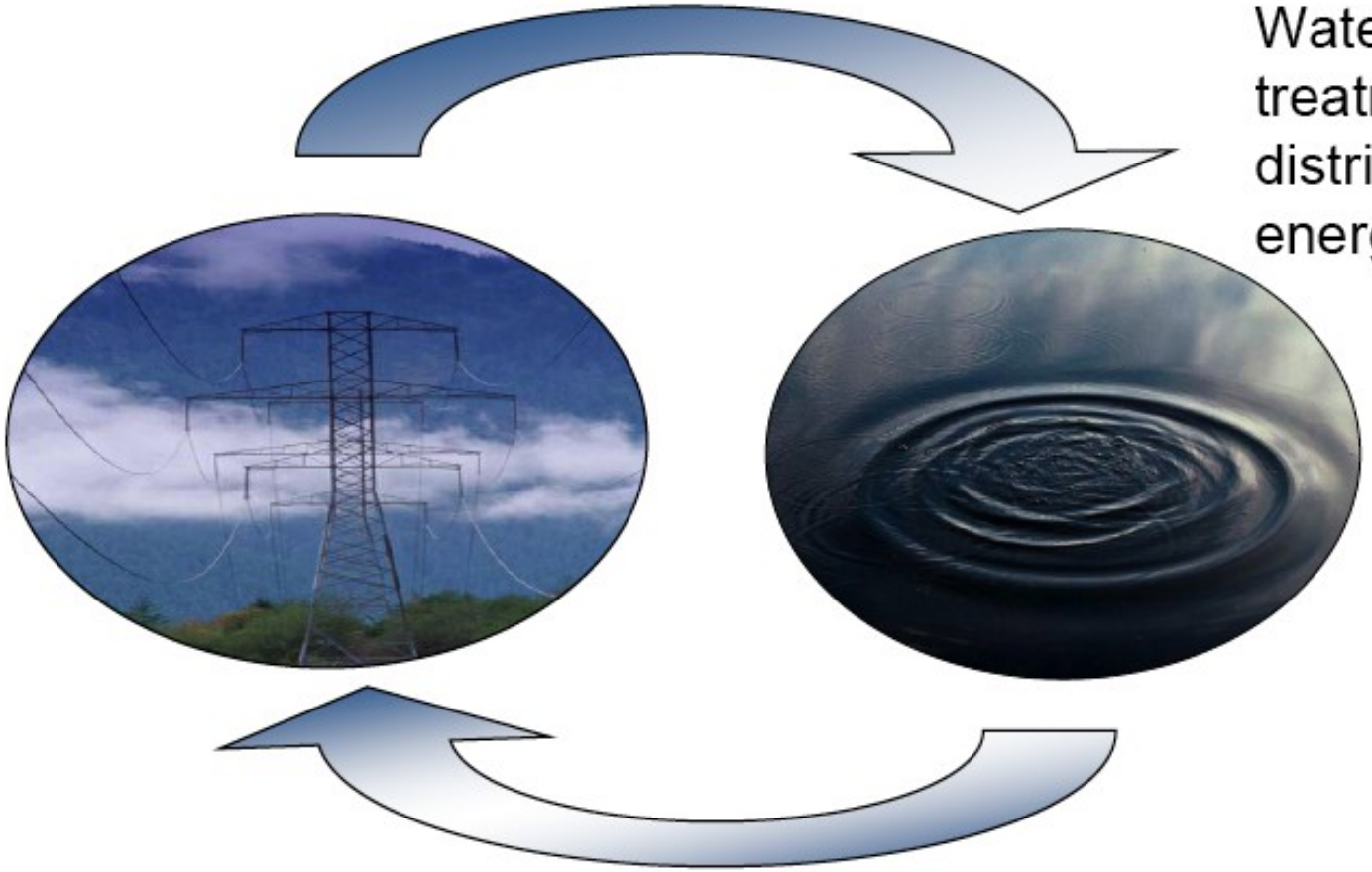
Characterizing Water Demand:
Energy

Christopher Scott

The Water-Energy Nexus



Water pumping, treatment, and distribution require energy

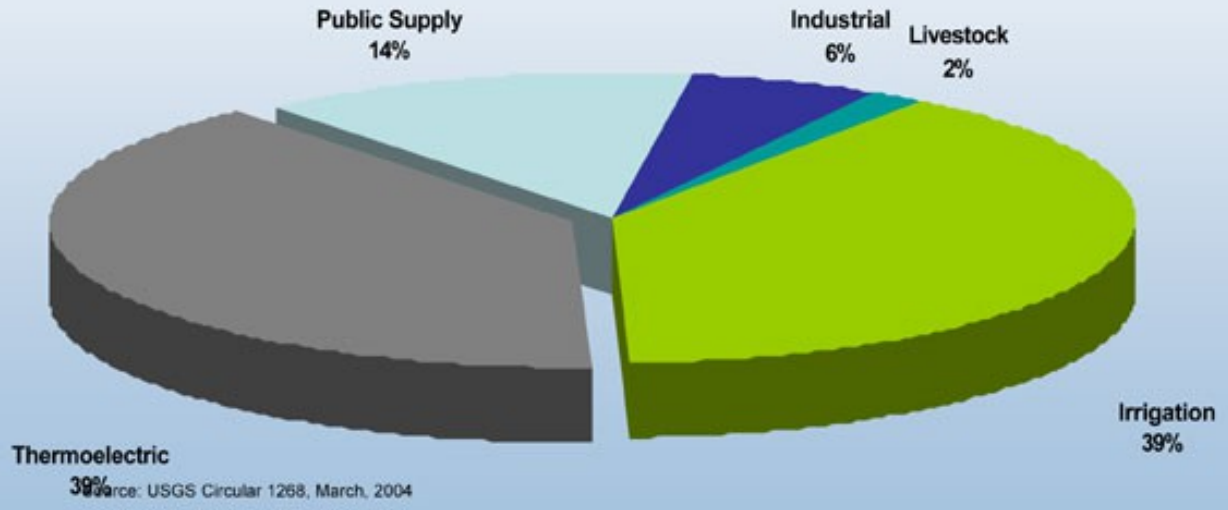
Energy production and generation require water

Water for Energy: example USA

Energy Requires Water

Cumulative Water Use for Electricity Production Equals Water Use for Irrigation

Estimated Freshwater Withdrawals by Sector, 2000

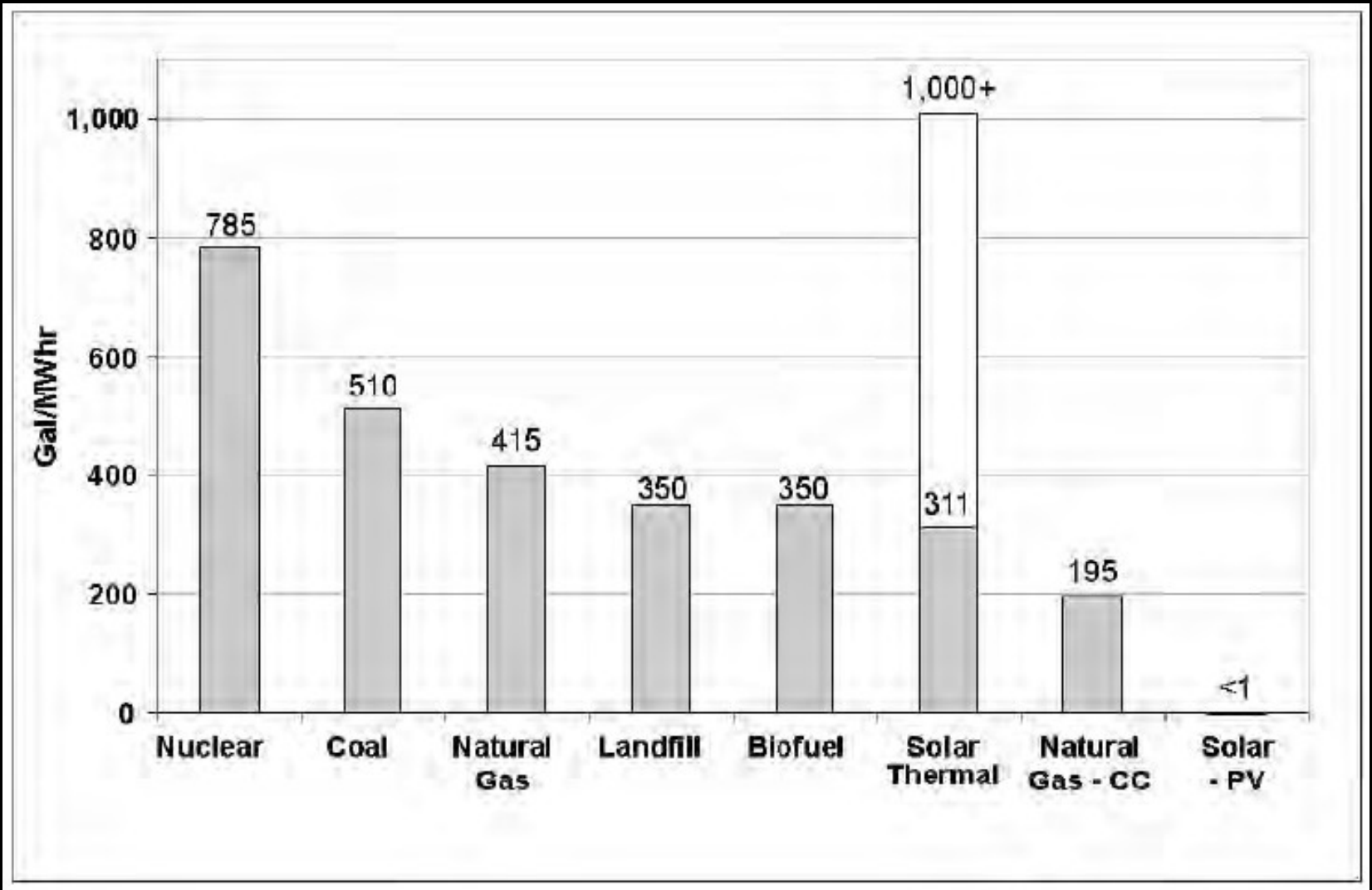


Source: USGS Circular 1268, March, 2004

EAO Energy Analysis Office
Understanding Energy Issues

NREL National Renewable Energy Laboratory

Water intensities of electricity generation



Source: Scott and Pasqualetti, 2010

Water Use & Consumption for Electricity Generation

Plant-type	Cooling Process	Water Use Intensity (gal/MWhe)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	20,000–50,000	~200-300	~30
	Closed-loop	300–600	300–480	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	~30
	Closed-loop	500–1,100	400–720	
Natural Gas Combined-Cycle	Open-loop	7,500–20,000	100	7–10
	Closed-loop	230	180	
Integrated Gasification Combined-Cycle	Closed-loop	200	180	150
Carbon sequestration for fossil energy generation	~60% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	2000	1350	50
Concentrating Solar	Closed-loop	750	740	10
Wind and Solar Photovoltaic	N/A	0	0	1-2

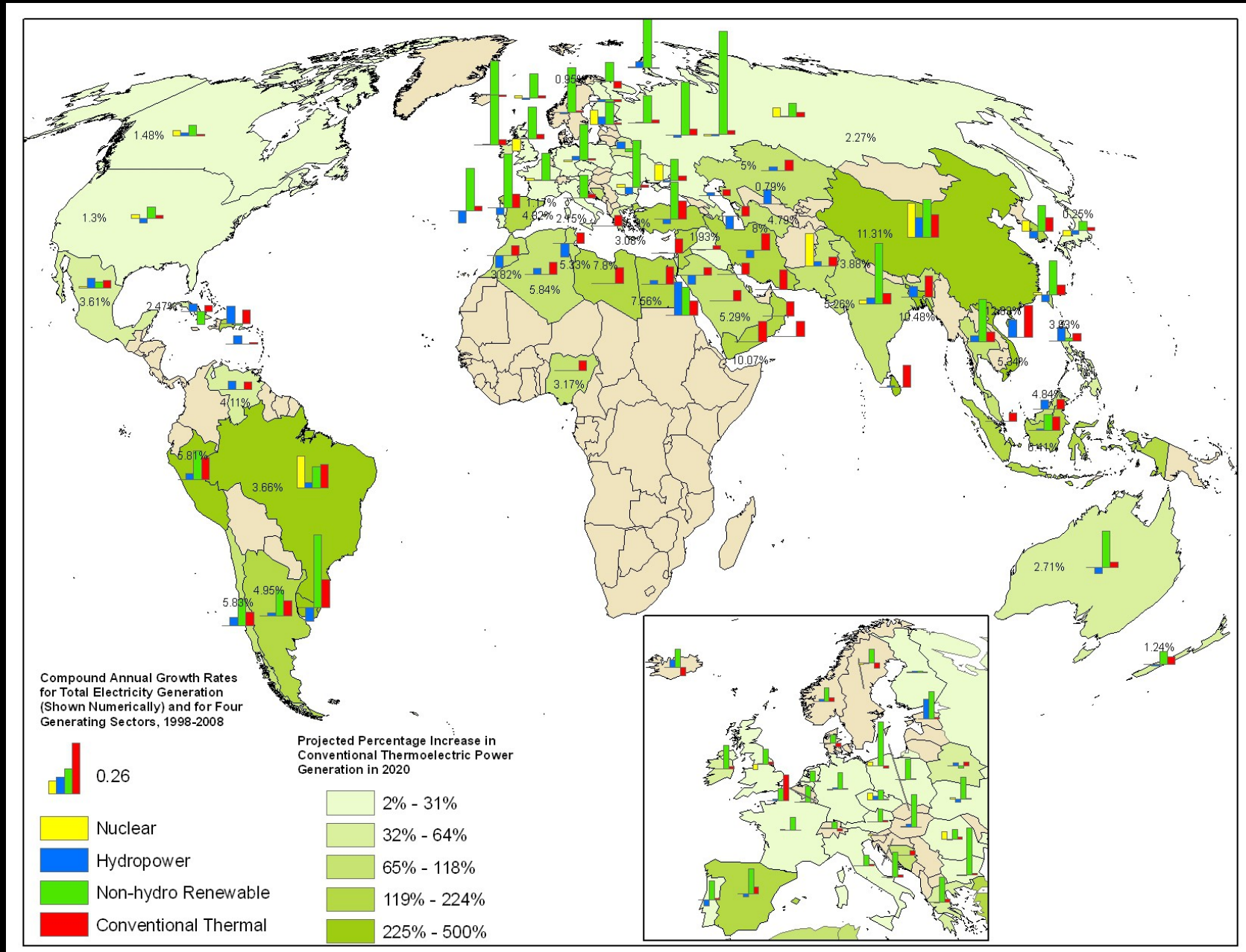
Fuel Type and Process	Relationship to Water Quantity	Relationship to Water Quality	Water Consumption	
			Water consumed per-unit-energy [gal / MMBTU] †	Average gal water consumed per gal fuel
Conventional Oil & Gas	Water needed to extract and refine; Water produced from extraction	Produced water generated from extraction; Wastewater generated from processing;		
- Oil Refining			7 – 20	~ 1.5
- NG extraction/Processing			2 – 3	~ 1.5
Biofuels	Water needed for growing feedstock and for fuel processing;	Wastewater generated from processing; Agricultural irrigation runoff and infiltration contaminated with fertilizer, herbicide, and pesticide compounds		
- Grain Ethanol Processing			12 - 160	~ 4
- Corn Irrigation for EtOH			2500 - 31600	~ 980*
- Biodiesel Processing			4 – 5	~ 1
- Soy Irrigation for Biodiesel			13800 – 60000	~ 6500*
- Lignocellulosic Ethanol and other synthesized Biomass to Liquid (BTL) fuels	Water for processing; Energy crop impacts on hydrologic flows	Wastewater generated; Water quality benefits of perennial energy crops	24 – 150 ‡§ (ethanol) 14 – 90 ‡§ (diesel)	~ 2 - 6 ‡§ ~ 2 - 6 ‡§
Oil Shale	Water needed to Extract / Refine	Wastewater generated; In-situ impact uncertain; Surface leachate runoff		
- In situ retort			1 – 9 ‡	~ 2 ‡
- Ex situ retort			15 - 40 ‡	~ 3 ‡
Oil Sands	Water needed to Extract / Refine	Wastewater generated; Leachate runoff	20 - 50	~ 4 - 6
Synthetic Fuels	Water needed for synthesis and/or steam reforming of natural gas (NG)	Wastewater generated from coal mining and CTL processing		
- Coal to Liquid (CTL)			35 - 70	~ 4.5- 9.0
- Hydrogen RE Electrolysis			20 – 24 ‡	~ 3 ‡
- Hydrogen (NG Reforming)			40 – 50 ‡	~ 7 ‡

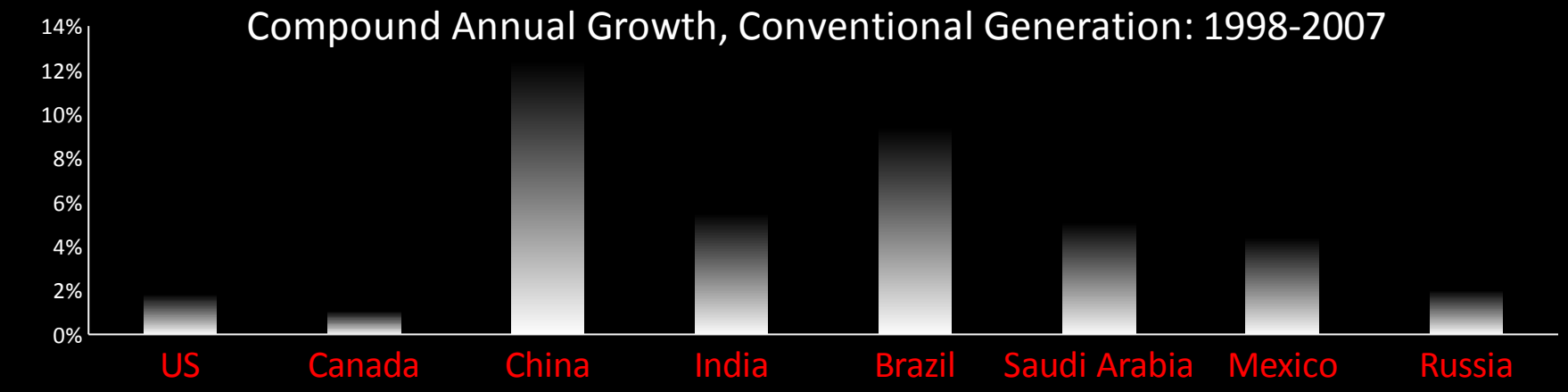
† Ranges of water use per unit energy largely based on data taken from the Energy-Water Report to Congress (DOE, 2007)

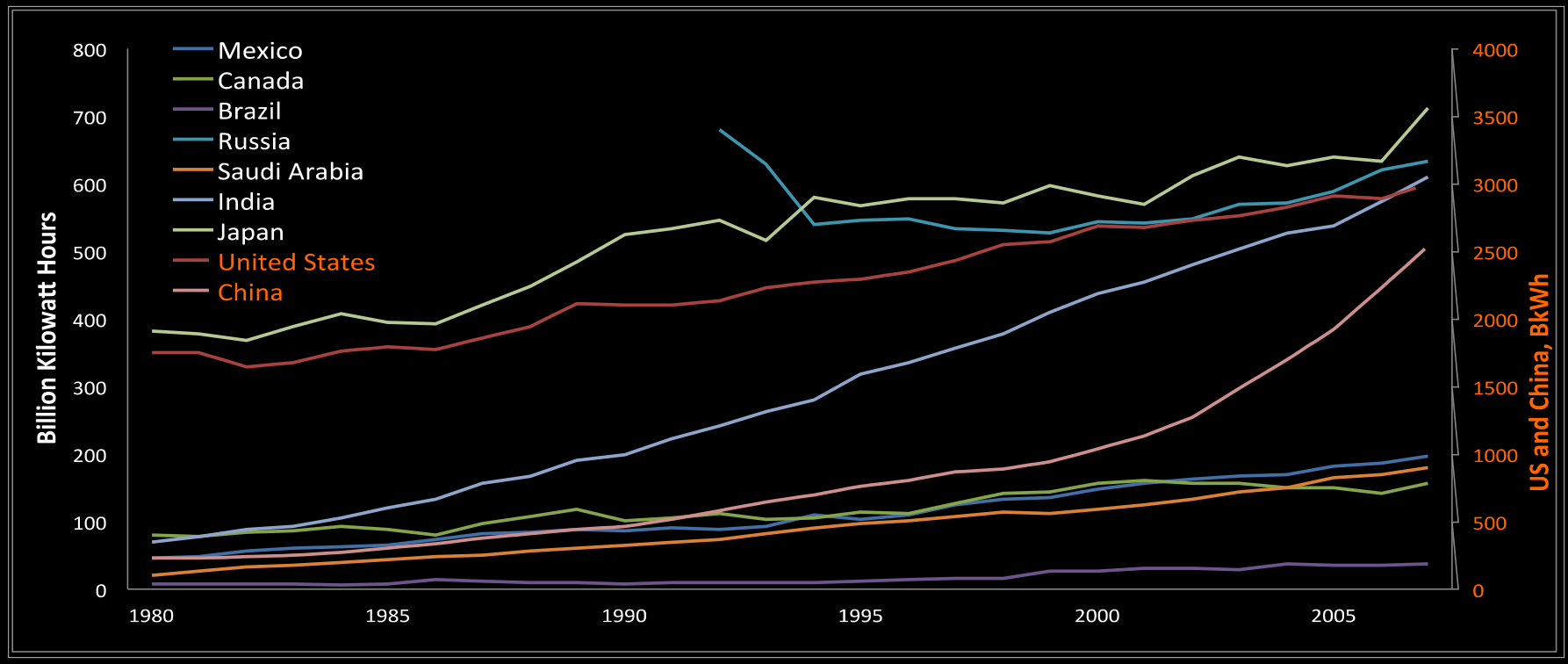
* Conservative estimates of water use intensity for irrigated feedstock production based on per-acre crop water demand and fuel yield

‡ Estimates based on unvalidated projections for commercial processing; § Assuming rain-fed biomass feedstock production

Energy futures: water and carbon impacts



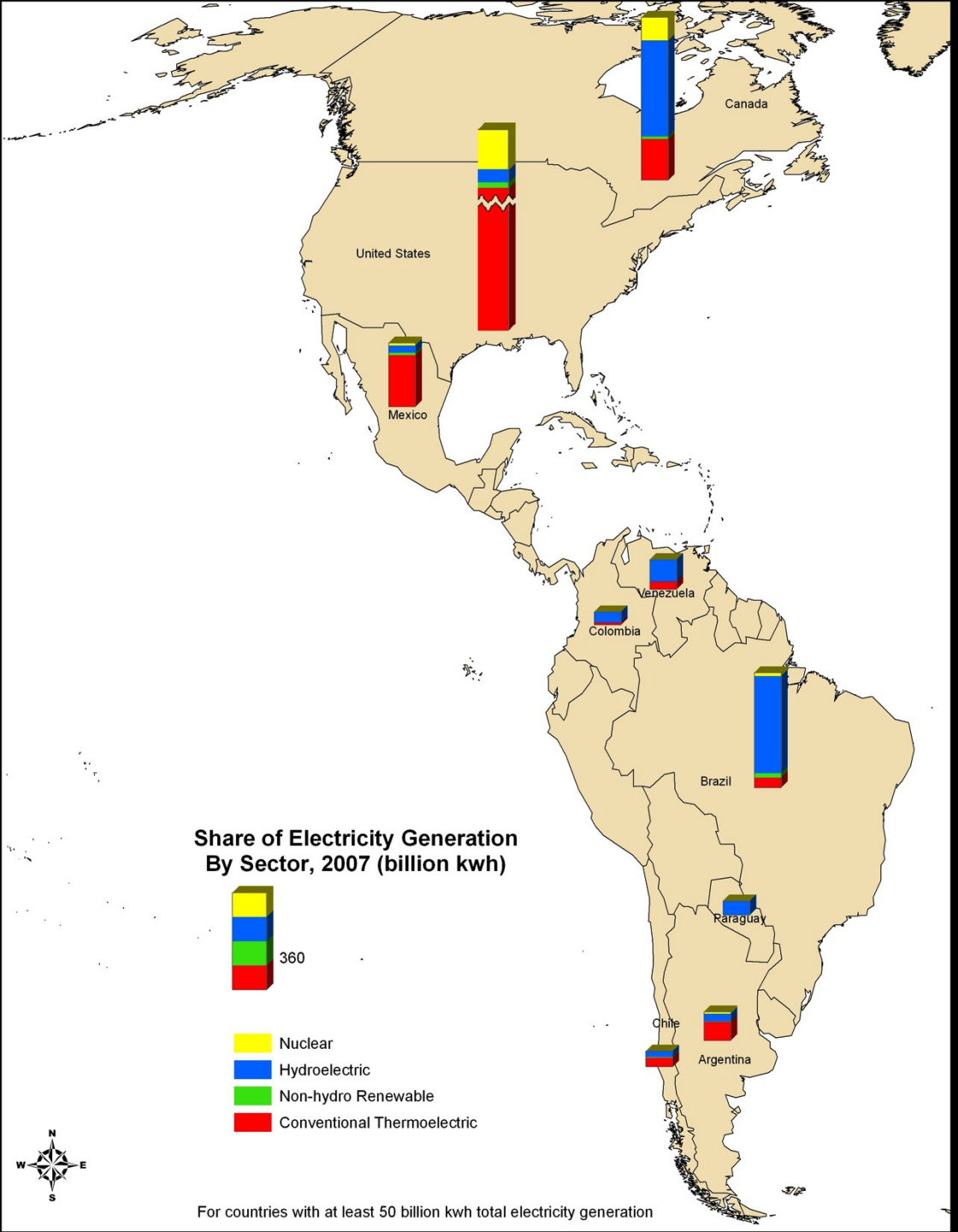




Slight increases in renewables, but no indication that water-extractive/consumptive conventional thermal generation will stop increasing. This will continue to place a demand on available water supplies.

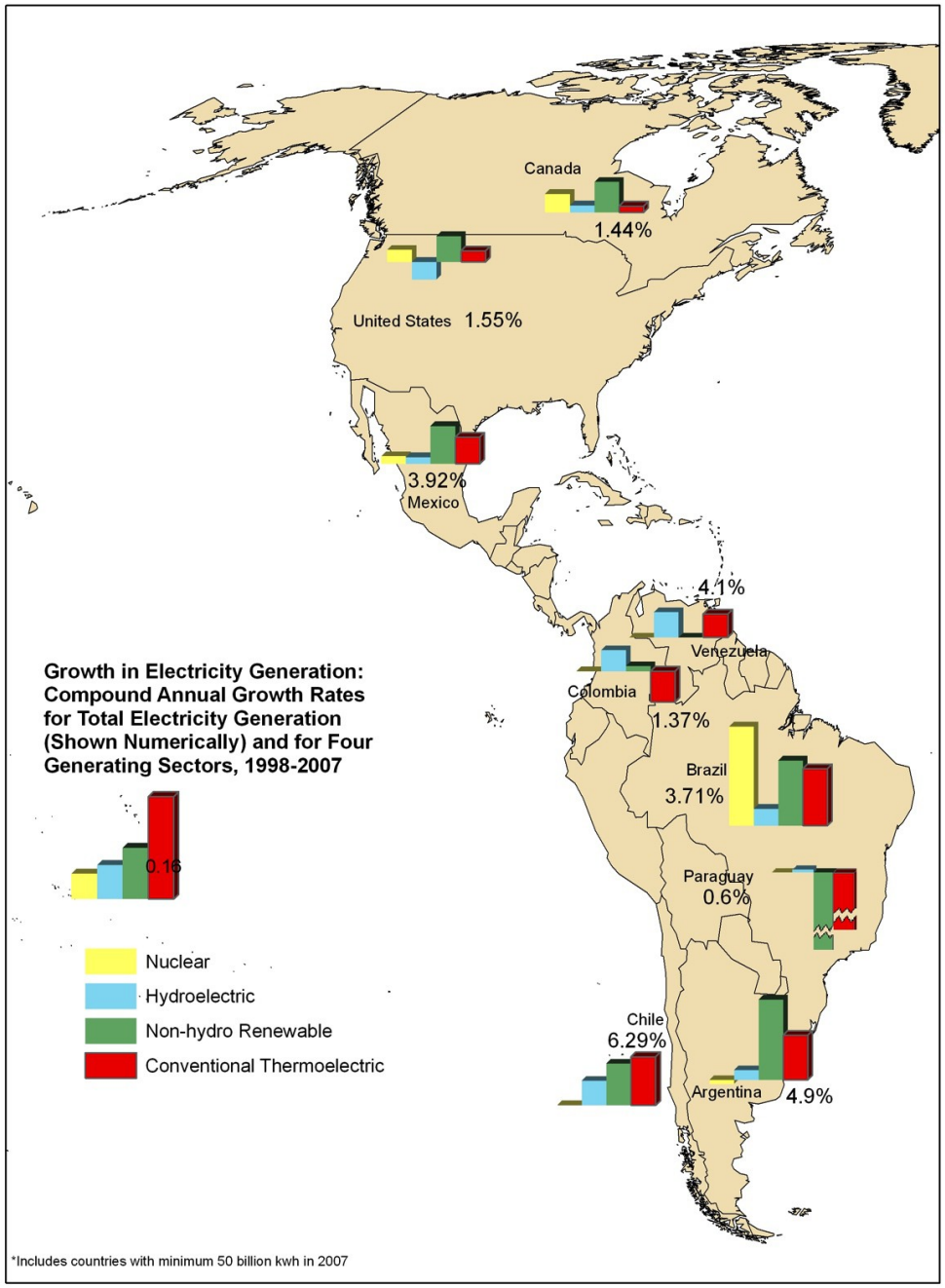
Key trends - global electricity production

- Electricity demand to double, 2005-2030 (Maheu, 2009)
  - Non-OECD demand to increase 84%; OECD 14%
- Generation to increase 87%, 2010-2035 (EIA, 2010)
  - Hydroelectricity (reservoir evaporation) highest energy nexus water consumption but low adoption of new hydropower (Maheu, 2009). Brazil?
  - Fossil fuel generation next level water consumption; share of renewables continues to rise
- Global energy price increases, government incentives, and GHG mitigation = interest in nuclear and renewables. Fukushima effect?
- Renewables long-term prospects excellent



2007 Baseline Electricity Generation portfolios

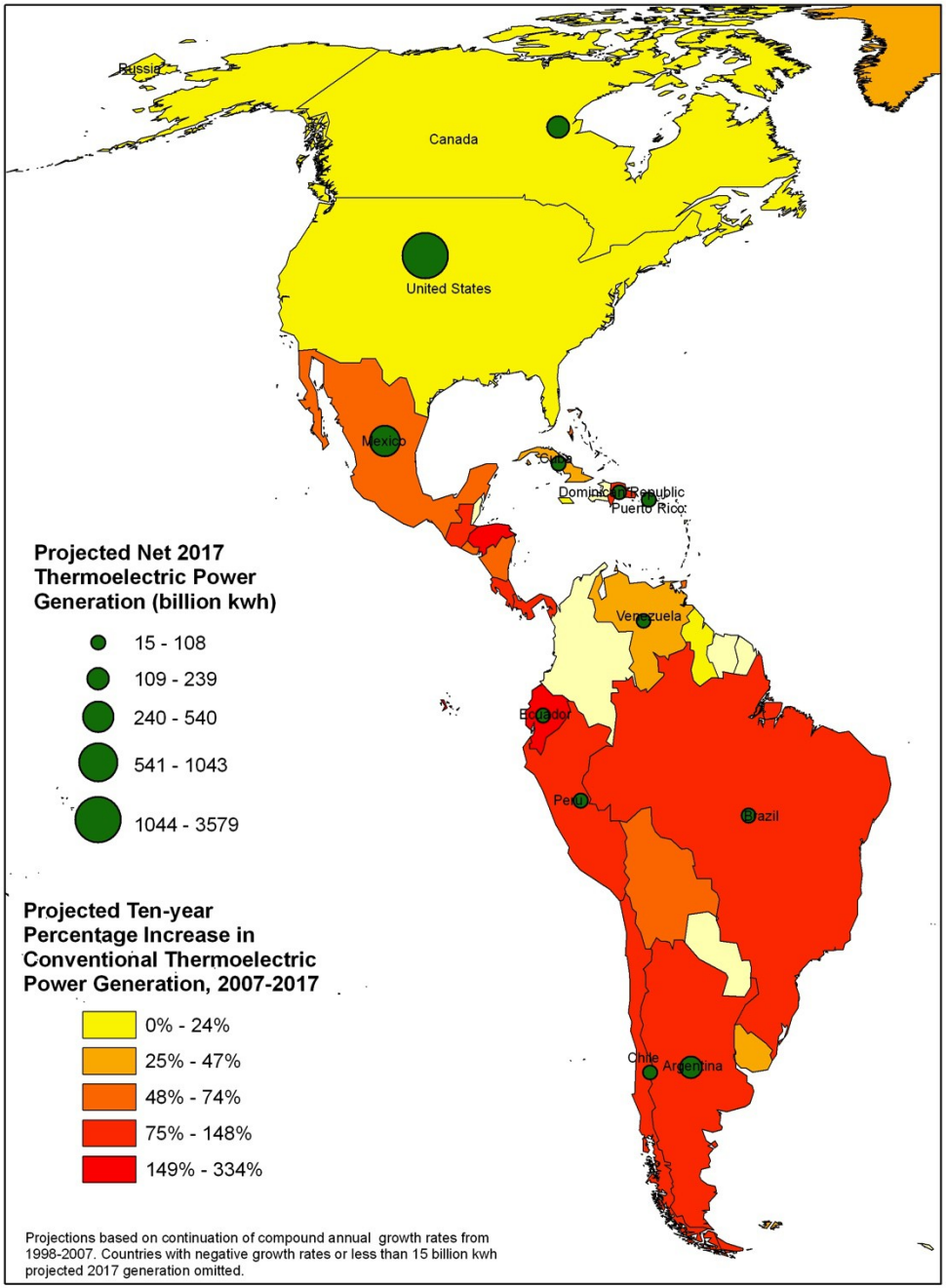
S. American countries and Canada highly reliant on hydropower.



How do these broader scale trends vary among countries in the Americas?

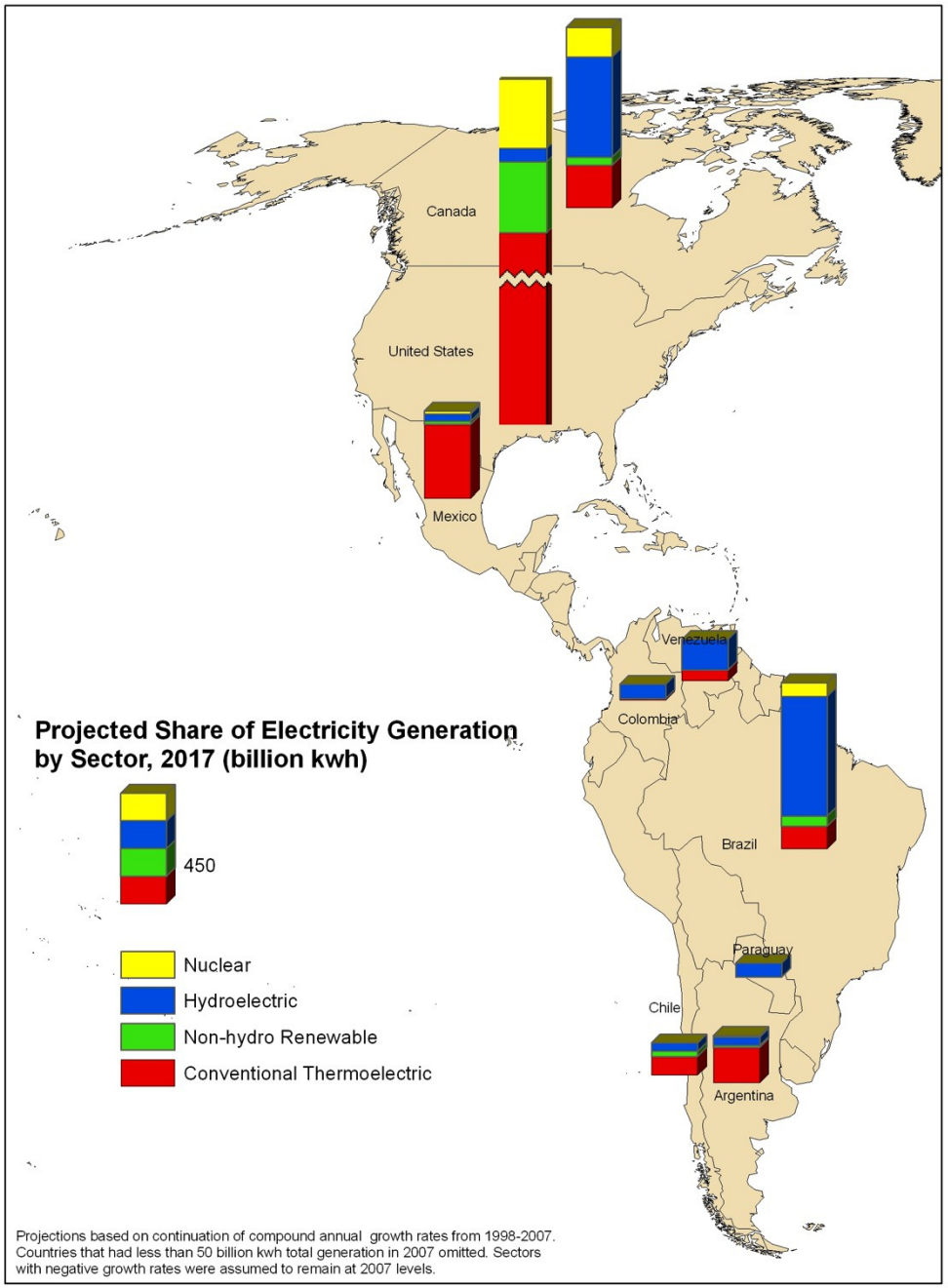
Last 10 years saw growth in renewables and hydropower in S. American countries,

Renewable energy production in the Americas is on the rise in several countries, both hydroelectric and non-hydro.



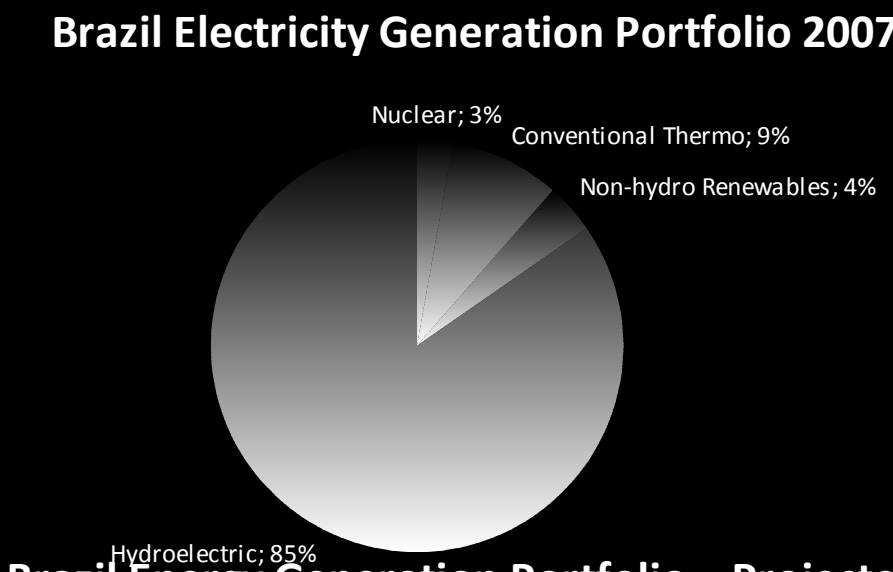
The U.S. and China will remain by far the biggest producers of thermal electric power. However, based on recent growth rates, several Central and South American nations are likely to experience substantial increases in thermal power generation by 2017 relative to the 2007 baseline.

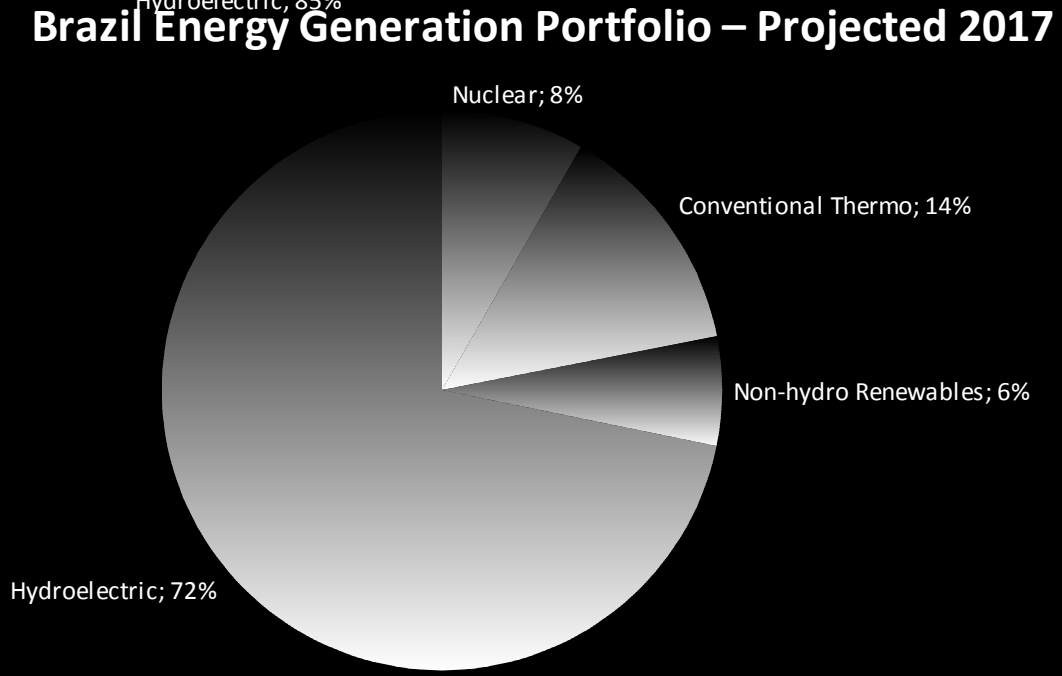
Potential Energy Future Portfolios



Brazil

- Huge amount of hydropower, with dam sites possible for more. Potentially vulnerable to altered rainfall regime due to GCC.
- Bioenergy typically a major consumer of water, but Brazilian ethanol primarily from sugar cane is rain fed. (de Fraiture et al., 2008)
- Assuming recent growth rates continue, fossil fuel electricity generation could potentially increase by 145% by 2017.





Nuclear in Brazil: high water consumption

Several countries showed positive growth in nuclear capacity in recent years, but Brazil by far the most rapid recent growth in nuclear thermo electric generation in the Americas. Roughly the same capacity as India.

Country	Compound Annual Growth Rate 1997-2008	Total Capacity, BkWh
Brazil	16%	14
China	19%	65
Russia	5%	152
South Korea	5%	143
Czech Republic	8%	25
India	5%	13
U.S.A.	2%	806
Canada	3%	89

Based on CAGR 1997-2008 and total generation for 2008

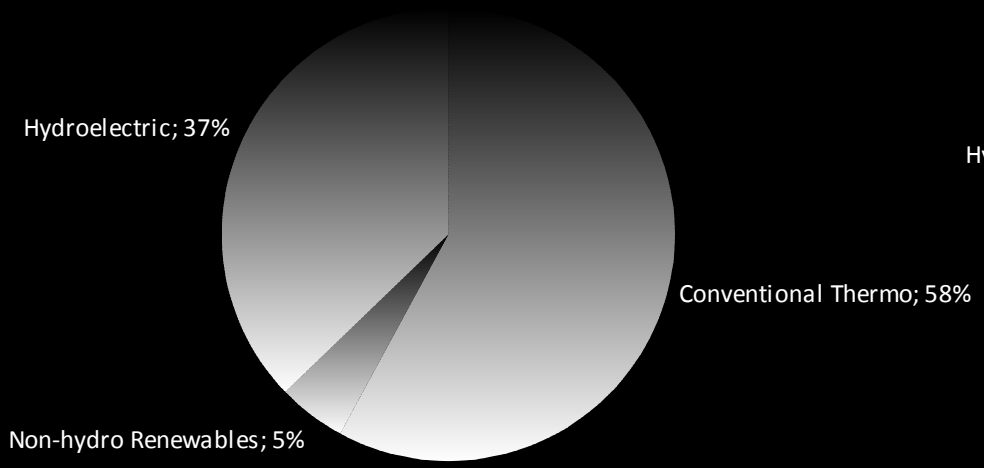
Brazil: Key future tradeoff questions

- Will growth in hydropower capacity continue?
- Will growth in nuclear revive?
- If neither, how much will fossil fuel electricity sources have to increase to meet demand?
- How will energy policy be driven by climate/carbon considerations? Implications for fossil/non-fossil mix?
- Every scenario and future portfolio has energy-water tradeoffs related to spatial distribution of water supplies and water withdrawal and consumption intensities of each technology.
- Biofuels currently for ethanol. What future biodiesel? Water (irrigation) implications?

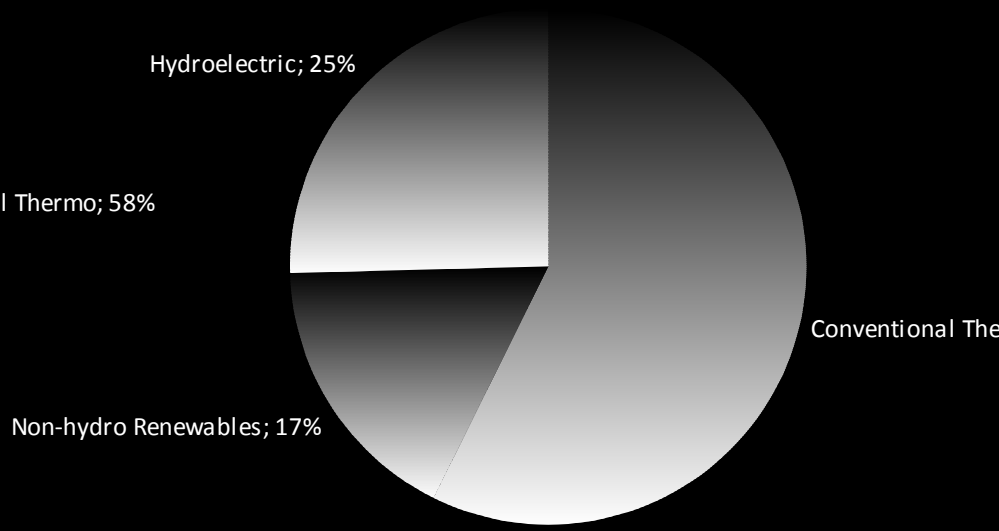
Chile

- Hydro share of total electricity to decrease (but net hydro increase); other renewables increase
- Chilean government pursuit and approval of controversial Patagonia hydro project*
- How much could contentious hydropower development be offset by renewable energy?
- What tradeoffs between water/environmental and hydropower when the electricity sector legally over-rides the water sector? (Bauer, 2009)
- How might increasing control of river systems through hydropower infrastructure and reservoir creation increase vulnerability to altered hydrologic cycle due to climate change? “Build first, ask questions later” (Bauer, 2009 p. 649)

Chile Electricity Generation Portfolio



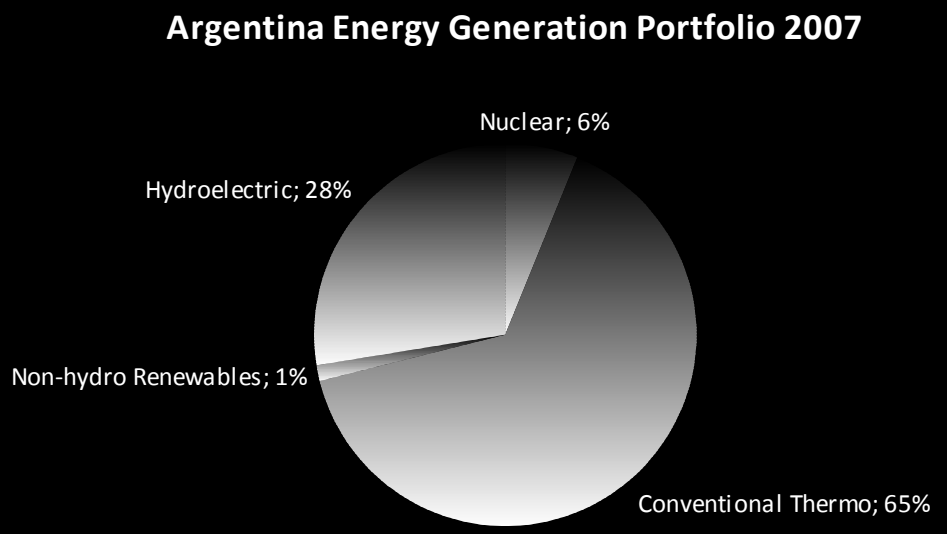
Chile Electricity Generation Portfolio – Projected 2017



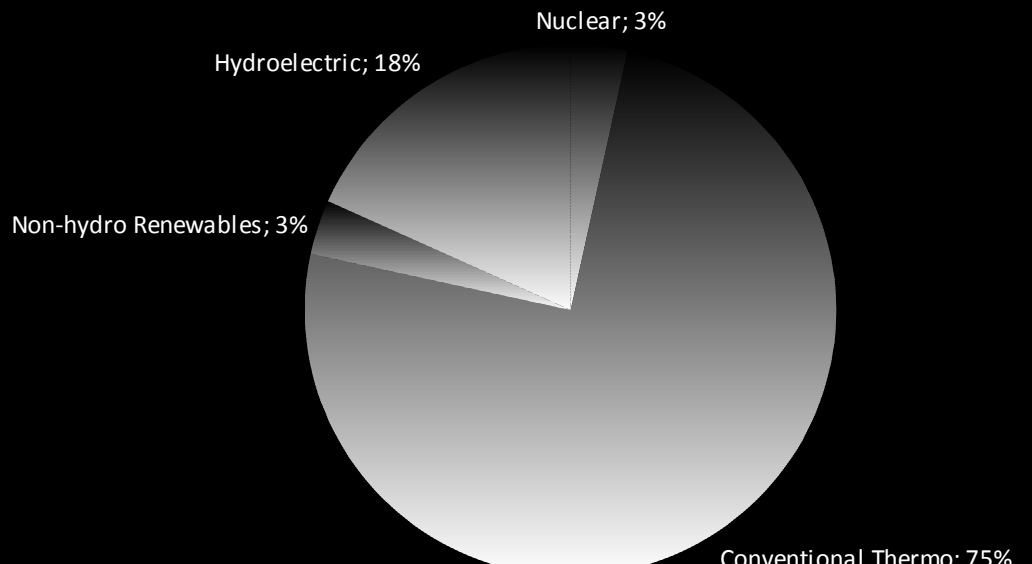
*http://www.guardian.co.uk/environment/2011/may/10/chile-hydroelectric-dam
*http://www.guardian.co.uk/environment/2011/may/10/chile-patagonia-dams-hydroelectricity

Argentina

- Overall electricity growth increase lower than neighbors
- Conventional thermo increase
  - GHG and water implications are important
- Hydro constant (decreased share of national generation)

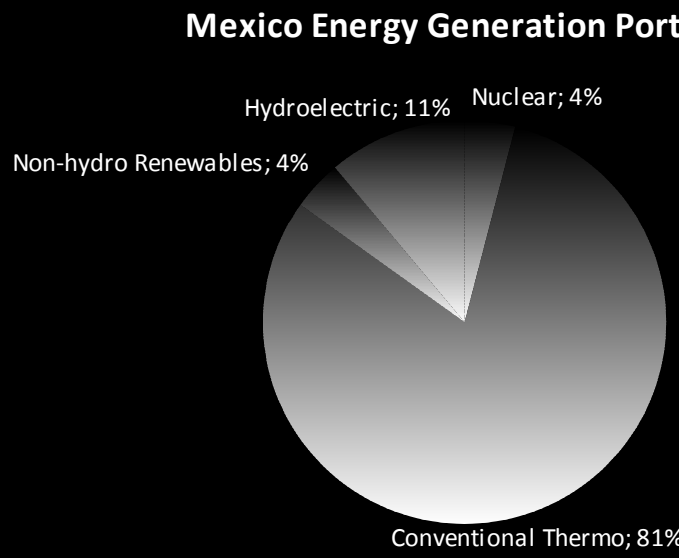


Argentina Energy Generation Portfolio – Projected 2017

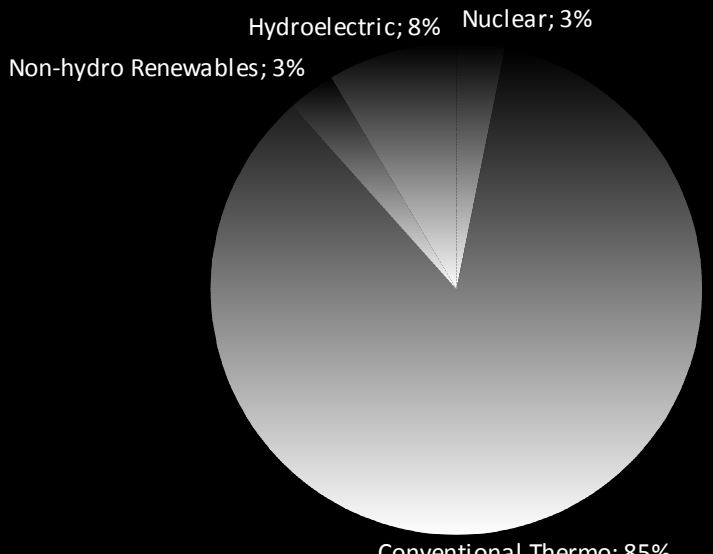


Mexico

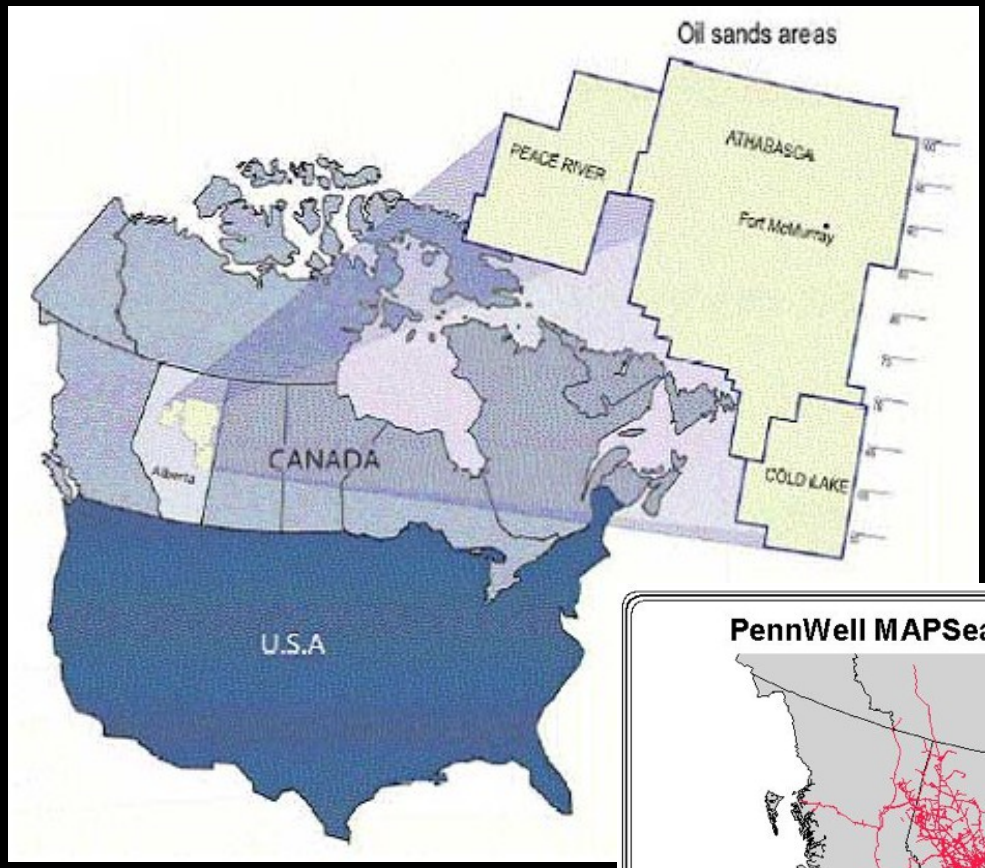
- Highest thermo share of any larger Latin American country
  - Water impacts (esp. groundwater) are extreme
- Major renewables potential (solar in Northwest, wind in Tehuantepec Isthmus)
- Ambitious renewables targets, but inadequate investment



Mexico Energy Generation Portfolio – Projected 2017



North American “energy independence” - Alberta tar sands


Oil sands areas
PEACE RIVER
ATHABASCA
Fort McMurray
COLD LAKE
Alberta
CANADA
U.S.A


CANADA
Fort McMurray
Edmonton
Hardisty
Keystone pipeline
U.S.
Proposed Keystone expansion
Neb.
St. Louis
Ogallala Aquifer
Houston
Port Arthur
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800
MILES
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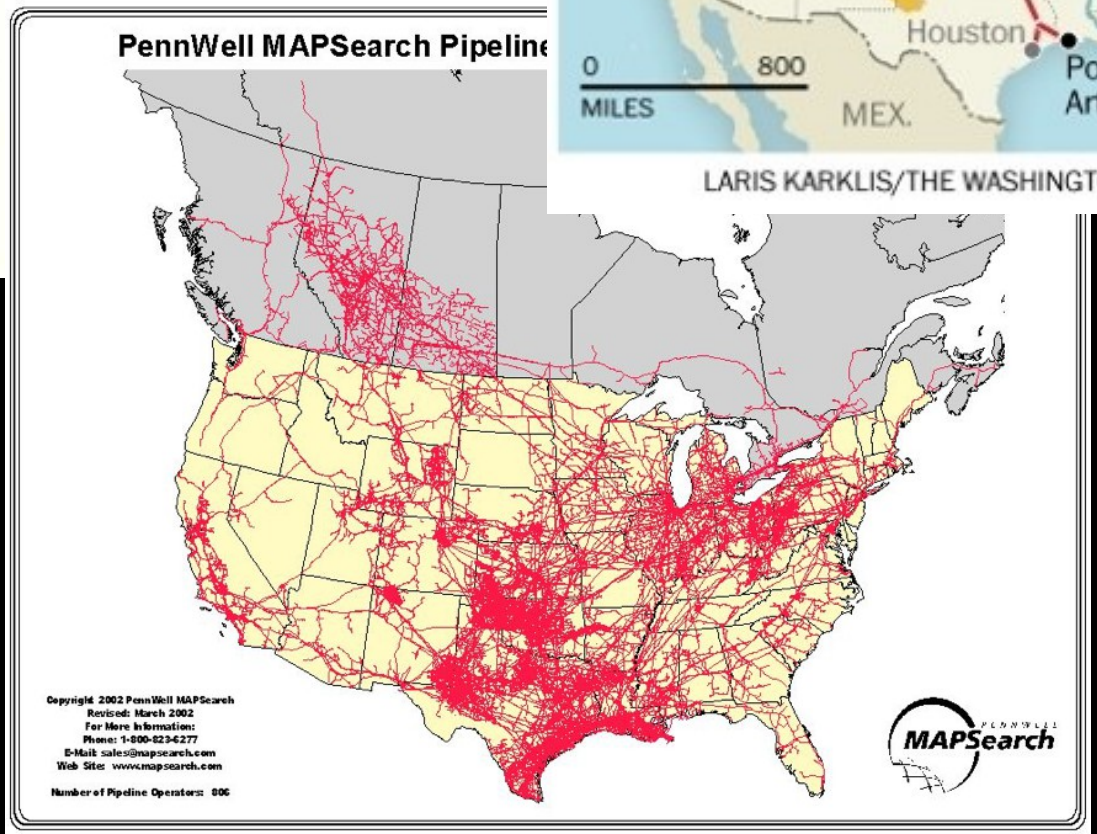
LARIS KARKLIS/THE WASHINGTON POST


PennWell MAPSearch Pipeline
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Revised: March 2002
For More Information:
Phone: 1-800-823-6277
E-Mail: sales@mapsearch.com
Web Site: www.mapsearch.com
Number of Pipeline Operators: 806
MAPSearch

Surface mining & subsurface drilling

First nation peoples & livelihoods at risk

Yes, In my back y

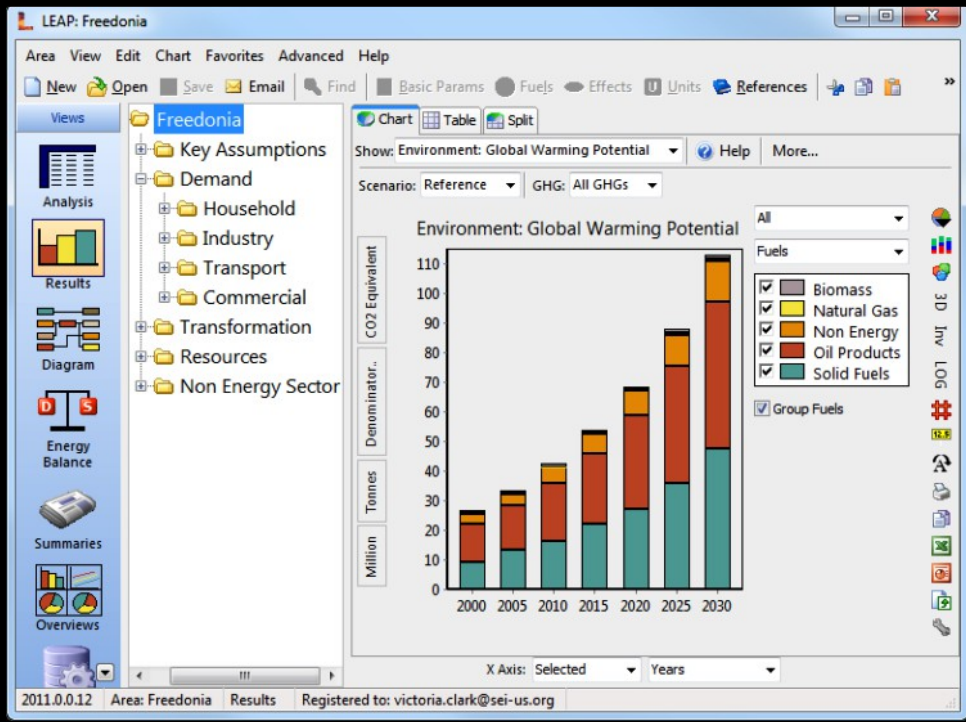
UNION SUPPORT for pipeline jobs

protest


NOT
TARSANDS
CLIMATE CHANGE IS NOT
IN OUR NATIONAL INTEREST
No Tar Sands Keystone XL Pipeline
NO TAR SANDS XL PIPELINE

Water-Energy Training Institute

Dates to be announced via IAI, AQUASEC, etc.



Thank you

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http://aquasec.org/wrpg/nexus