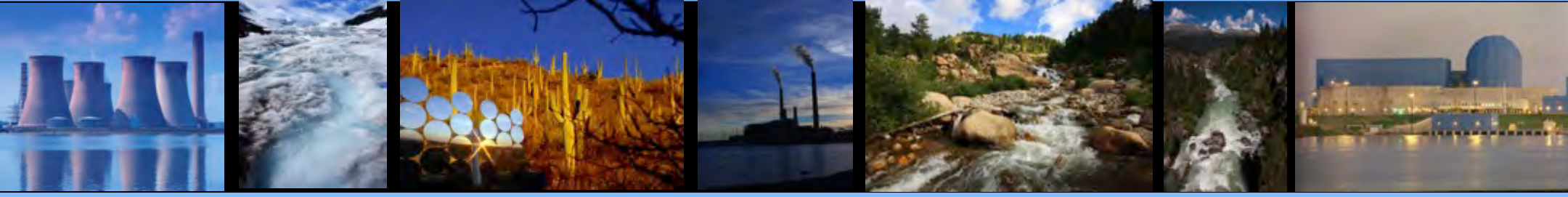
- ***China and India have low per capita water consumption vis-à-vis the U.S. and Europe***

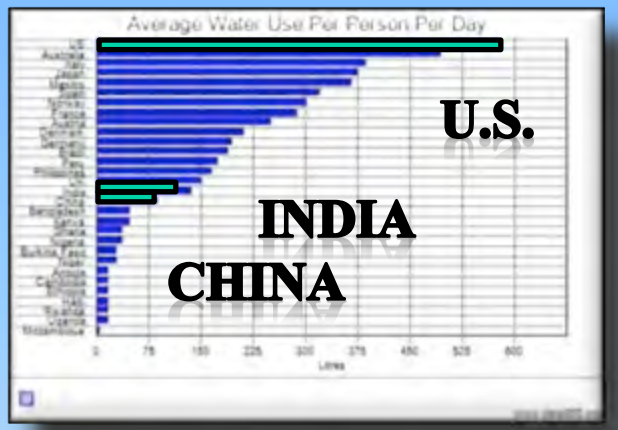


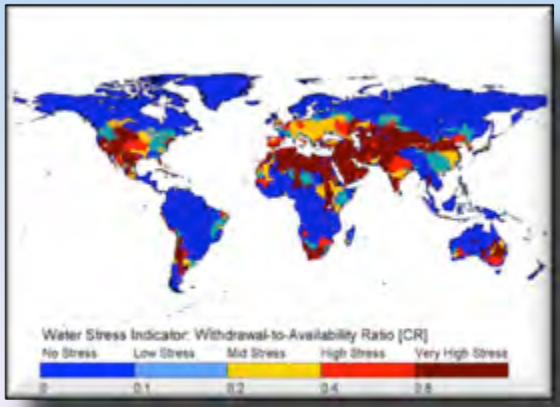
WATER STRESS

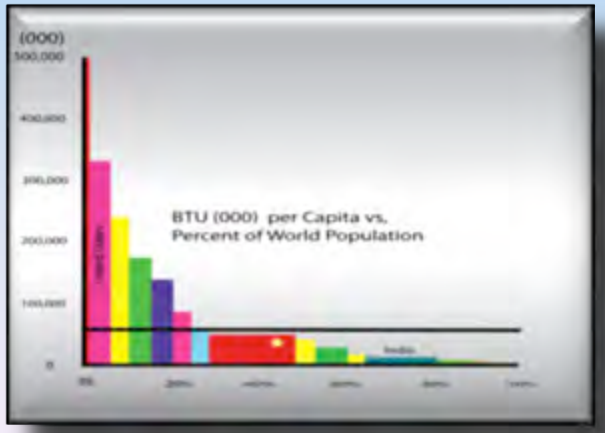


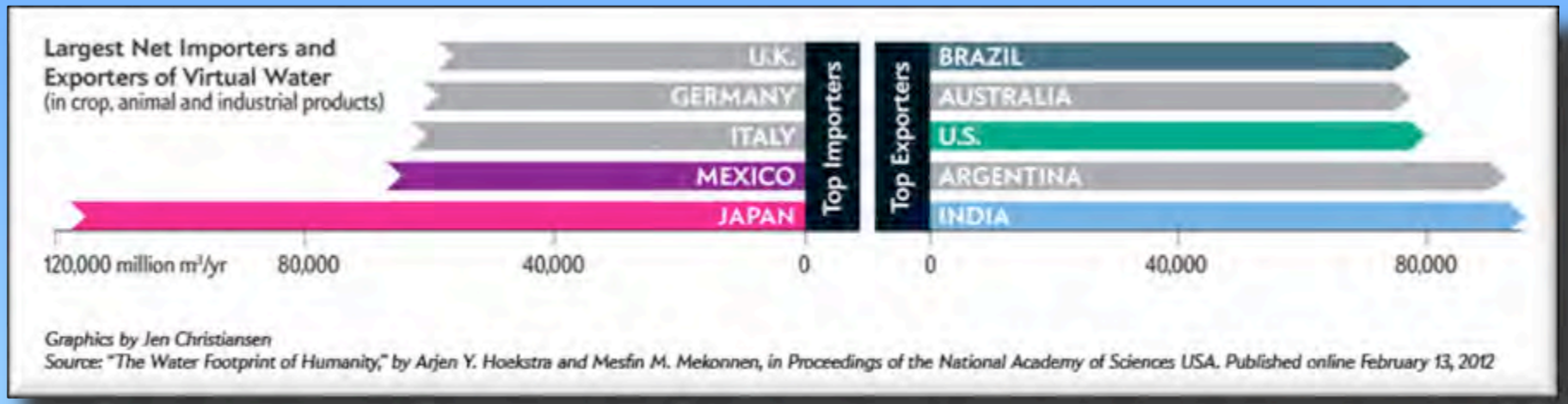
- ***And both China and India have considerable water stress***

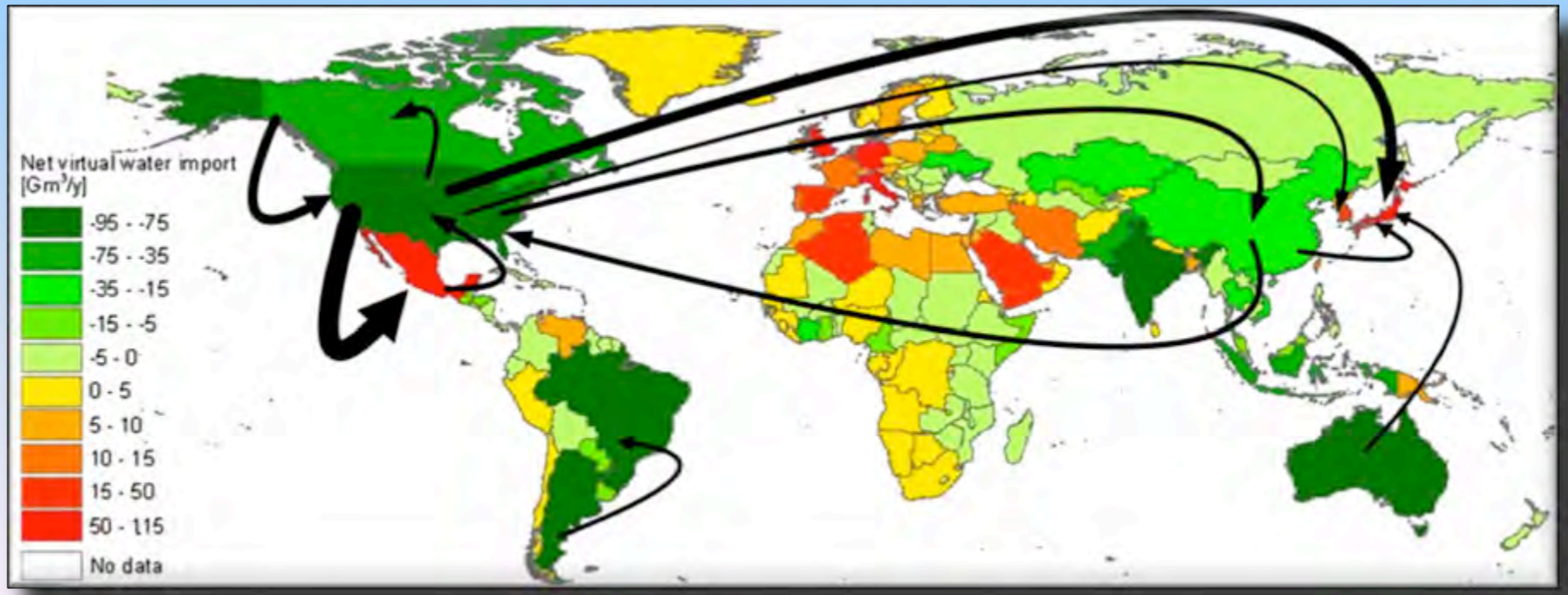



Average Water Use Per Person Per Day
U.S.
INDIA
CHINA

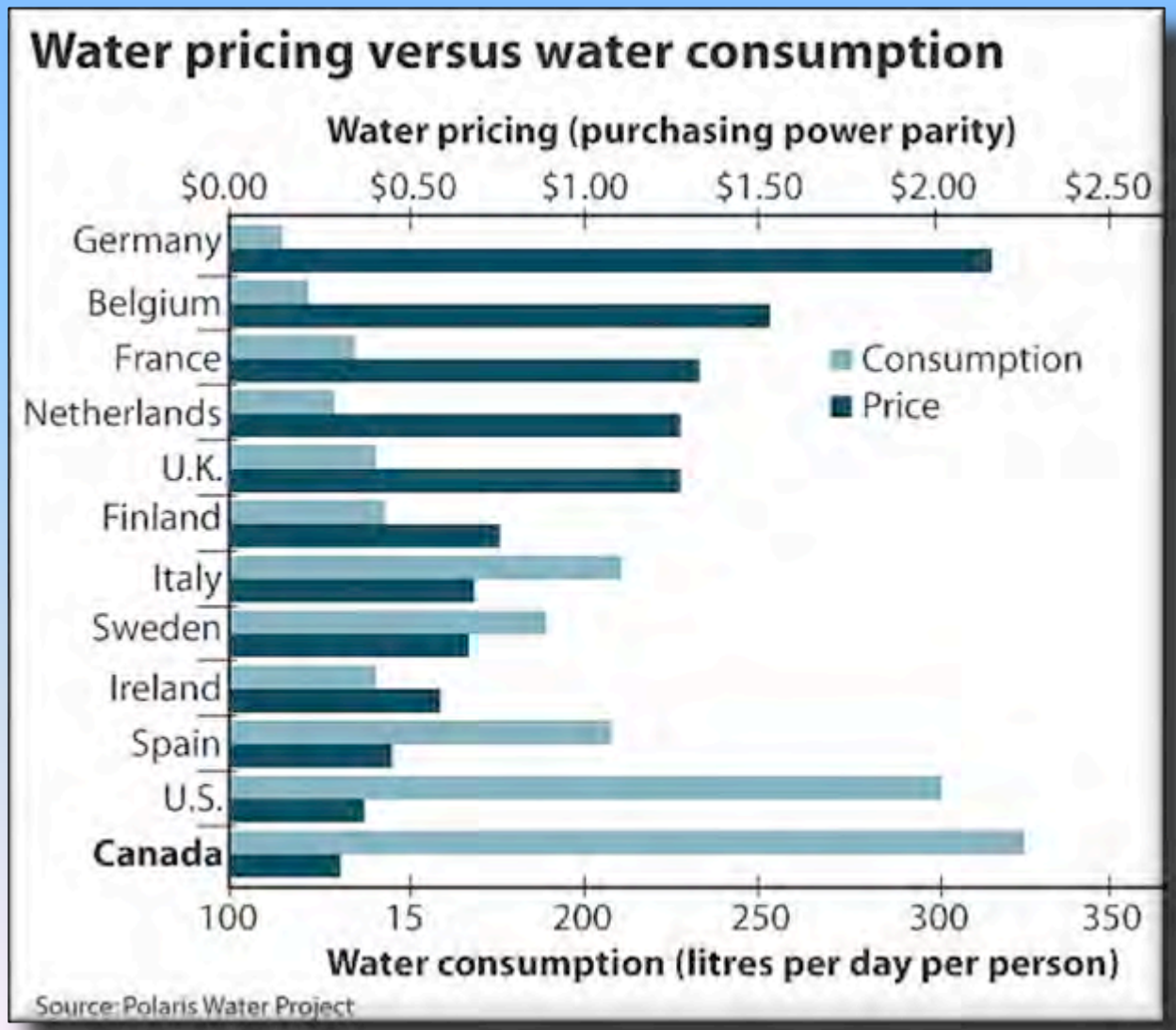

Water Stress Indicator: Withdrawal-to-Availability Ratio [CR]
No Stress
Low Stress
Mid Stress
High Stress
Very High Stress


(000)
BTU (000) per Capita vs.
Percent of World Population


Largest Net Importers and Exporters of Virtual Water
(in crop, animal and industrial products)
U.K.
GERMANY
ITALY
MEXICO
JAPAN
Top Importers
Top Exporters
BRAZIL
AUSTRALIA
U.S.
ARGENTINA
INDIA
120,000 million m³/yr
80,000
40,000
0
0
40,000
80,000
Graphics by Jen Christiansen
Source: "The Water Footprint of Humanity," by Arjen Y. Hoekstra and Mesfin M. Mekonnen, in Proceedings of the National Academy of Sciences USA. Published online February 13, 2012


Net virtual water import
[Gm³/y]
-95 - -75
-75 - -35
-35 - -15
-15 - -5
-5 - 0
0 - 5
5 - 10
10 - 15
15 - 50
50 - 115
No data

SUPPLY DEMAND CHART



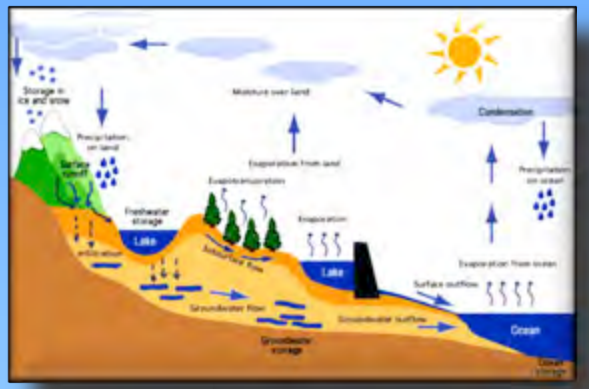
The 800 Pound Gorilla in the Water Energy Equation is not

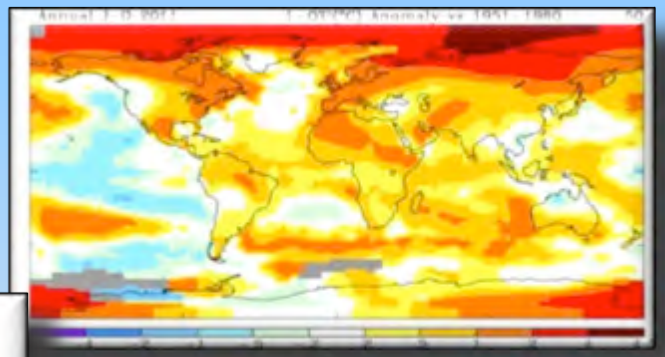
Oil

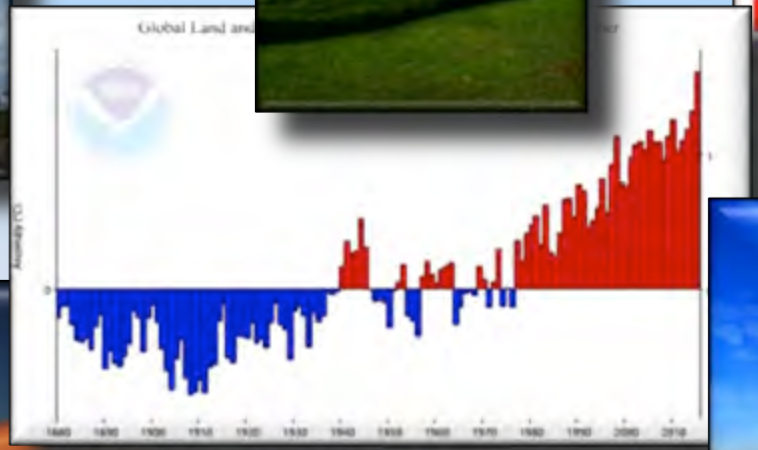
or Gas

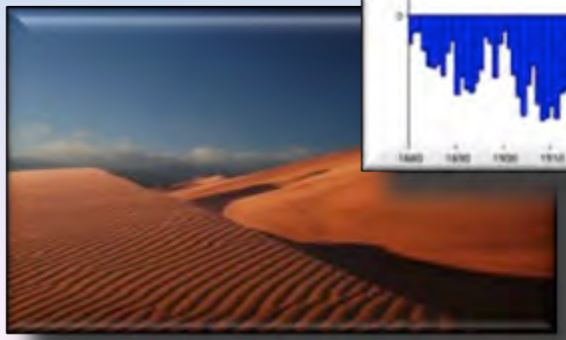
or Electric

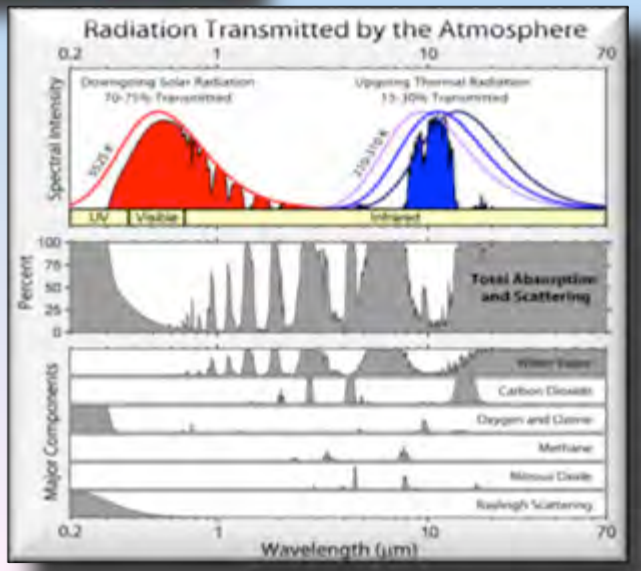
CLIMATE CHANGE
HYDROLOGICAL CYCLE

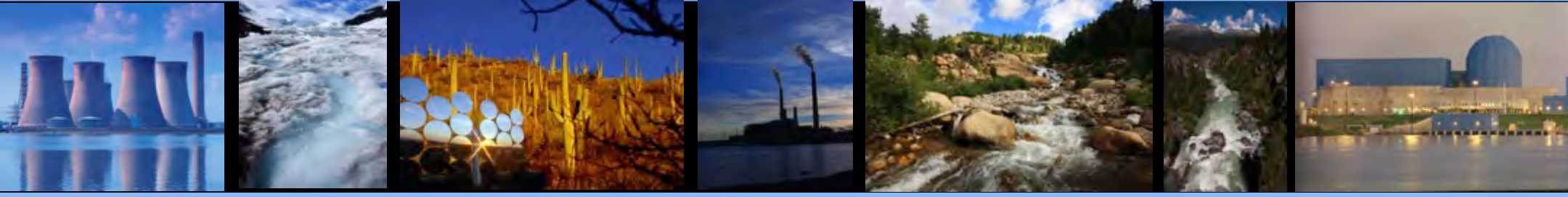


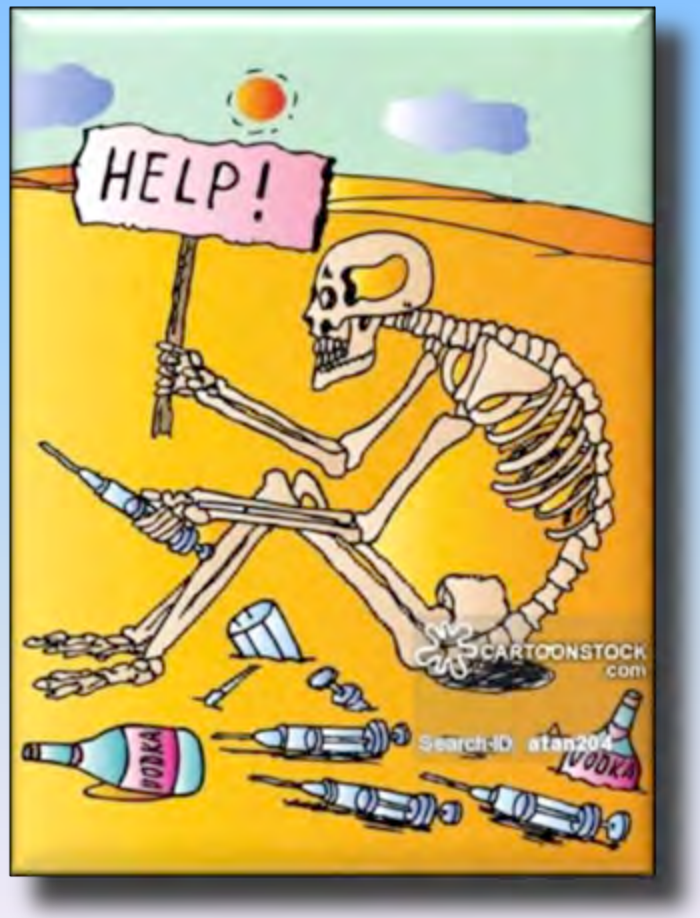






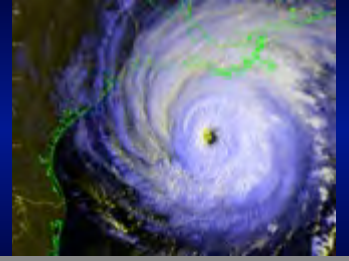


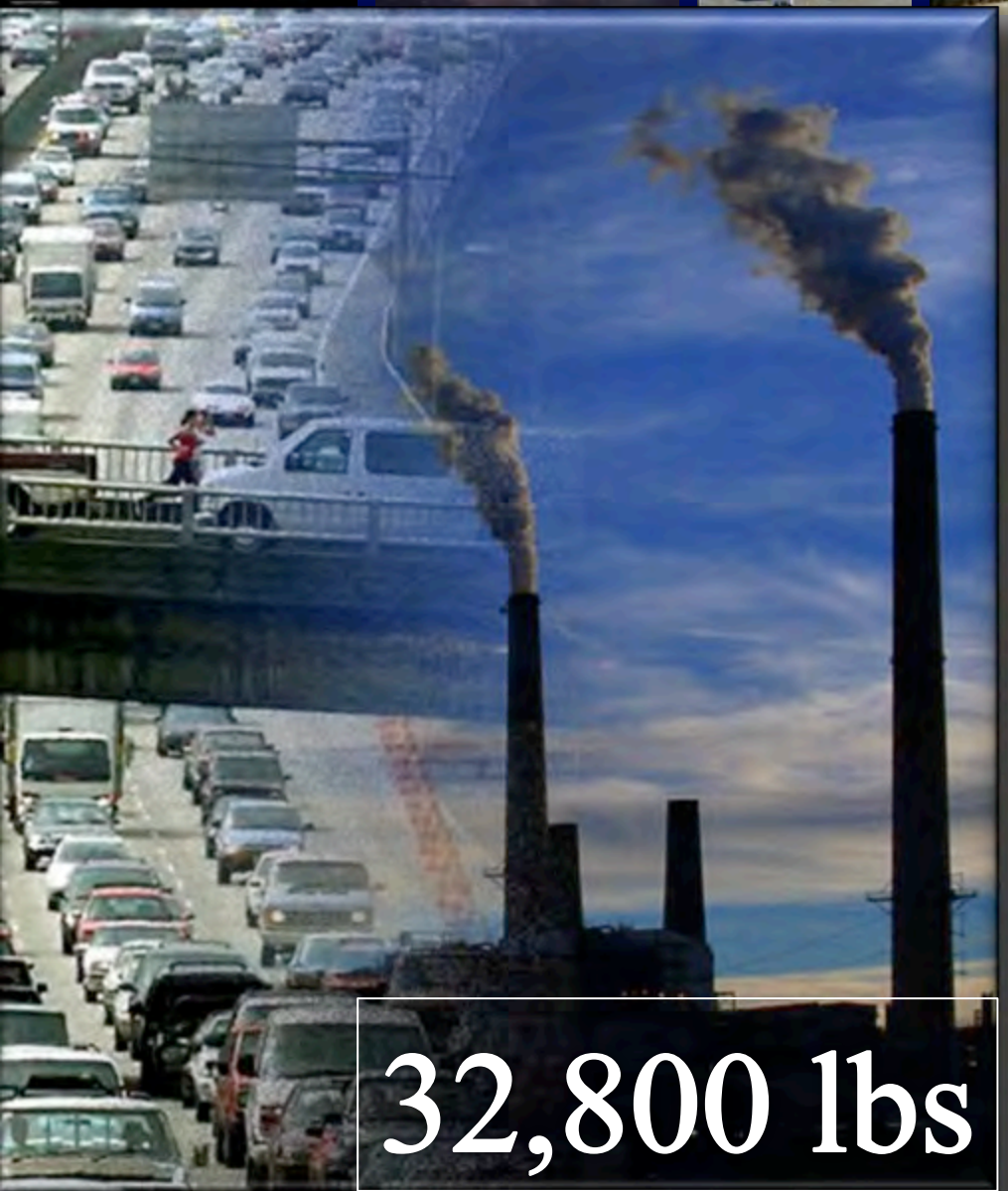




- ***One of our largest problems as a society is that the longer we put of making the hard decisions on Climate Change and Ocean Acidification***
- ***the less time we will have, and***
- ***the harder it will be as we will have increased our dependence on fossil fuels while needing to decrease usage at a faster rate.***



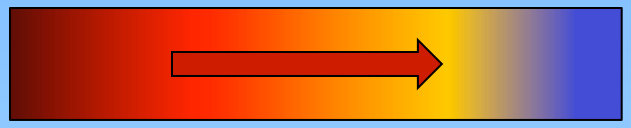





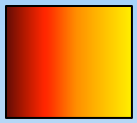
In 2011, the world emitted 39.8 billion tons of carbon dioxide.

ANOTHER 2,524,099 POUNDS

CONDUCTION



CONVECTION



RADIATION

BLACK BODY RADIATION




ANY *object at a temperature above absolute zero emits radiation*

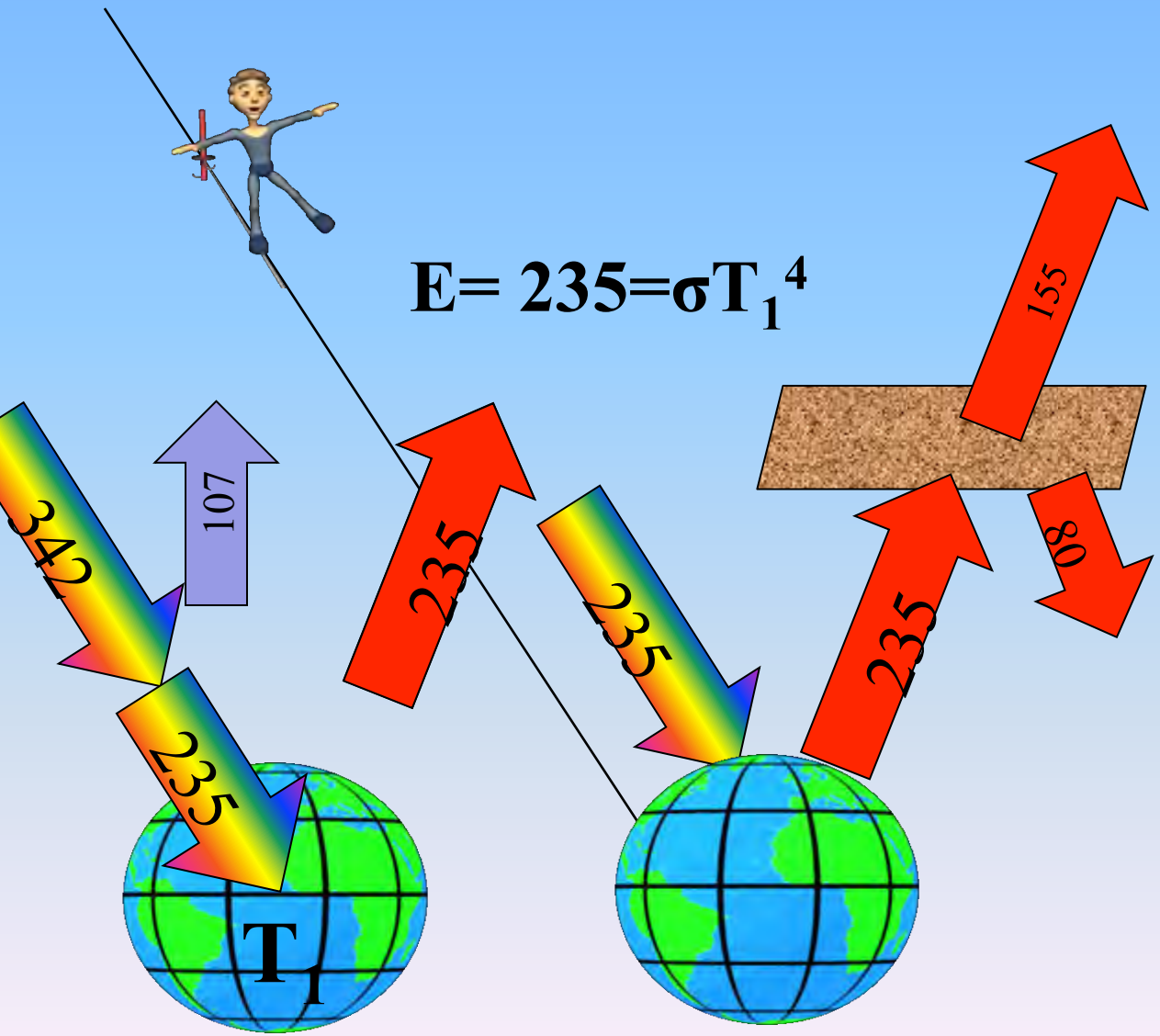
$$E = \sigma T^4$$

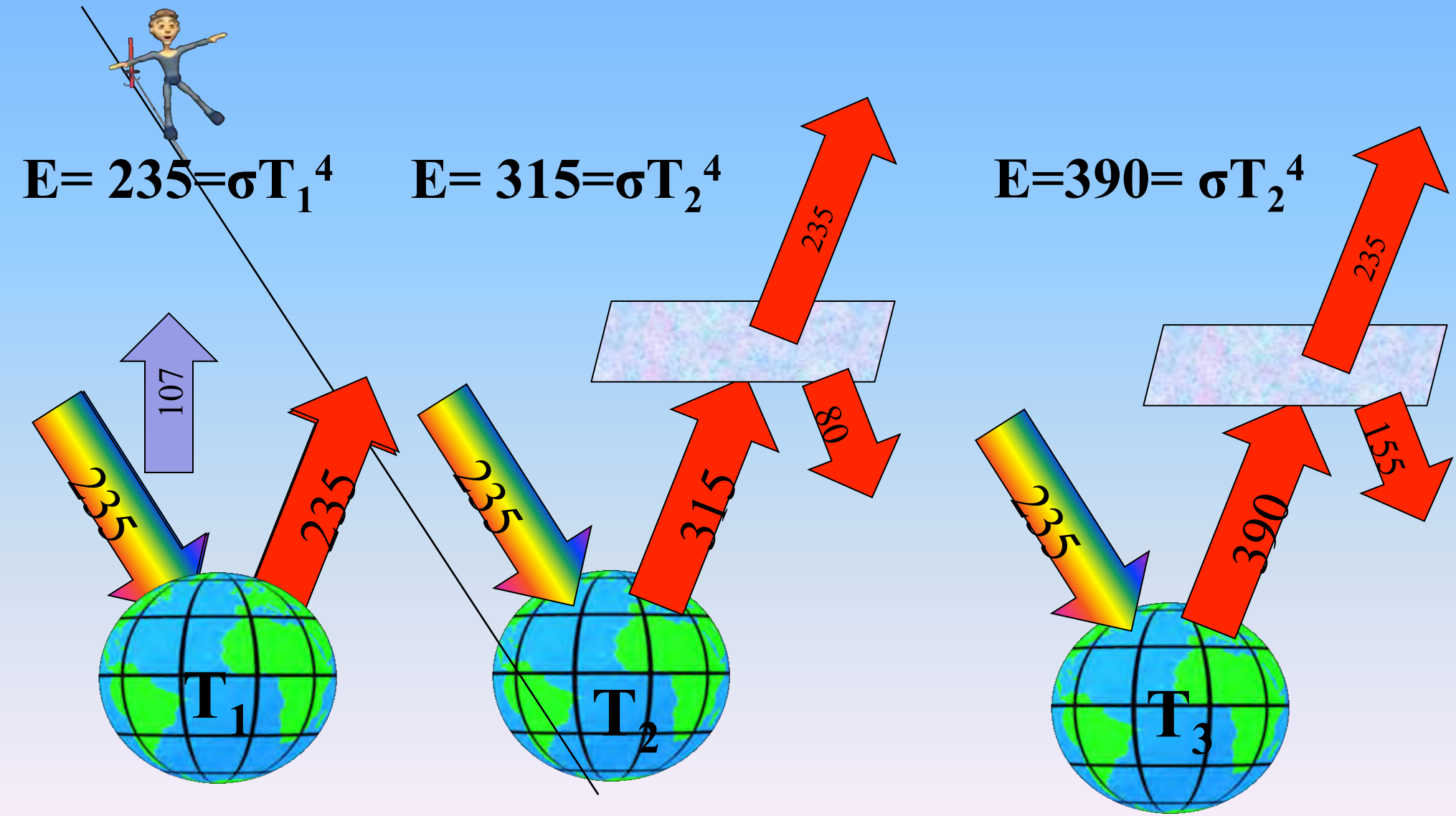
σ = *Stefan-Boltzmann Constant*

5.67×10^{-8} $J/m^2K^4Sec.$

See Wikipedia Article

Discovered in 1879


E= 235=σT1 4
342
107
235
235
235
235
155
80
T1

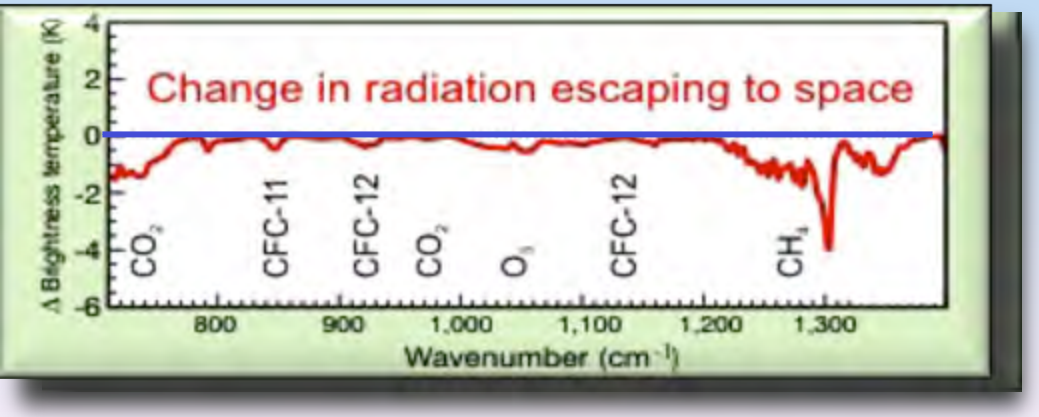


The better the blanket the hotter it will be

ENERGY CAN NEITHER BE CREATED NOR DESTROYED

NASA

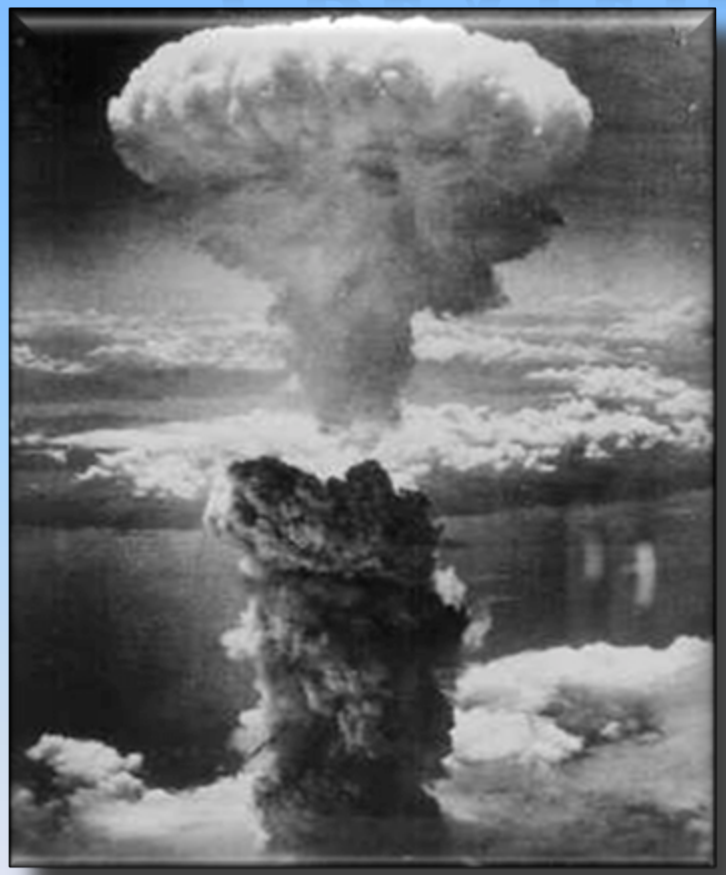
- ***The Earth is radiating less energy due to Atmospheric absorption.***
- ***If it is not being radiated and can't be destroyed, where is it going***

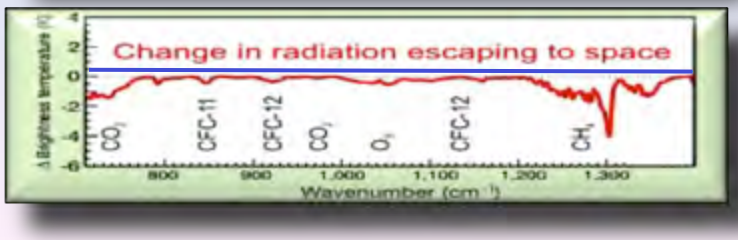


Changes in spectrum from 1971 to 1996 due to trace gases

AN INCONVENIENT GRAPH

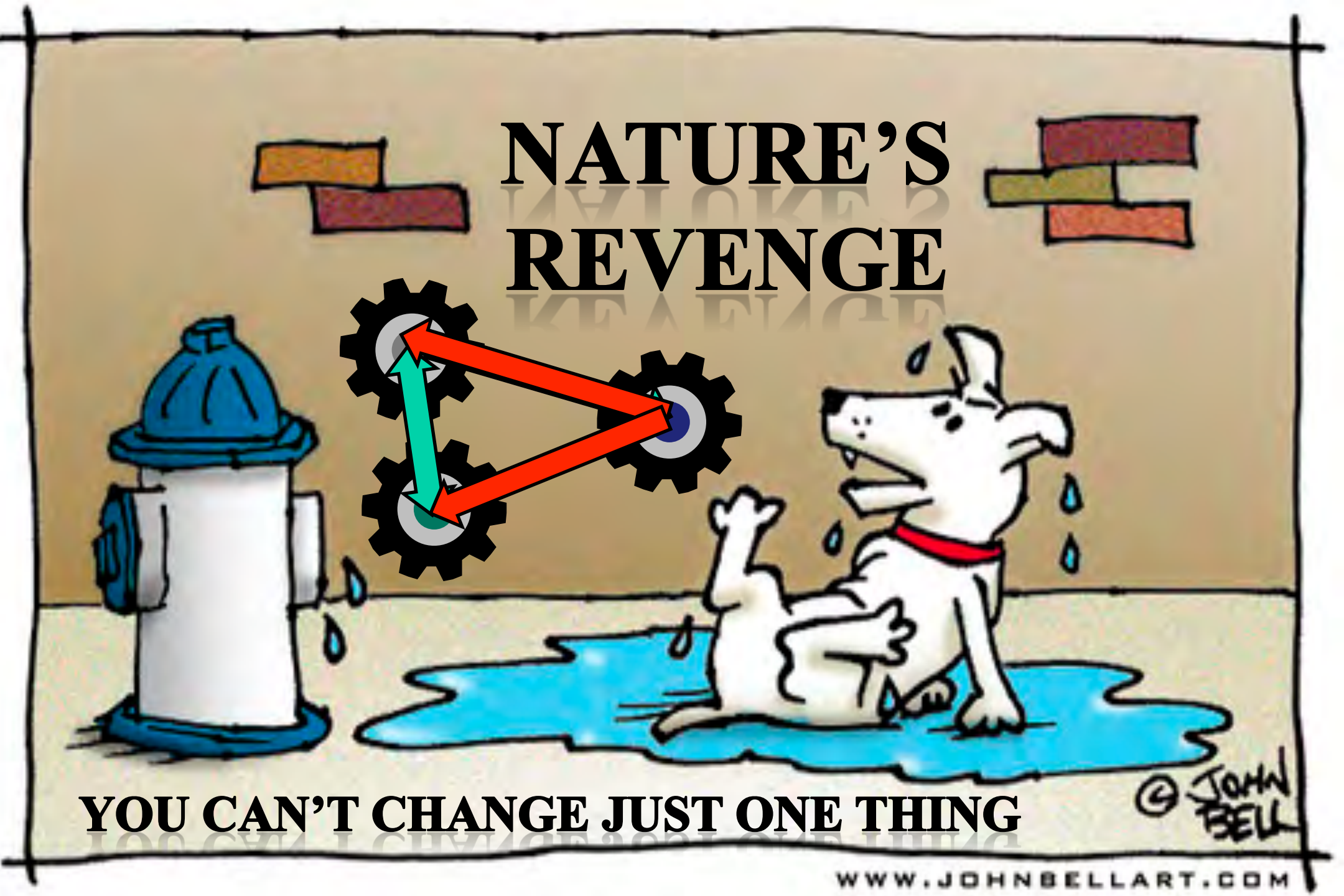
ENERGY CAN NEITHER BE CREATED NOR DESTROYED



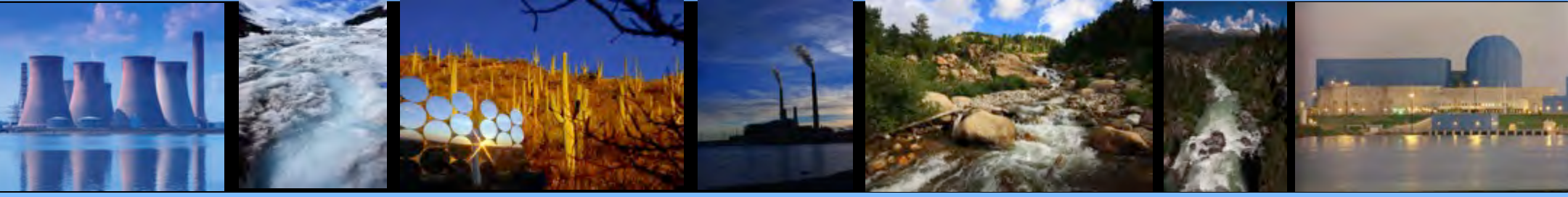


- *The difference between outgoing and incoming radiation is about*
- *0.8 watts per square meter. Integrating that over the earths area.*
- *It is equivalent to three-four Hiroshima Bombs*
- *EVERY SECOND*

NATURE'S REVENGE

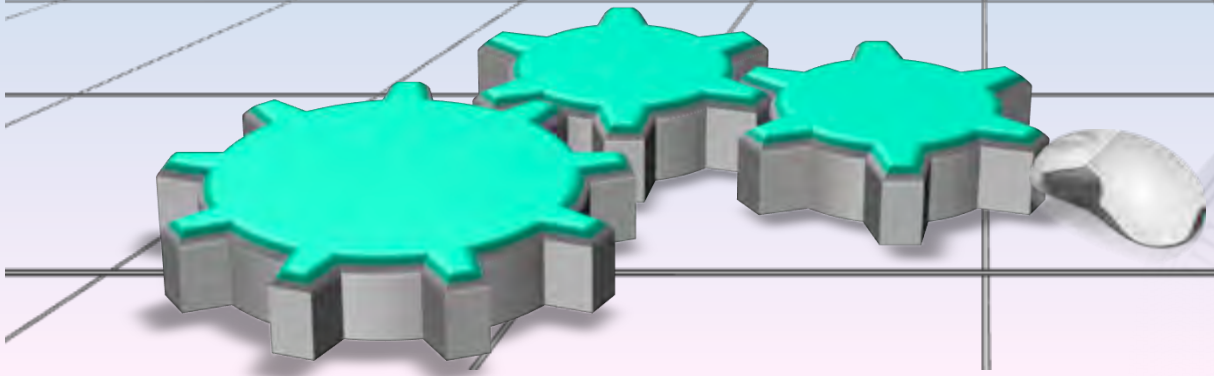


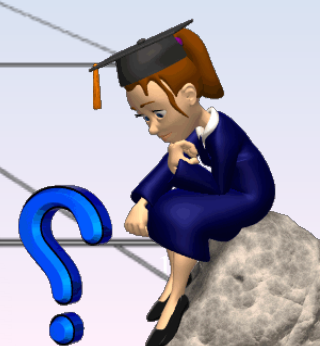
YOU CAN'T CHANGE JUST ONE THING

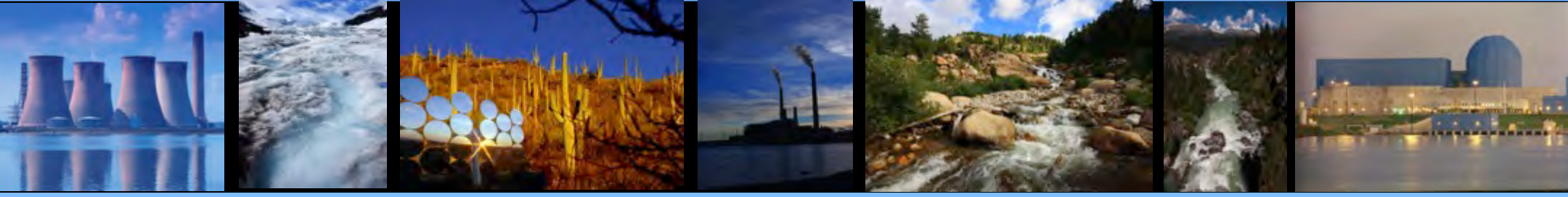


OVER TIME INCREASING TEMPERATURES WILL

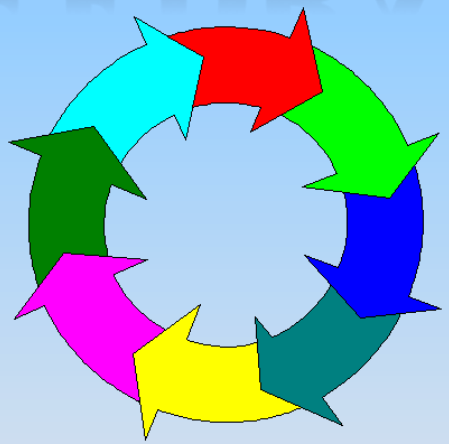
- Increase the demand for cooling,
- increase the demand for electricity
- Decrease the efficiency of power plants requiring more fuel.
- Discharge more waste heat



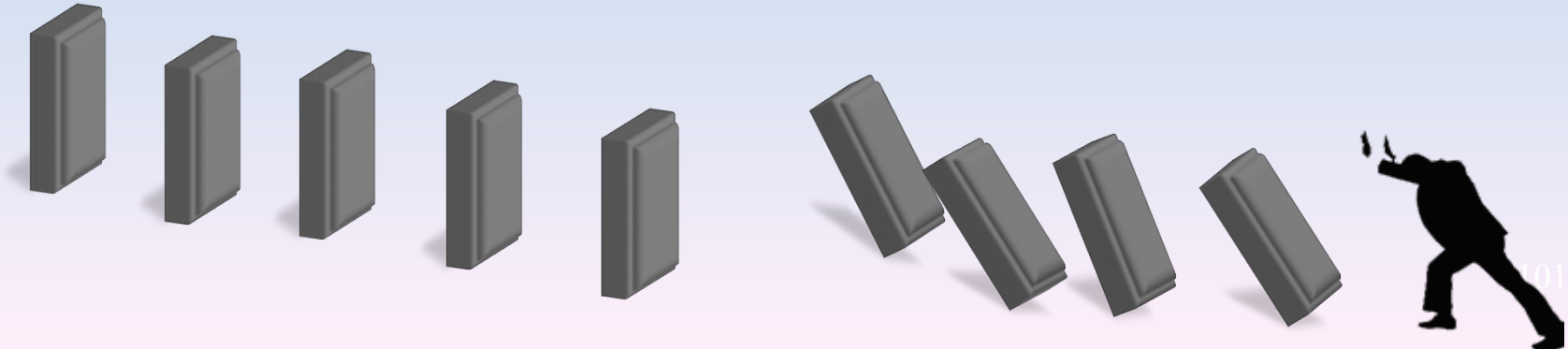


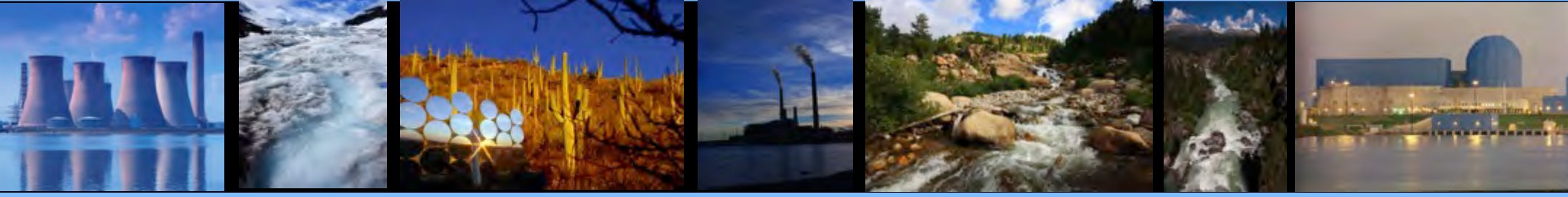


FEEDBACK



- *Rising Temperatures will also increase water consumption for agricultural crops and domestic use.*
- *An increase in corn ethanol would increase water use.*
- *These changes require more energy.*



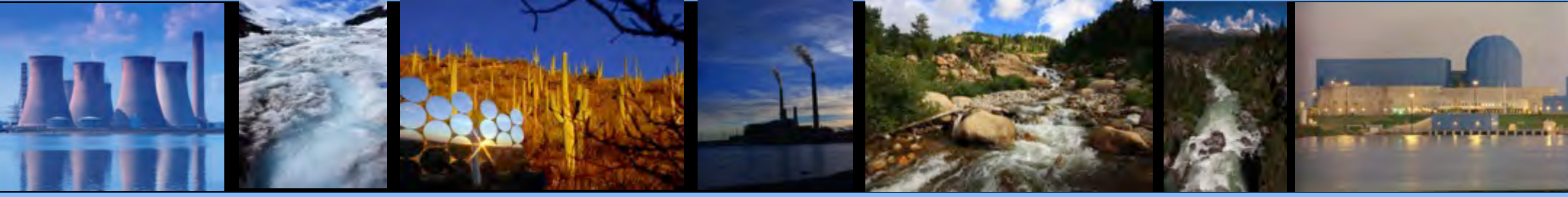


WEATHER PATTERNS

Fergama Valley Uzbeckistan

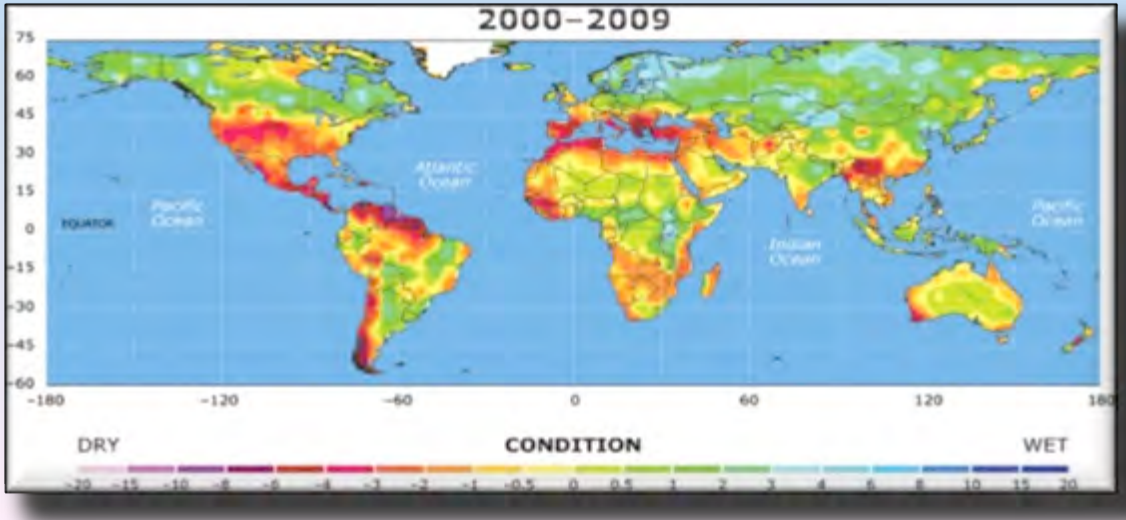
Namibia

- ***By far the largest and most damaging effect of climate change will be the change in weather patterns.***
- ***Most studies show wet areas getting wetter and dry areas getting drier and droughts becoming widespread.***
- ***Droughts in turn kill one of our largest carbon sinks, trees.***



DROUGHT INDEX

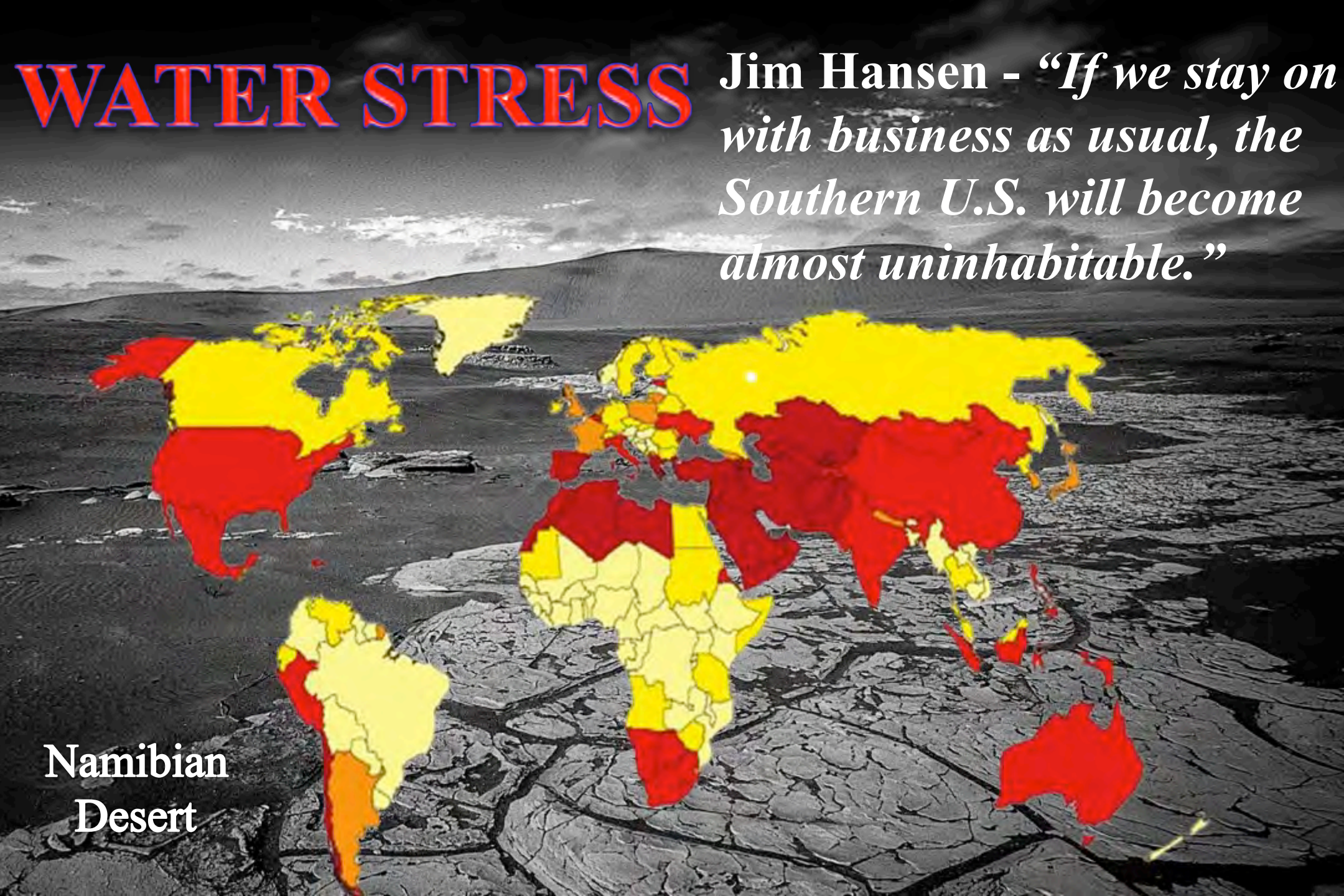
- *The index in the Great Plains during the "Dust Bowl" temporarily hit -3.*
- *By the end of the century, many populated areas, including parts of the United States, could face readings in the range of -8 to -10, and much of the Mediterranean could fall to -10 to -15.*

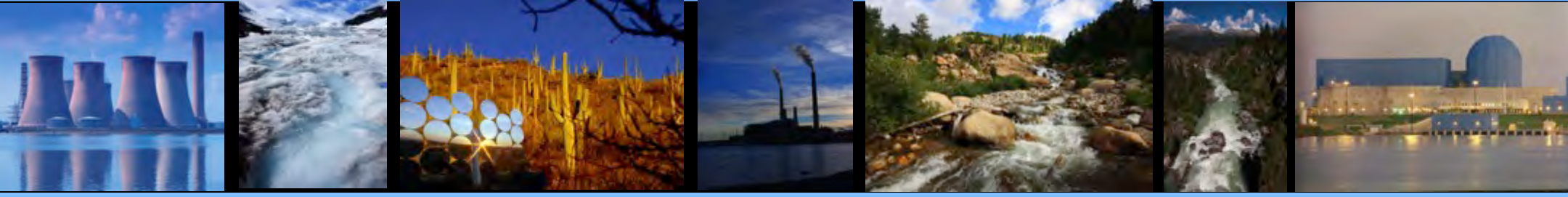


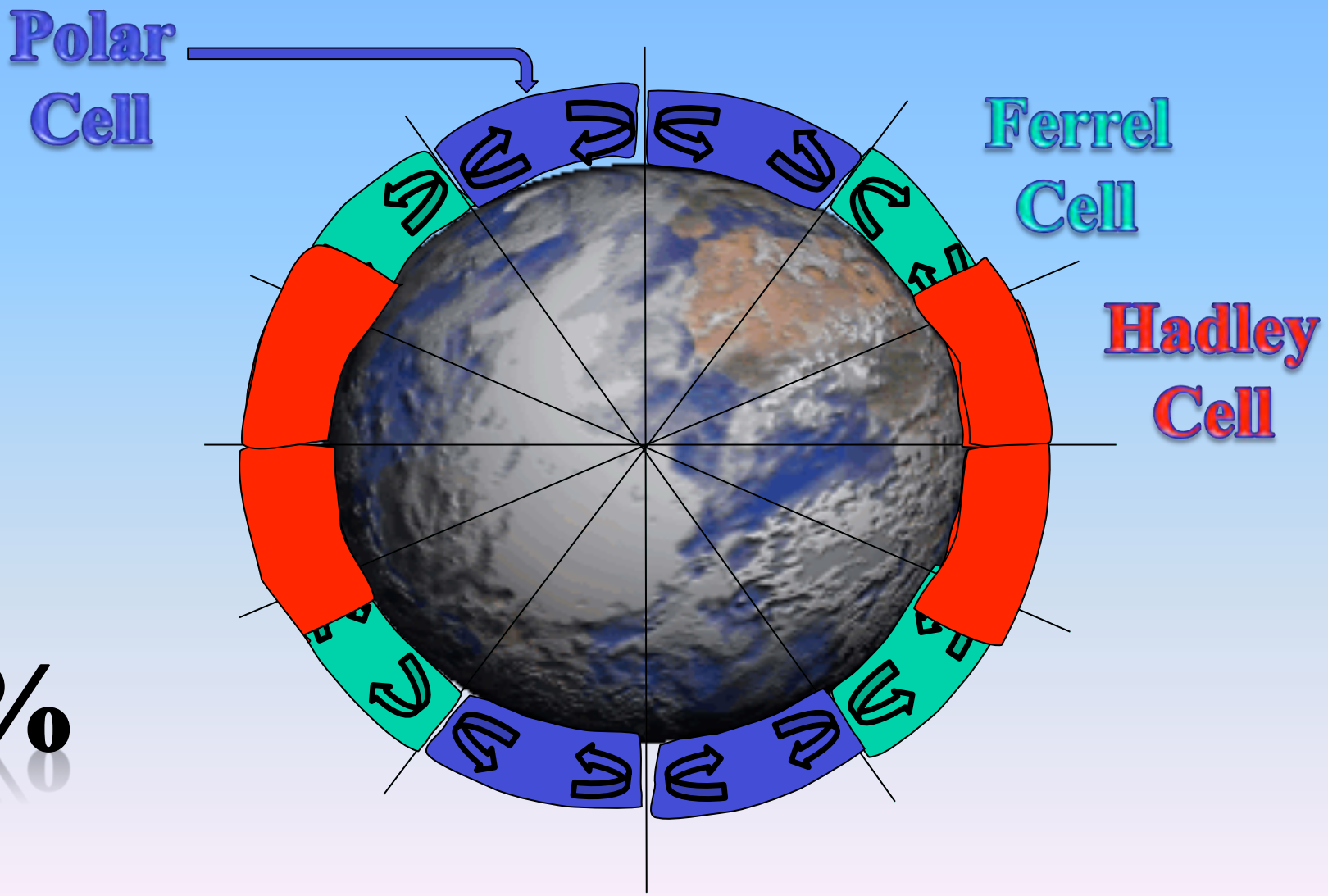
National Center for atmospheric Research
http://onlinelibrary.wiley.com/doi/10.1002/wcc.81/full

WATER STRESS

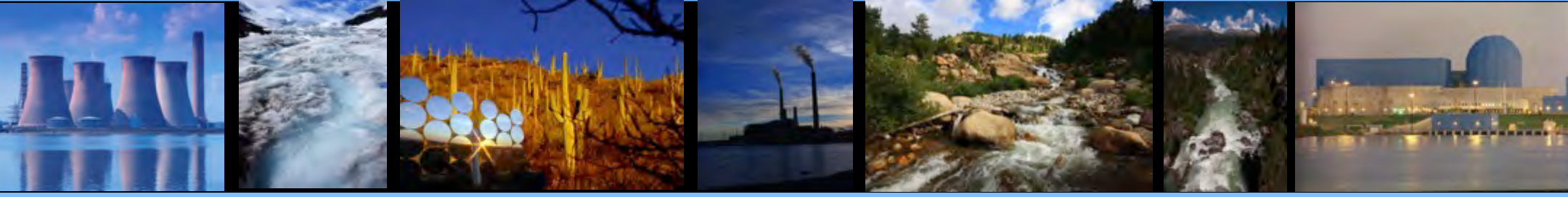
Jim Hansen - *"If we stay on with business as usual, the Southern U.S. will become almost uninhabitable."*





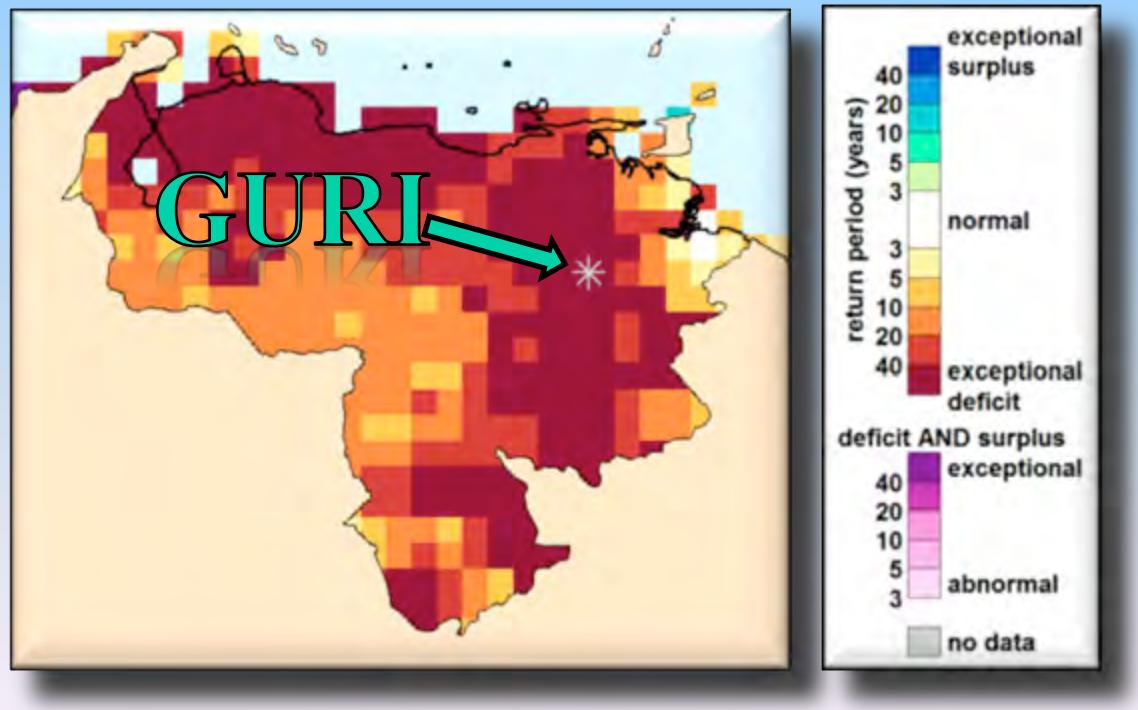


4%

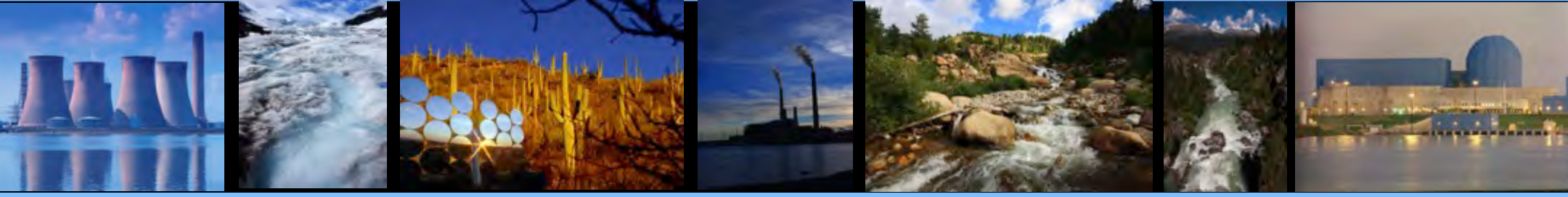


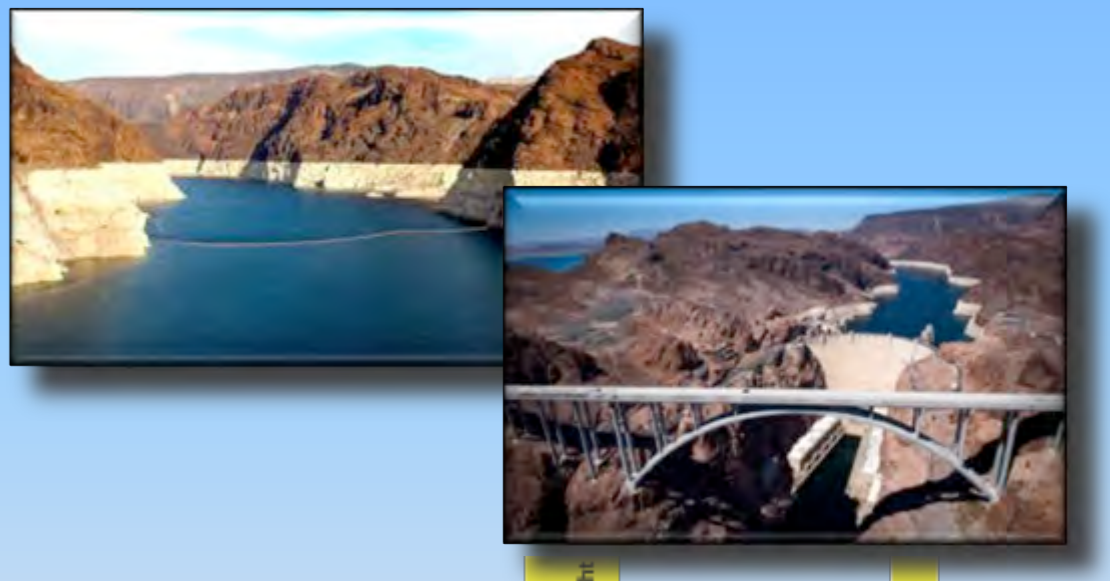
VENEZUELA WATER

ANOMALY DEC 14-FEB 15

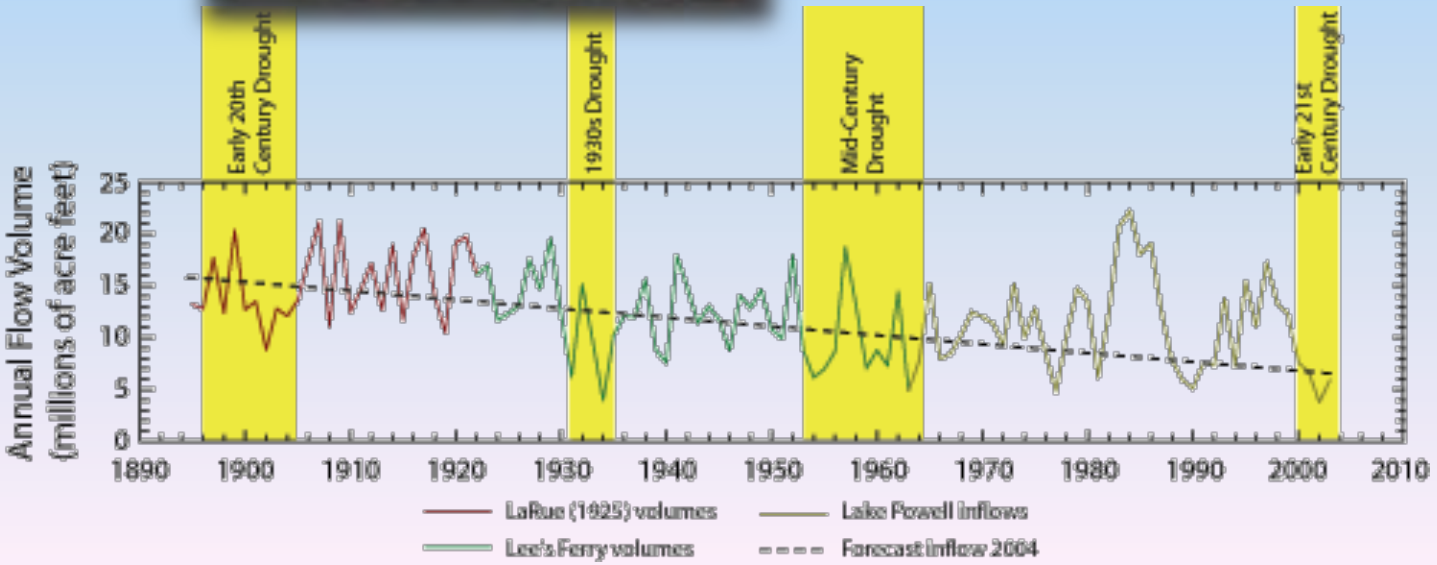


- *Many countries have experienced severe electricity shortages due to drought due to drought or high temperatures.*
- *One dam (Guri) supplies about 65% of Venezuela's electricity.*
- *Brazil gets 64% of its' electricity form hydro power.*
- *Large changes in rainfall patterns are expected due to climate change*





- ***And we are probably not far behind with Lake Mead and Lake Powell***



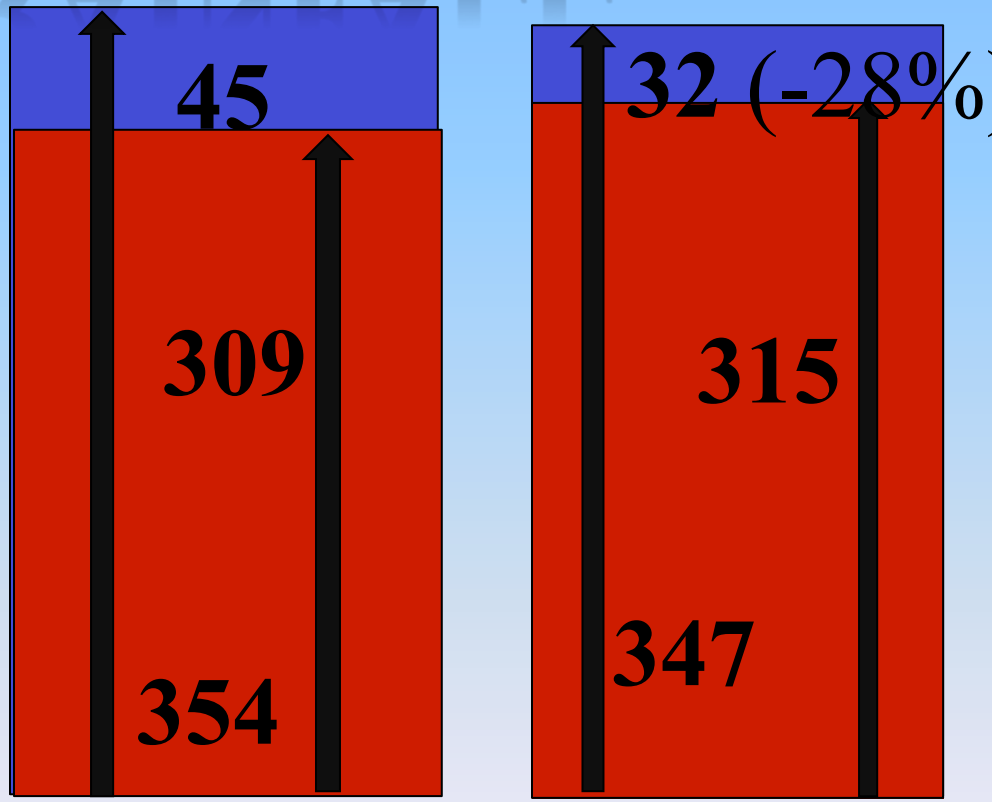
Rock Springs
Essential Power

$$Efficiency_{Max} = \frac{T_{IN} - T_{OUT}}{T_{in}}$$

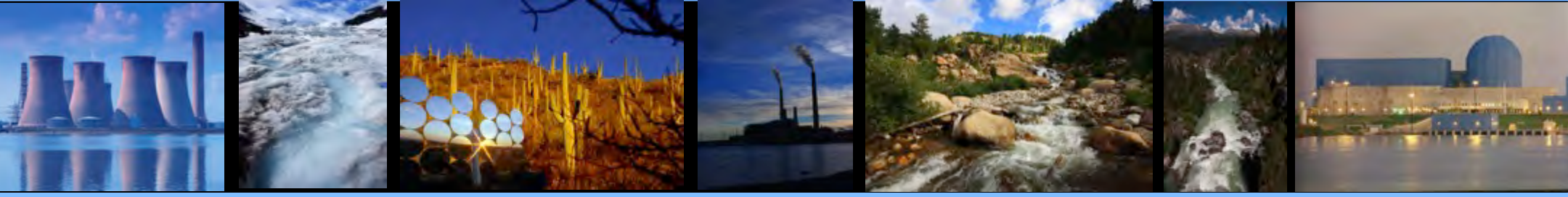
- *But rising temperatures also have an effect on Thermal plants*
- *As water temperatures rise plants become less efficient (remember entropy) thus they convert less of their input energy into energy and discharge more as waste heat.*
- *This has obvious effects on the ecosystem.*

CLIMATE CHANGES WATER RUNOFF VS. RAINFALL

- A 2% decrease in in rain doesn't equal a 2% decrease in runoff.
- In the Colorado River Basin 309 mm of the 354 mm of Rainfall evaporates or transpires.

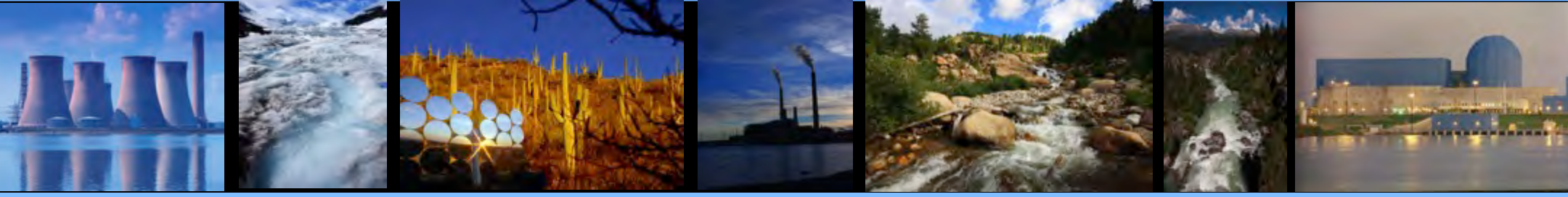


2% Change



POWER PLANT SHUTDOWNS

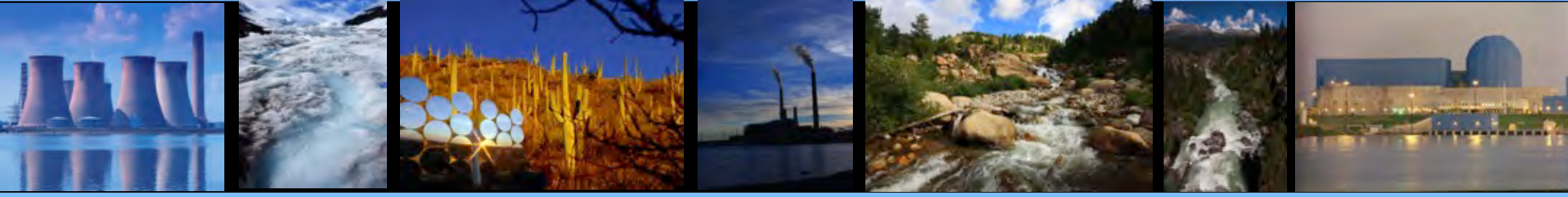
- *As runoff goes down and temperature increases some electric plants will be forced to shut down due to lack of water or high temperatures.*
- *17 nuclear power plants in Germany, France, Spain and Romania had to cut back production or shut down during one heat wave.*
- *I believe a significant number of plants in the Southern U.S. will be forced to shutdown.*

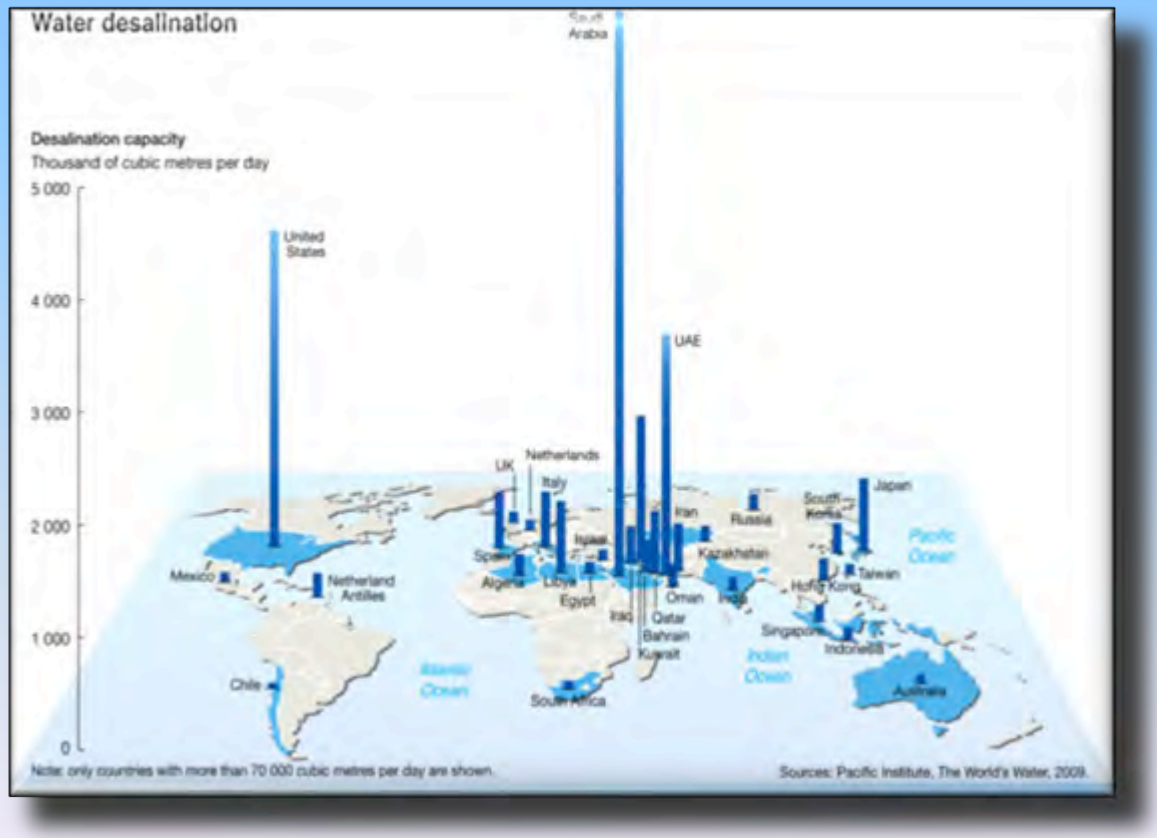


RISING SEA LEVELS

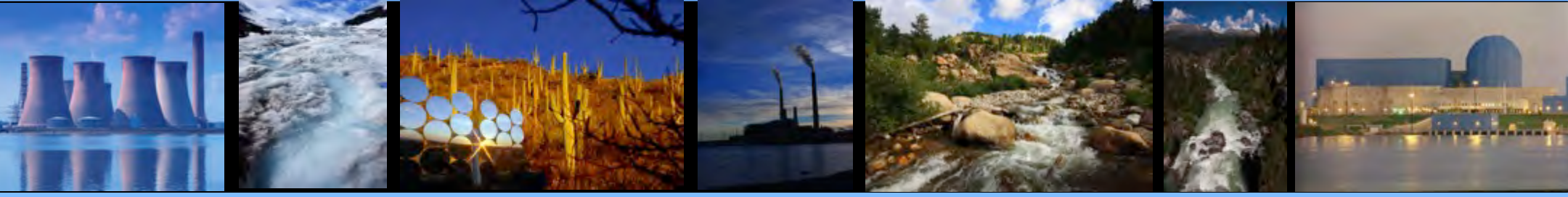
Seabrook
NextEra

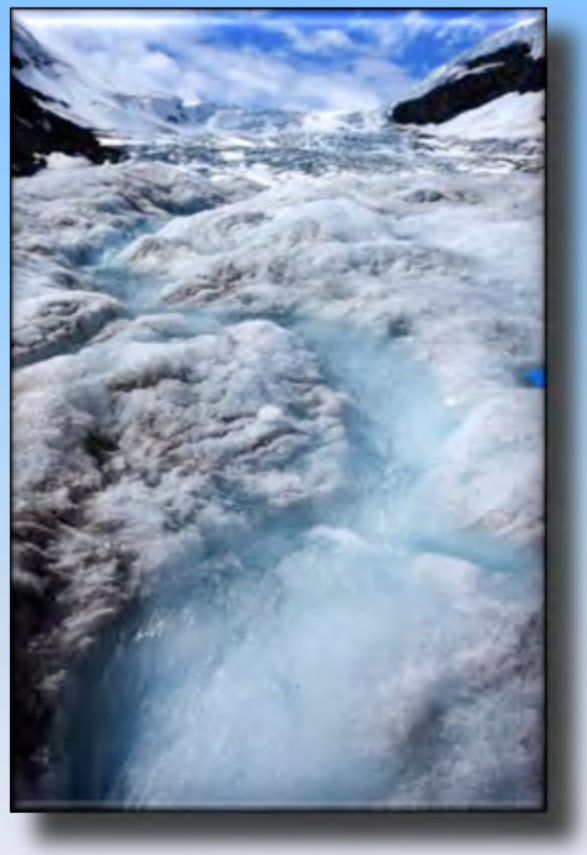
- ***Another reason for shutdowns (or frantic dike building) will be rising sea levels.***



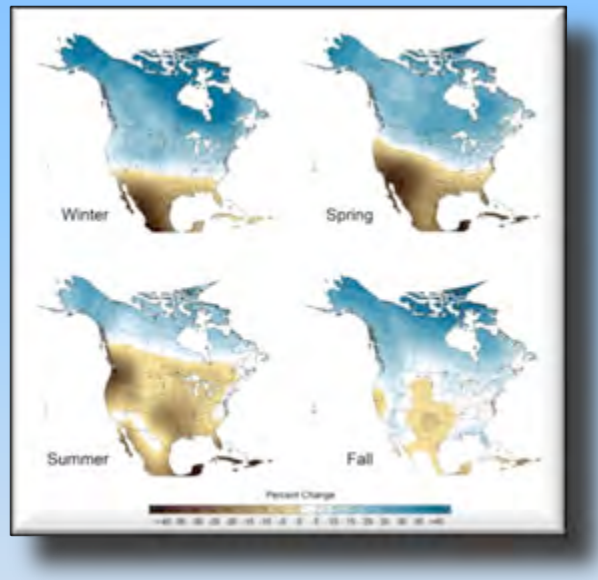


- ***As rainfall decreases many will turn to desalinization.***
- ***Desalination can be 100 times as energy intensive as treatment of fresh water so we must generate more energy which may led to more CO_2***
- ***But can we use waste heat or solar for desalinization***

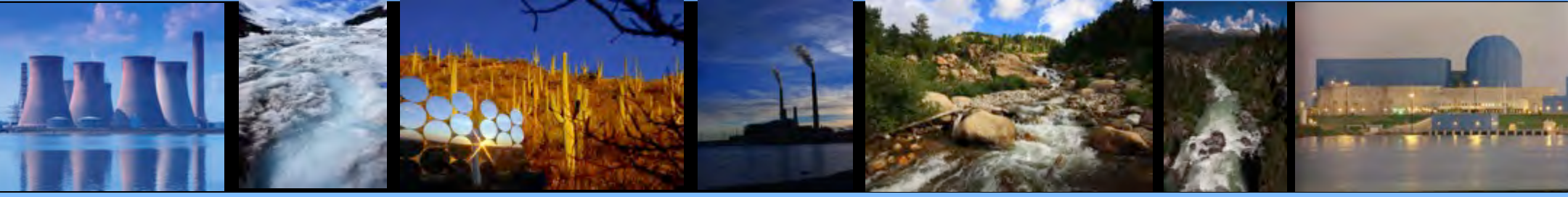




Athabasca Glacier
Alberta, Canada



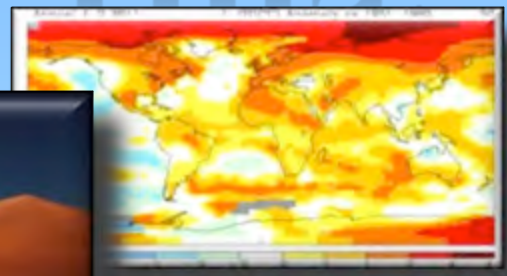
- ***We must consider not only the total water but the variations. Climate Change will mean less snowpack, thus less summer hydro and hence more generation from thermal sources.***

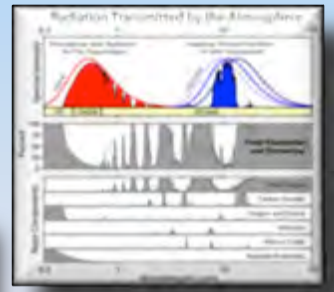


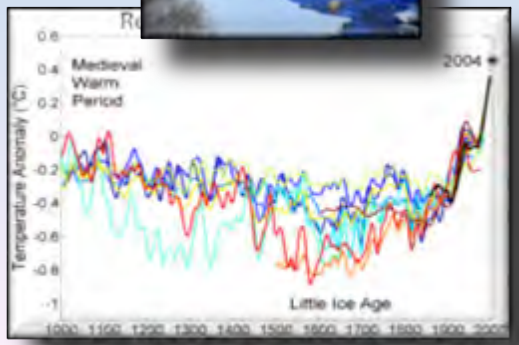
- ***Worldwide we must develop non-traditional water/energy solutions to provide additional flexibility and capacity for energy and water systems.***

Palo Verde Nuclear Plant (APS)

WHY CAN'T WE FIX THIS?



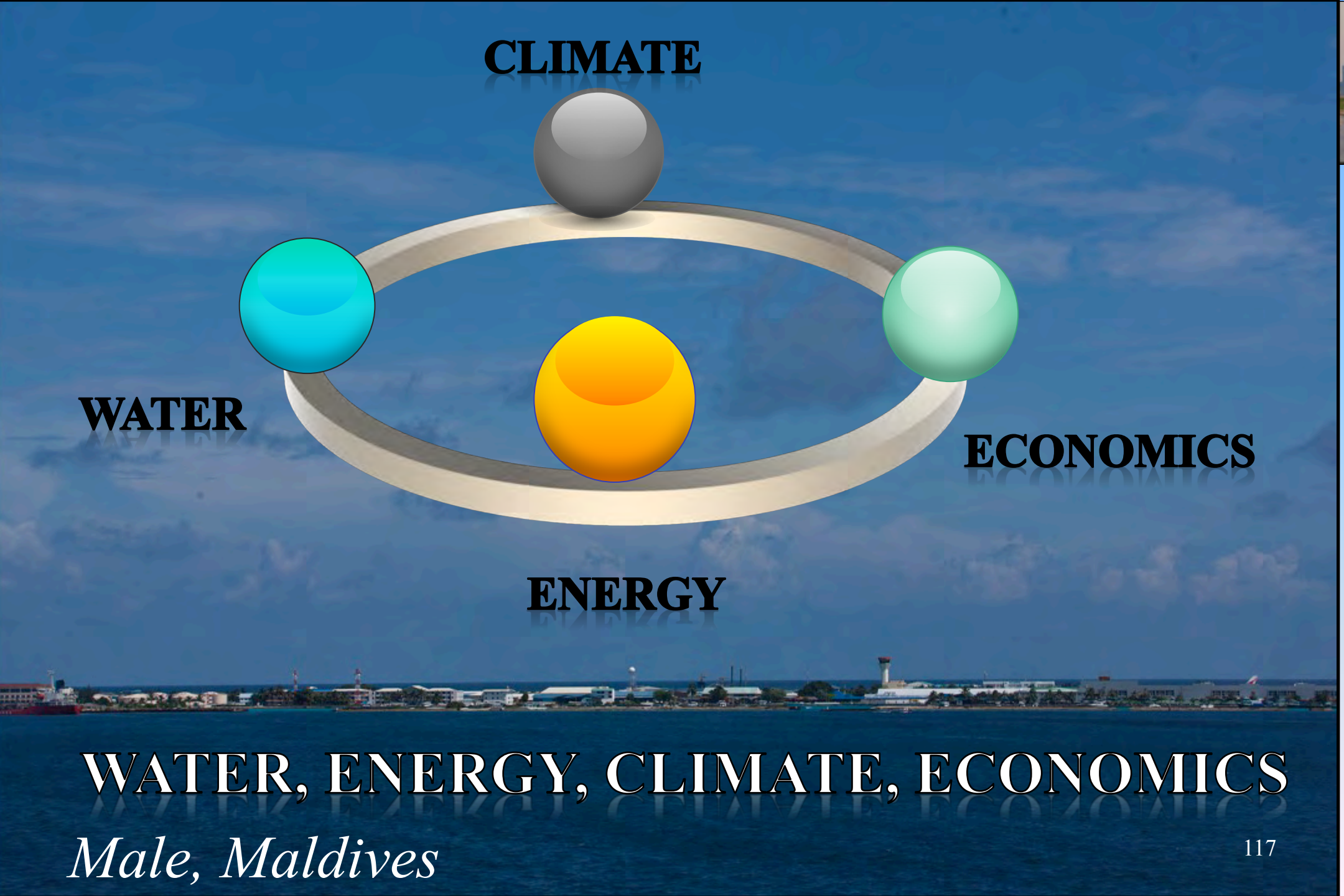




SUSTAINABILITY

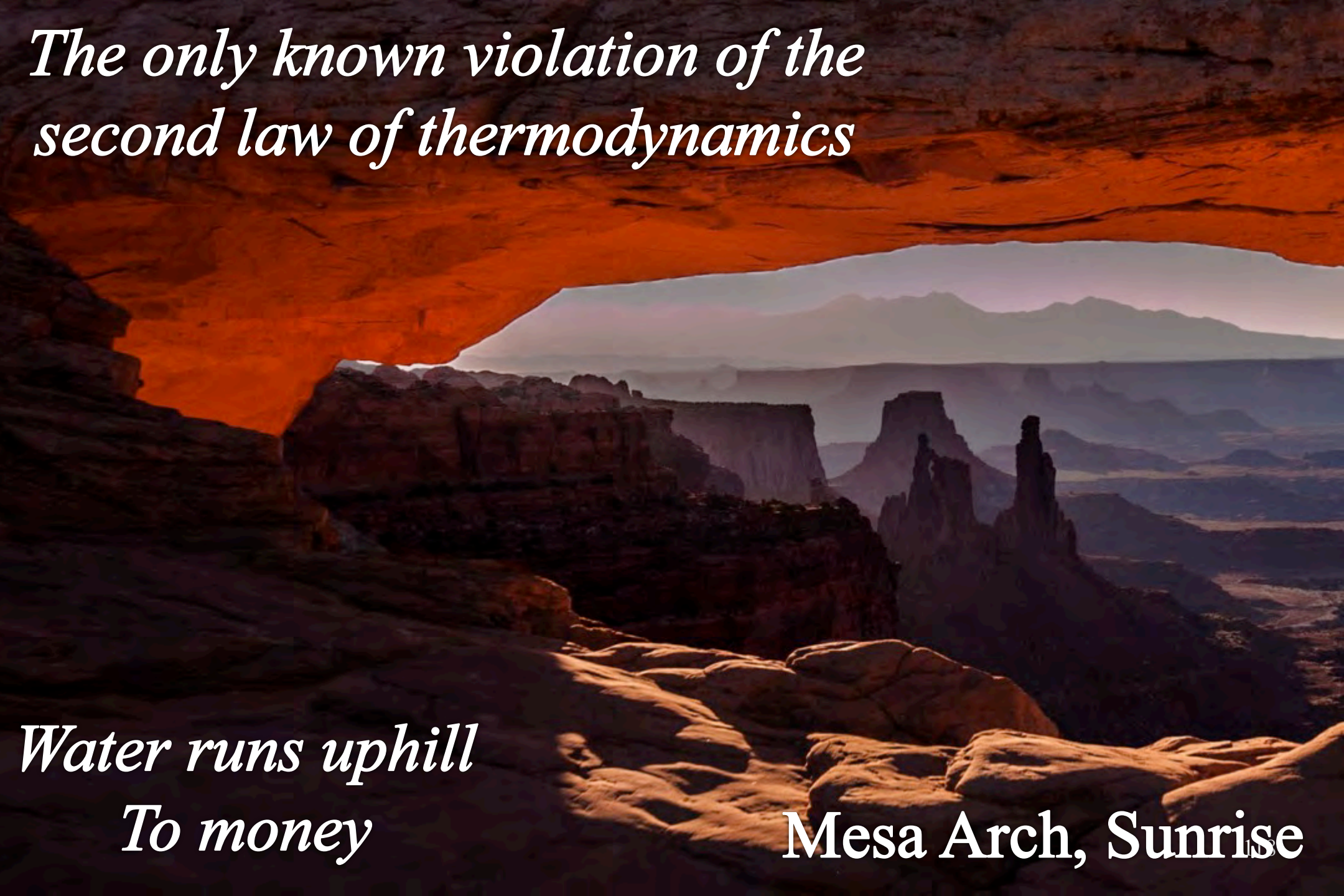
"Treating the earth like we intended to stay."

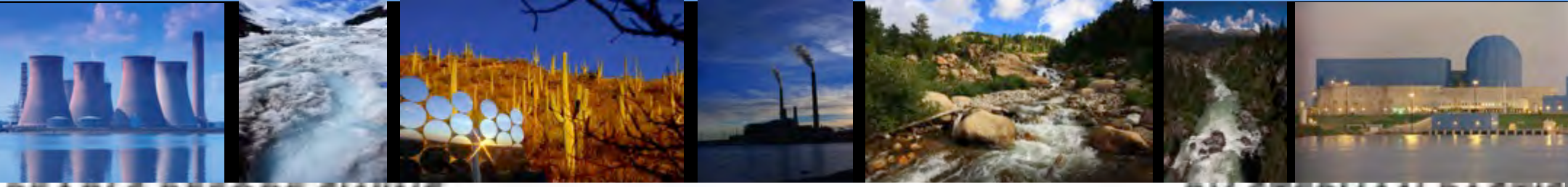
King Penguins, Antarctica



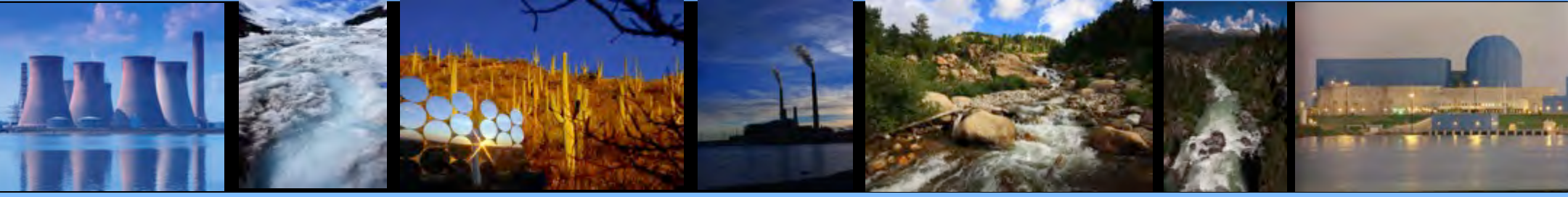
WATER, ENERGY, CLIMATE, ECONOMICS

Male, Maldives


The only known violation of the second law of thermodynamics
Water runs uphill To money
Mesa Arch, Sunrise

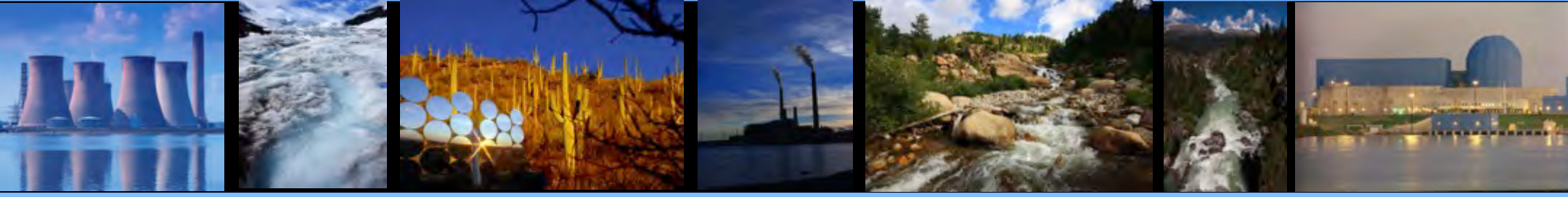


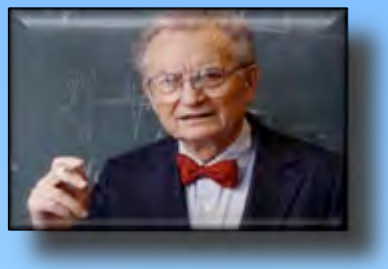
PEARLS BEFORE SWINE BY STEPHAN PASTIS



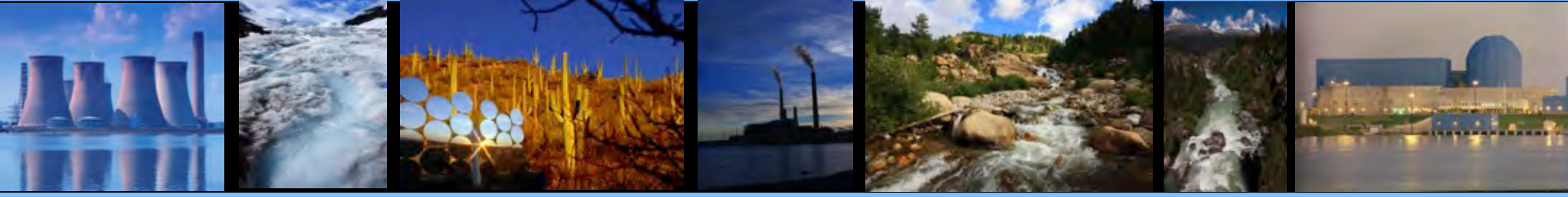
Joseph Schumpeter

- ***Solutions to Climate Change are a good example of the of the problem for policymakers that Joseph Schumpeter first pointed out in "Capitalism, Socialism and Democracy"; benefits and costs are not always distributed to the same people and this will influence decision making.***



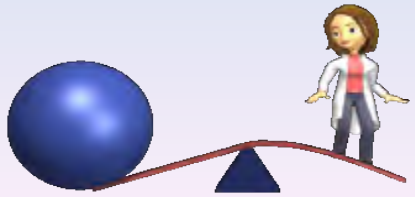


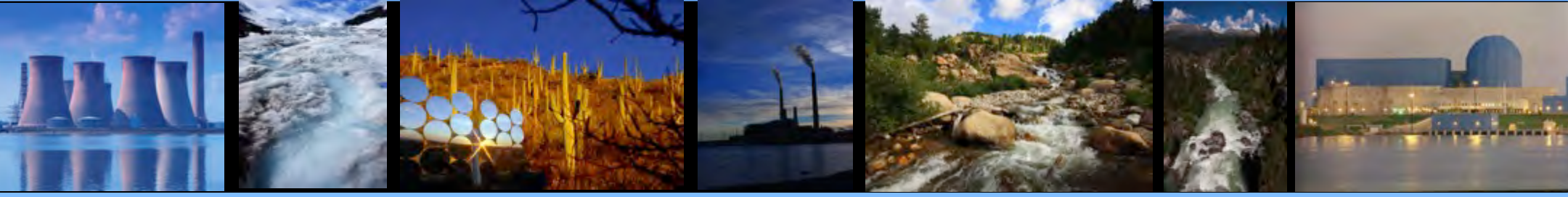
	RIVAL	NON-RIVAL
EXCLUDABLE	***PRIVATE GOODS*** **Food, clothing, houses, cars**	**CLUB GOODS** **Movies, camps, satellite or cable TV**
NON EXCLUDABLE	***COMMON GOODS*** **Fish stocks, timber, minerals**	***PUBLIC GOODS*** **Air, national defense**



FREE RIDER

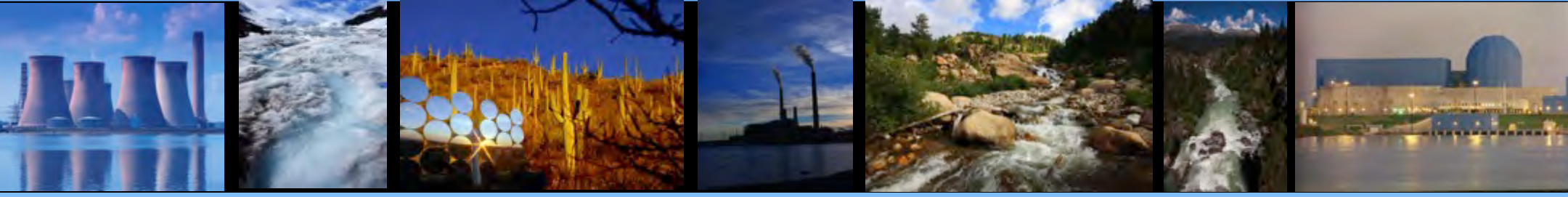
- *7 cents per kwh*
- *But this is a public good.*
- *Its' benefit is shared by 7 billion people.*
- *Per person benefit 7 cents/7E9 people.*
- *Or 1/1,000,000,000 of a cent per person benefit.*
- *"All blame disappears if you disperse it enough."*





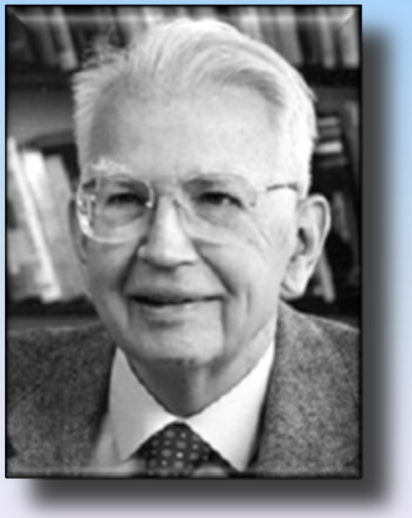
FREE RIDER

- *The free rider problem prevents people from acting.*
- *When people look at the consequences they will say:*
- *My contribution is negligible*
- *If I fix it, it will cost me money and won't solve the problem and, if the world solves the problem I will share in the benefits.*

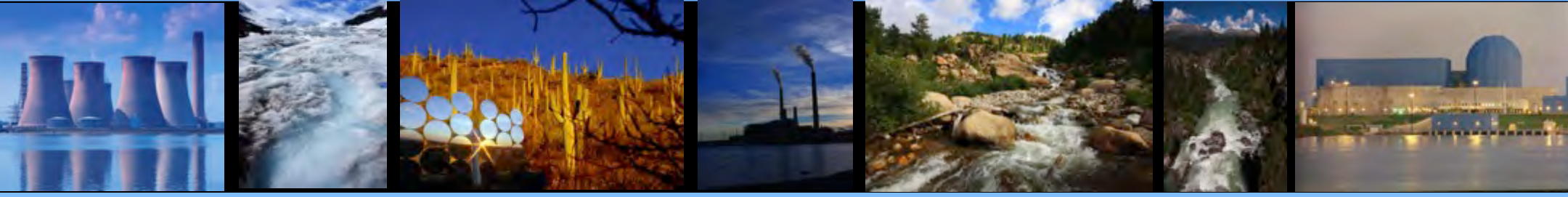


GOVERNMENTAL ACTION

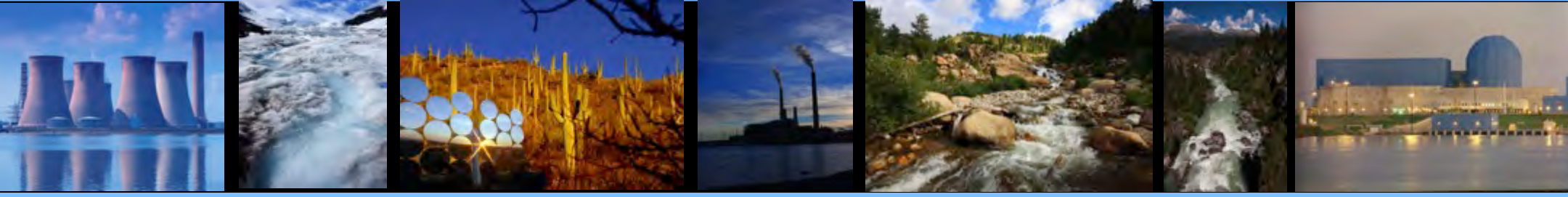
- *And, it is a perfect example of why Governments (including Commissions) must act to solve societal problems involving public goods.*
- *In the past we have acted;*
- *Acid Rain*
- *Environmental Protection Act*



Ronald Coase

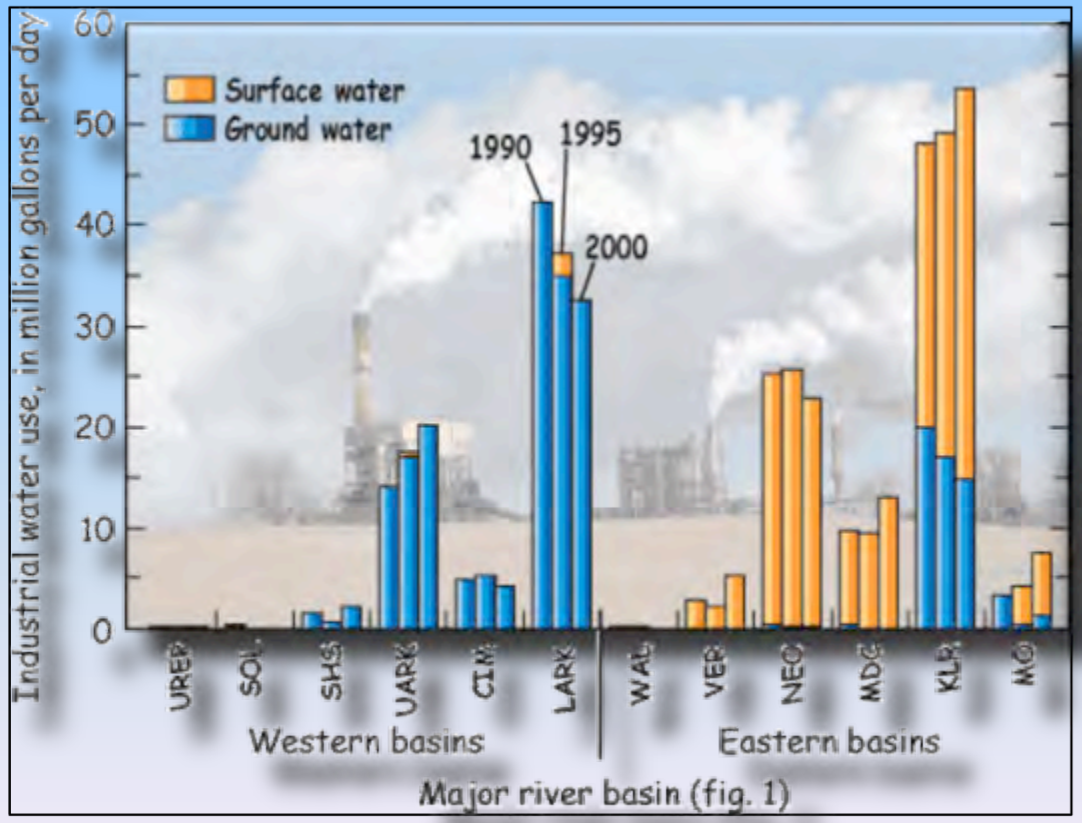


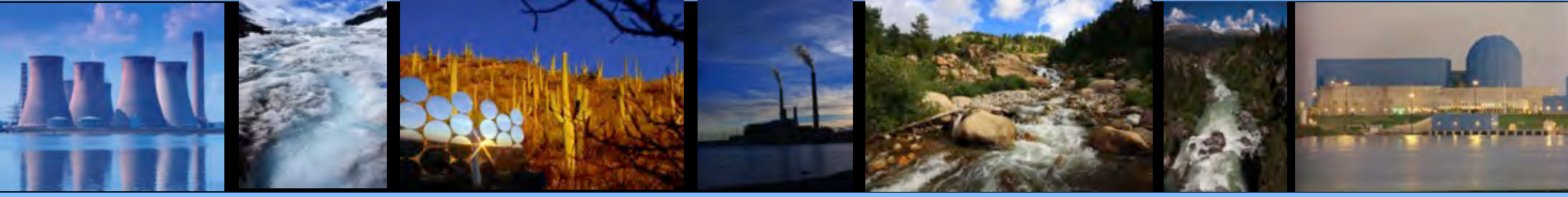
- ***Externalities are one of the main reasons that governing has become harder and politics more interesting.***
- ***In an agrarian economy anything you did only bothered your neighbors.***
- ***Today our actions effect people and the environment thousands of miles and hundreds of years in the future away but they are not part of the decision making process.***



A challenge to optimizing the water-energy nexus is the array of decision makers, including state planners, electric utilities, plant operators, environmental regulators, regional water resource managers, water utilities, refineries, oil & gas producers, citizens …….

GEOGRAPHIC DIFFERENCES

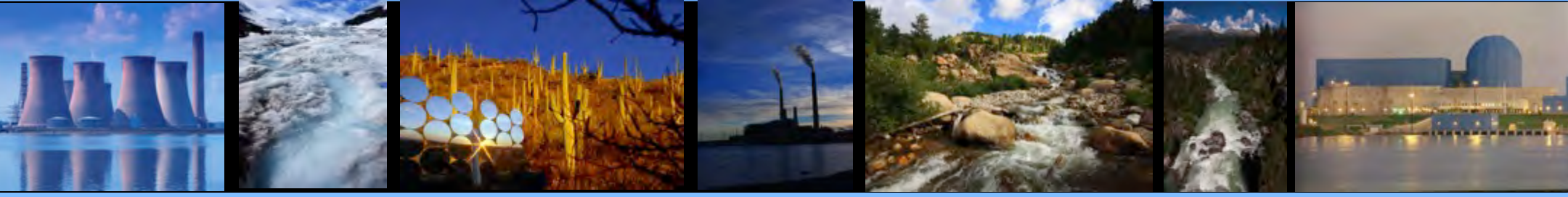




GEOENGINEERING

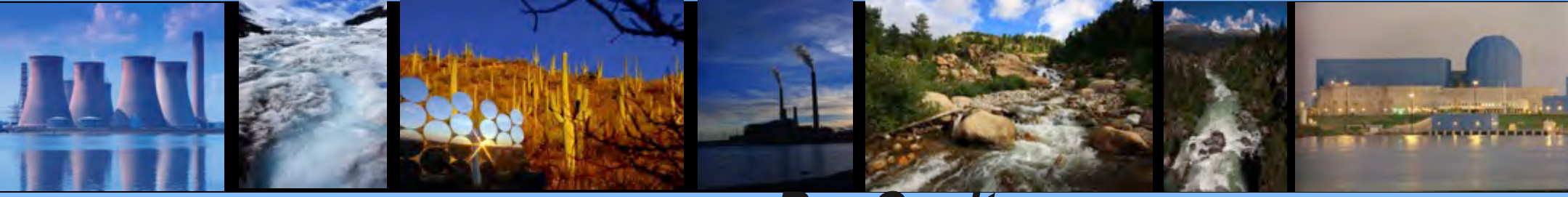
Mae West

- ***Many have suggested various schemes such as sulfur aerosols, giant balloons etc. to reflect sunlight away from the earth to combat climate change.***
- ***"When faced with the choice between two evils make sure to try the one you haven't already tried"***



THE CHOICE BETWEEN TWO EVILS

- *Even if these plans succeed they have one serious flaw.*
- *They do nothing for Ocean Acidification and we will need other plans to combat Acidification.*
- *It may be easier to reduce carbon emissions*



CHINA, THE WORLD'S LARGEST EMITTER 28% VS. U.S 16%

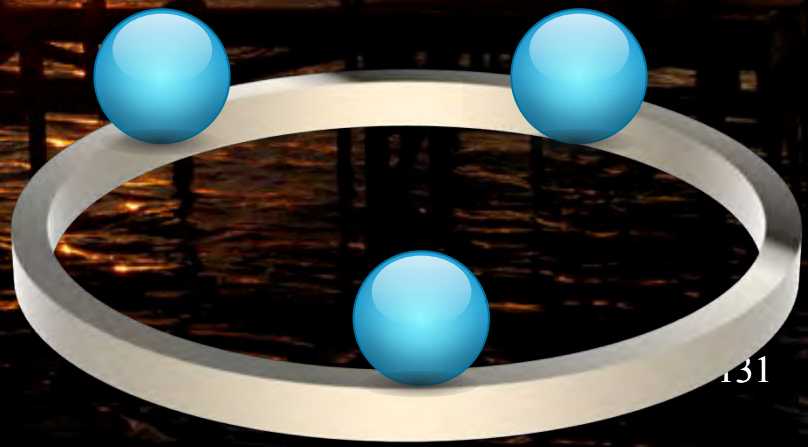
- *Per Capita*
- *U.S. per capita tonnes 17.7*
- *China 6.8*
- *Historical Emissions*
- *1. US: 339,174 MT or 28.8%*
- *2. China: 105,915 MT or 9.0%*
- *Outsourced Emissions*
- *Belgium 21.9*

  United States of America 20.2
  Ireland 16.2
  Finland 15.1
  Australia 13.8
  United Kingdom 11.5
- *.....China 4.3*

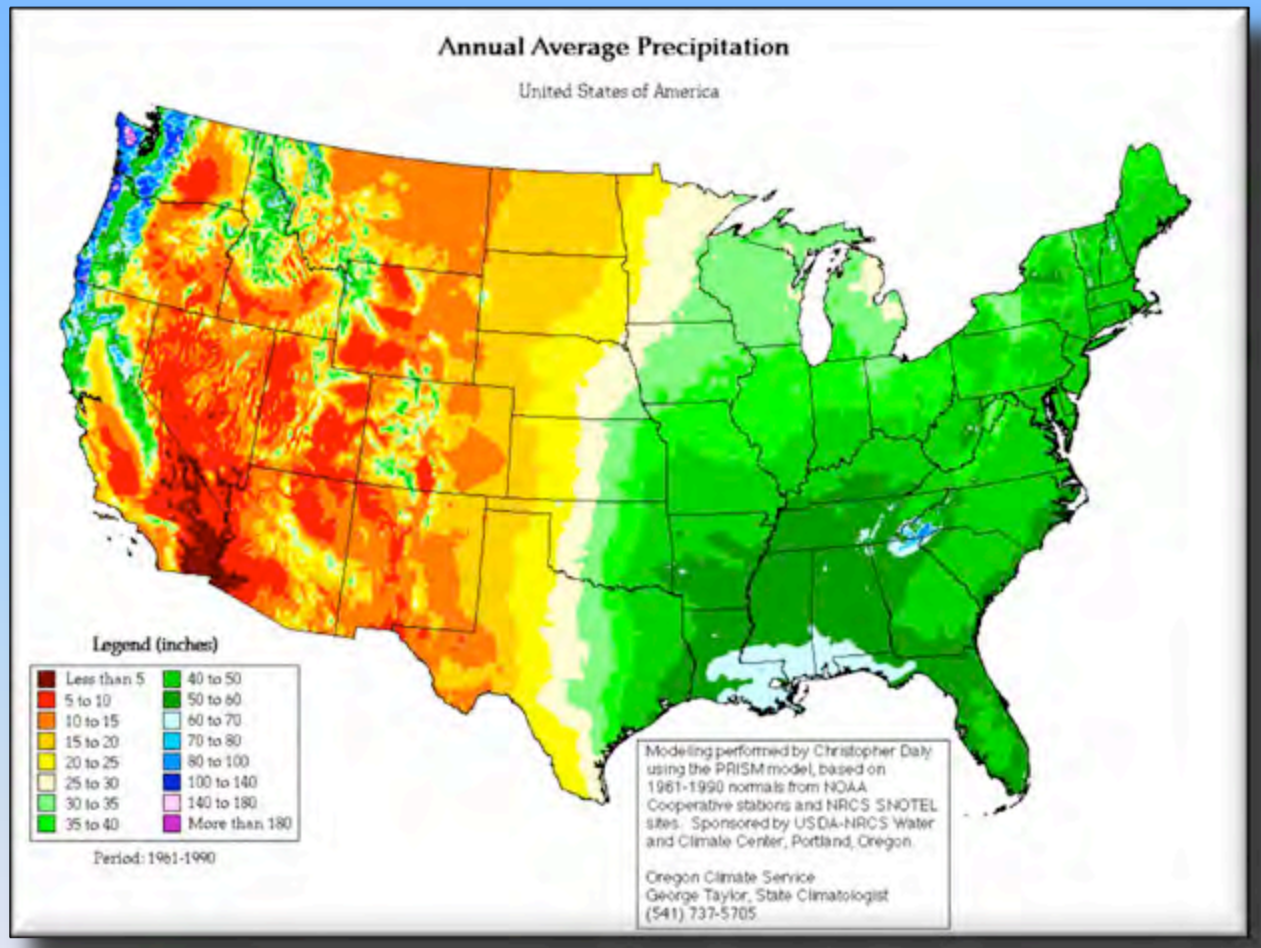
WATER ENERGY CLIMATE

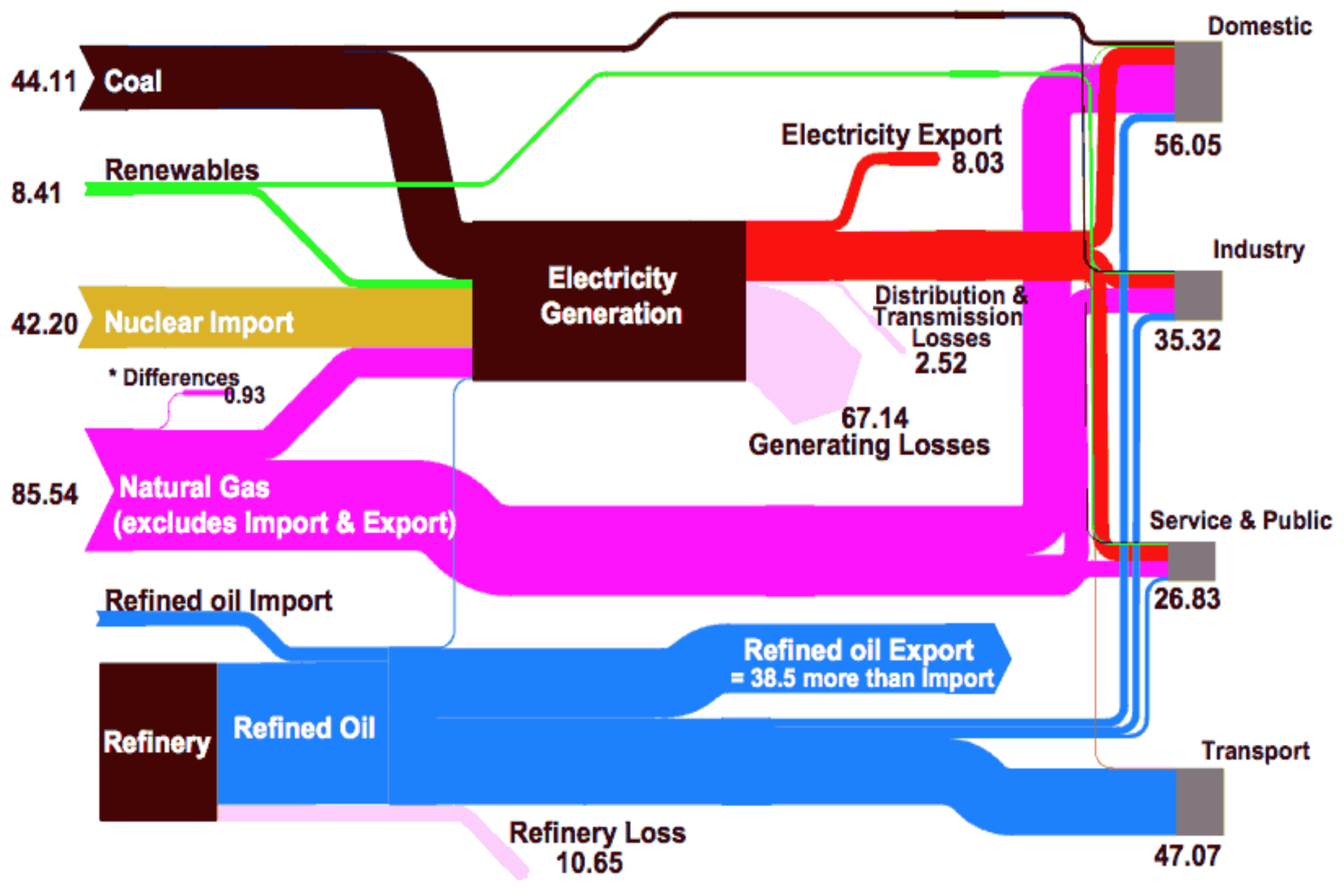
"Eventually, all things merge into one, and a river runs through it"

"A River Runs Through it." Norman Maclean

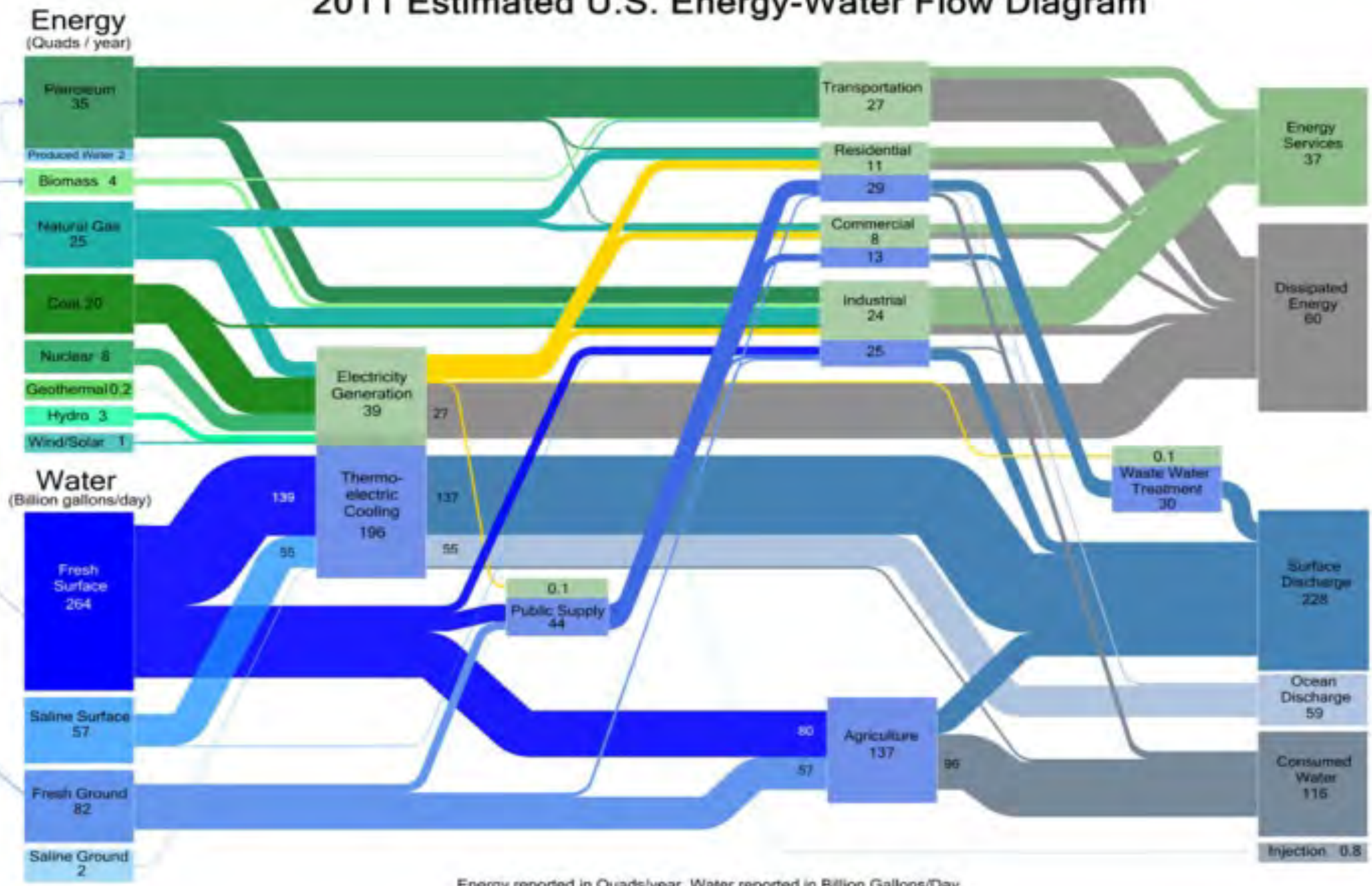


Sunset, Mauritius

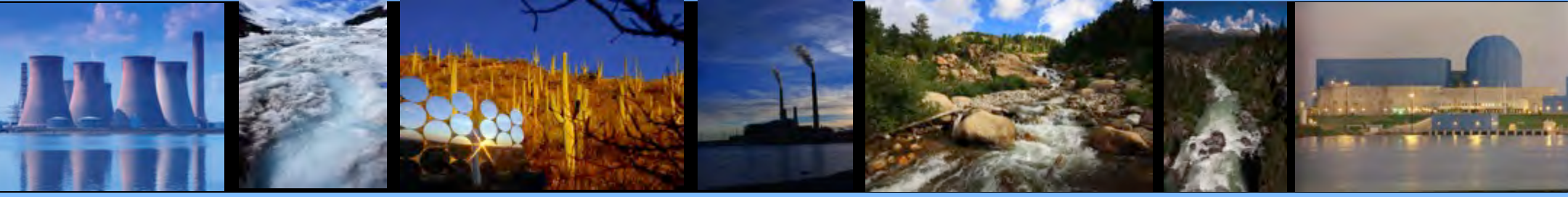

Annual Average Precipitation
United States of America
Legend (inches)
Less than 5
5 to 10
10 to 15
15 to 20
20 to 25
25 to 30
30 to 35
35 to 40
40 to 50
50 to 60
60 to 70
70 to 80
80 to 100
100 to 140
140 to 180
More than 180
Period: 1961-1990
Modeling performed by Christopher Daly using the PRISM model, based on 1961-1990 normals from NOAA Cooperative stations and NRCS SNOTEL sites. Sponsored by USDA-NRCS Water and Climate Center, Portland, Oregon.
Oregon Climate Service
George Taylor, State Climatologist
(541) 737-5705


44.11
Coal
8.41
Renewables
42.20
Nuclear Import
* Differences
0.93
85.54
Natural Gas
(excludes Import & Export)
Refined oil Import
Refinery
Refined Oil
Refinery Loss
10.65
Electricity
Generation
Electricity Export
8.03
Distribution &
Transmission
Losses
2.52
67.14
Generating Losses
Refined oil Export
= 38.5 more than Import
Domestic
56.05
Industry
35.32
Service & Public
26.83
Transport
47.07

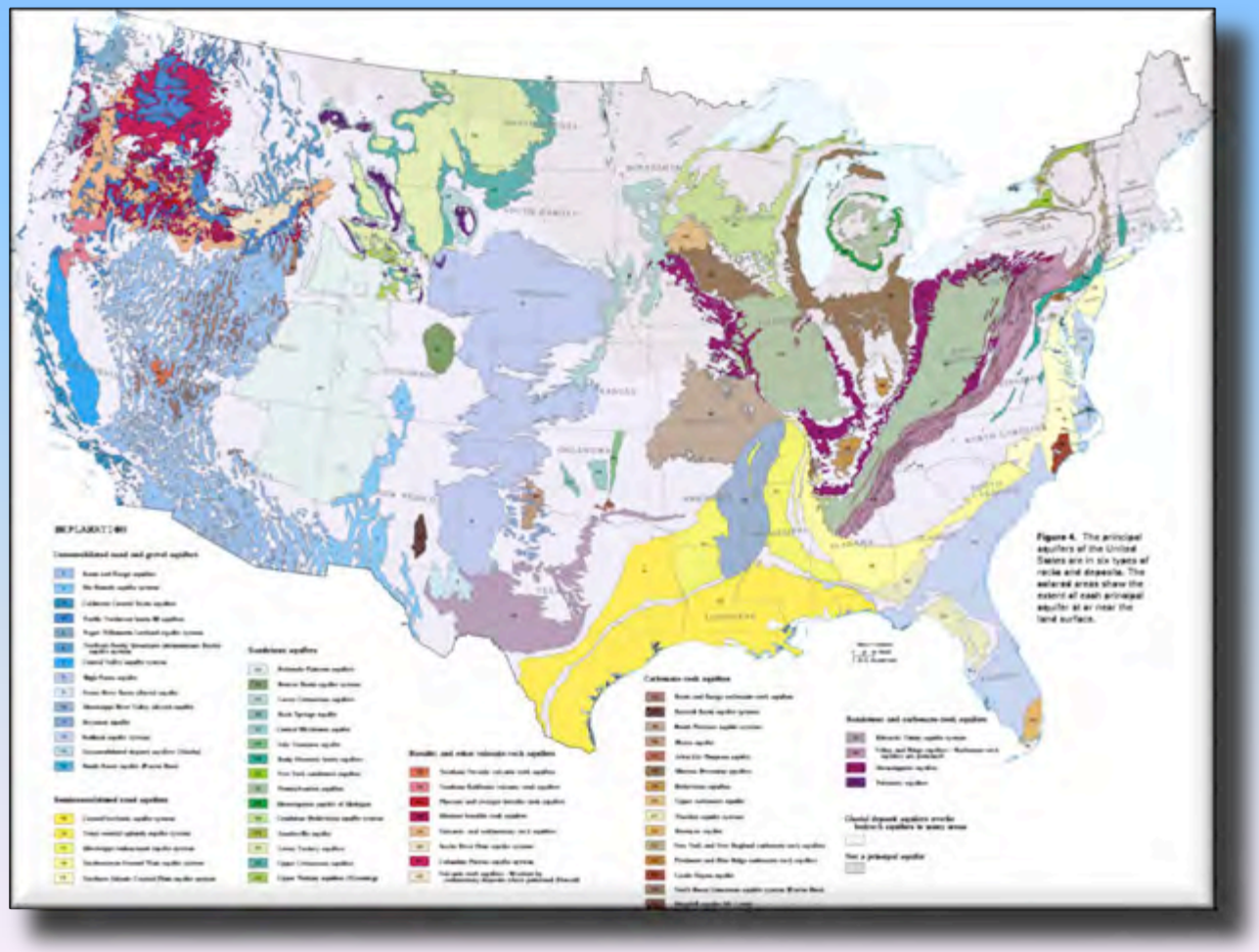
2011 Estimated U.S. Energy-Water Flow Diagram



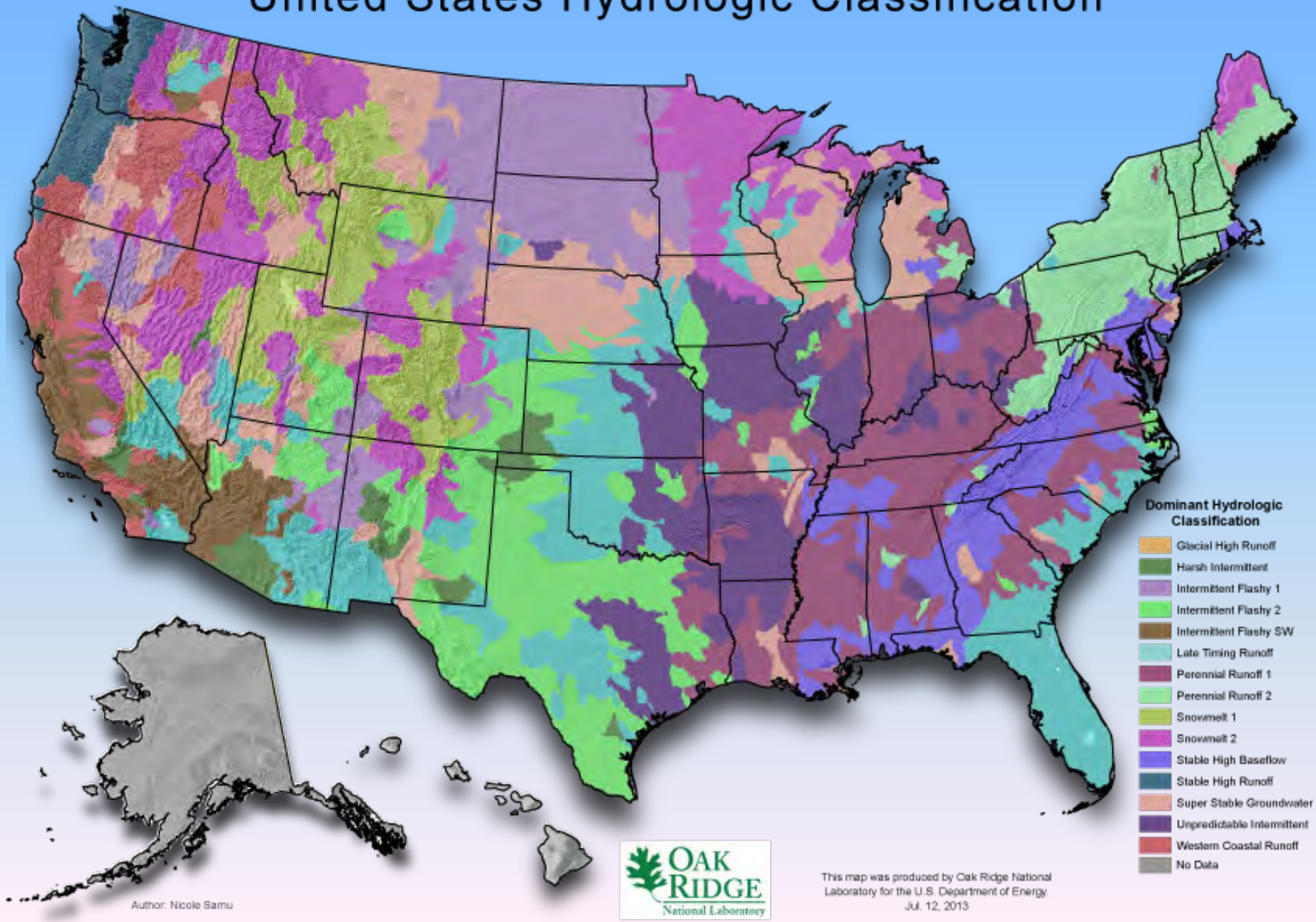
Energy reported in Quads/year. Water reported in Billion Gallons/Day.



- ***State of Aquifers***



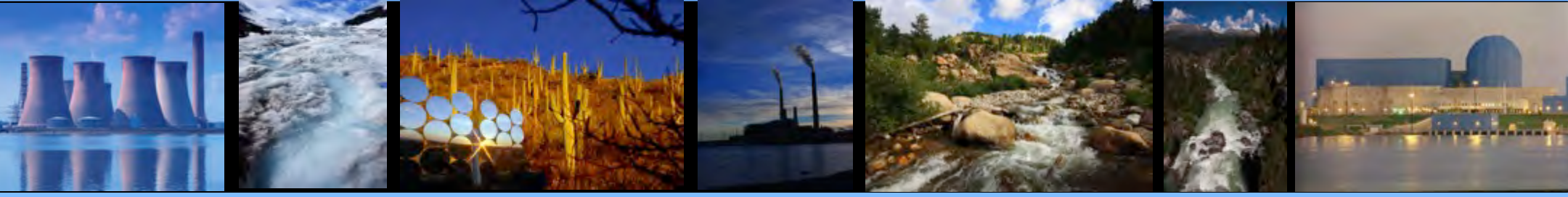
United States Hydrologic Classification



Author: Nicole Samu

OAK RIDGE National Laboratory

This map was produced by Oak Ridge National Laboratory for the U.S. Department of Energy.
Jul. 12, 2013



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- *ceb1618@aol.com*