The Water-Energy Nexus in Global Context

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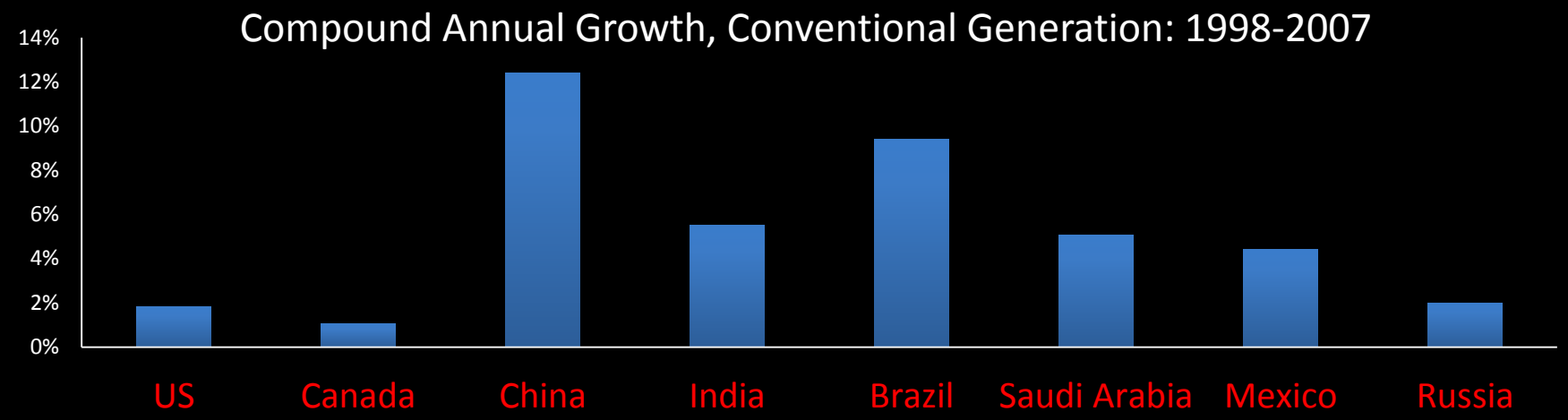
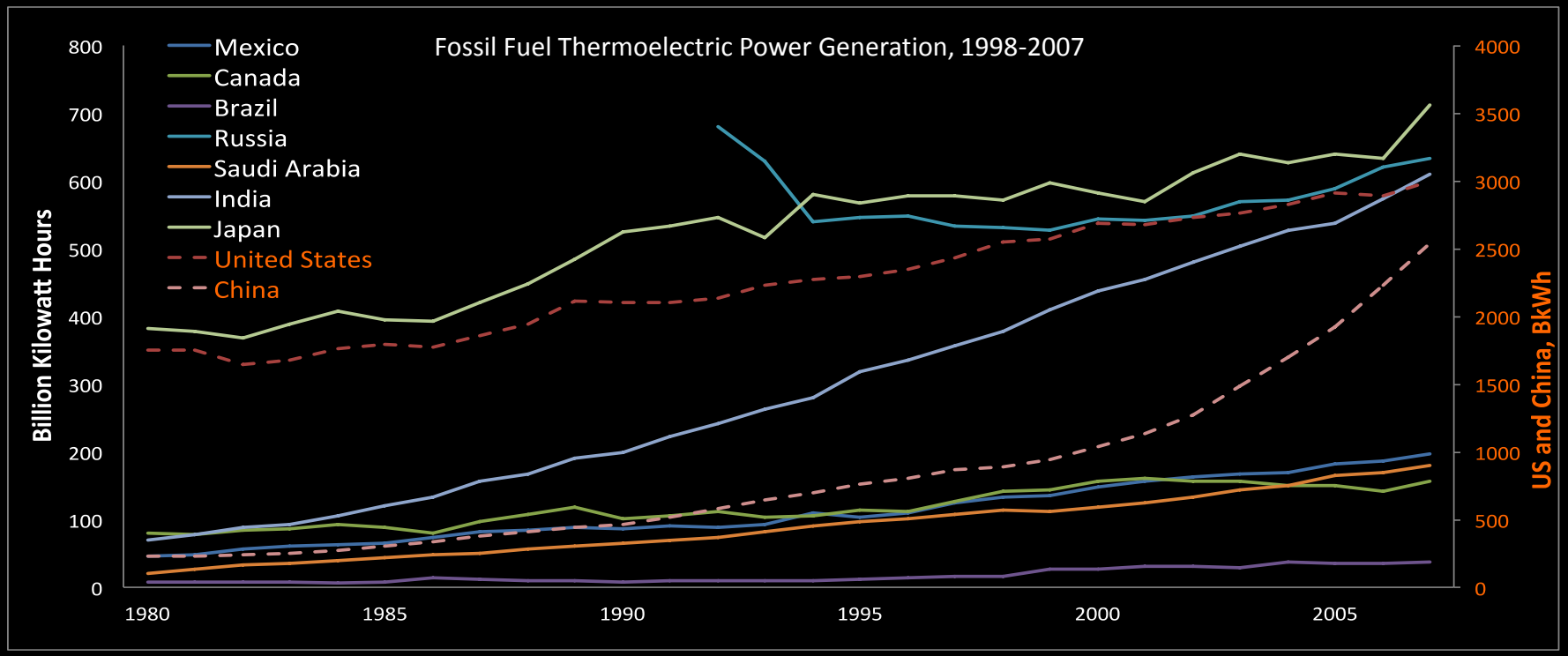
Overview & Science-Policy Questions

- Water implications of future power generation?
- Water-energy assessments either global (EIA, IEA, Maheu 2009) or country-level (data permitting).
- Here, U.S. Energy Info. Administration (EIA) country-level electricity generation data, 1980-2007:
  - Identify potential future electricity production trends to construct water-energy use scenarios.
  - Facilitate cross-country comparisons
  - Evaluate hot spot countries likely to experience acute water-energy tradeoffs, and identify avenues for exploring the nature of those tradeoffs.



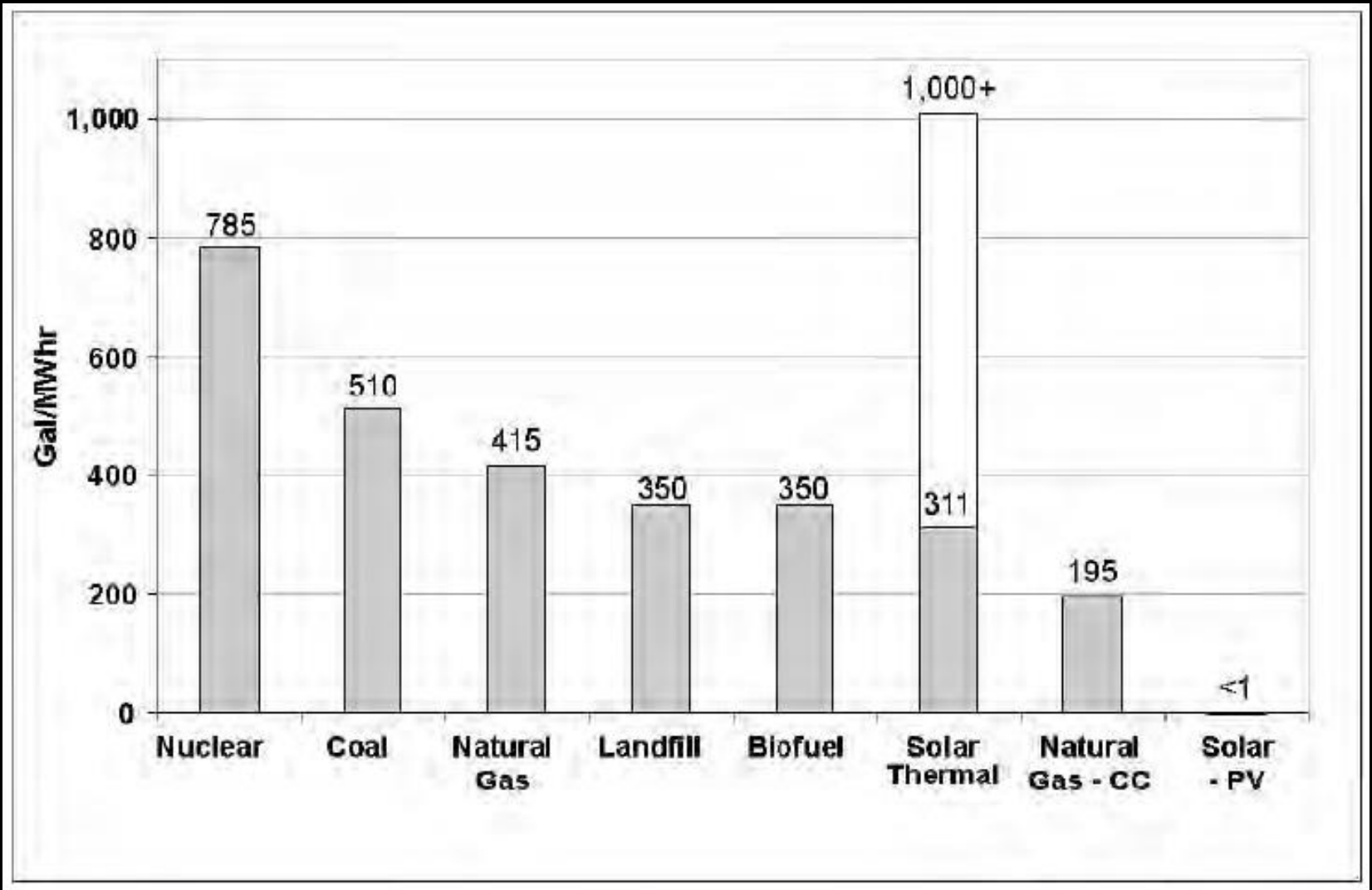


Slight increases in renewables, but no indication that water-extractive/consumptive conventional thermal generation will stop increasing. This will continue to place a demand on available water supplies.

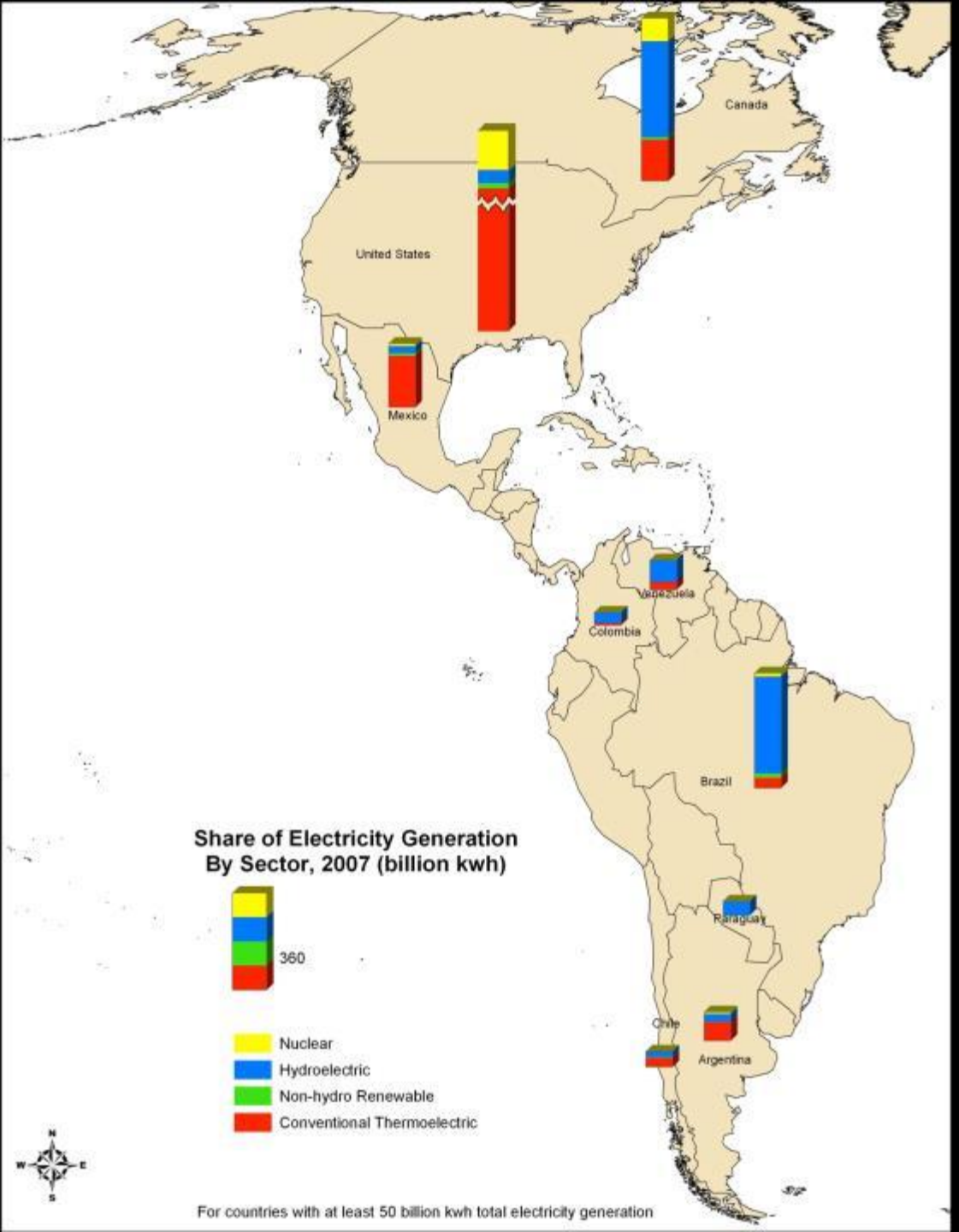
Key trends - global electricity production

- 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

Water intensities of generation

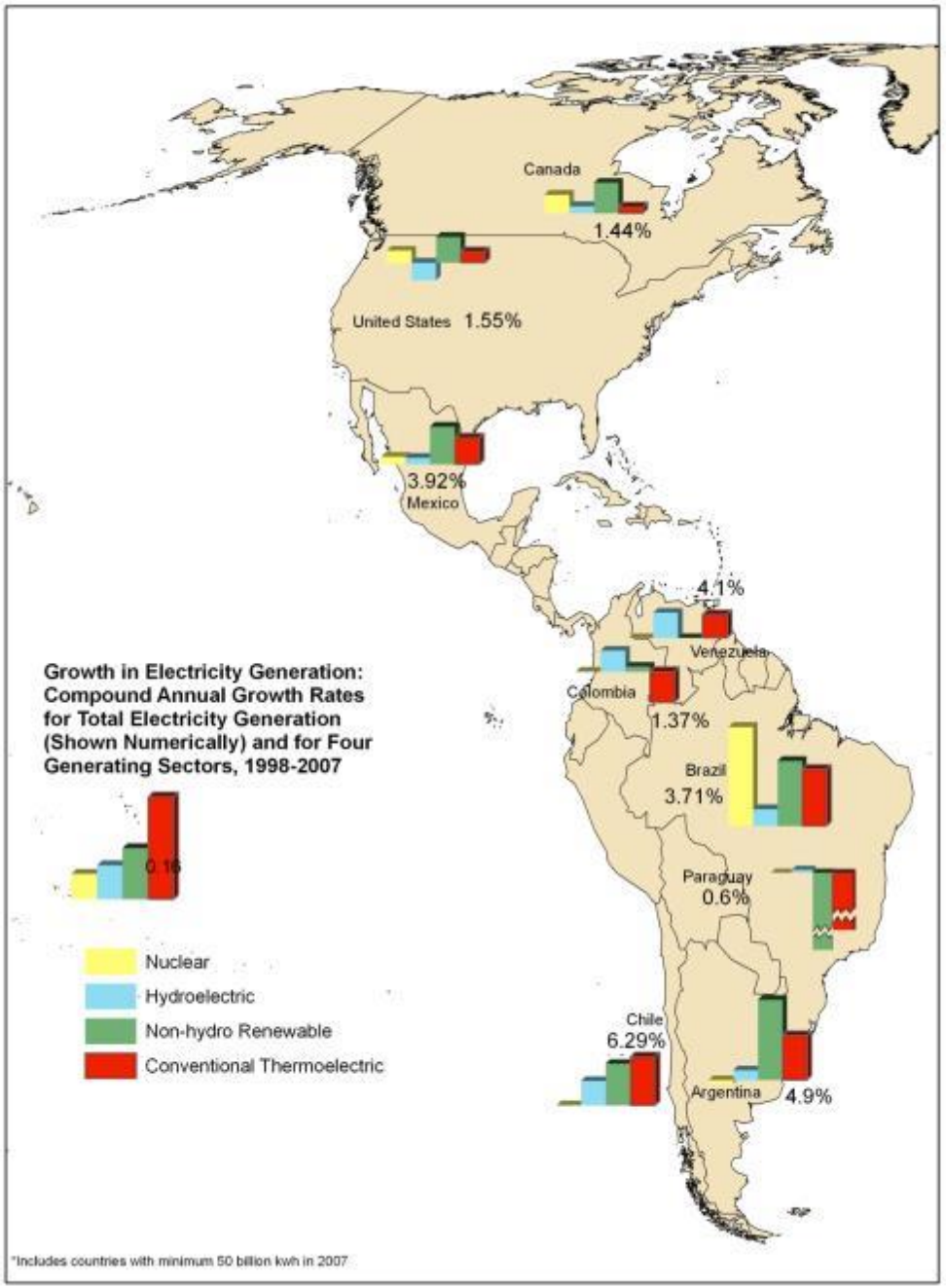


Source: Scott and Pasqualetti, 2010



2007 Baseline Electricity Generation portfolios

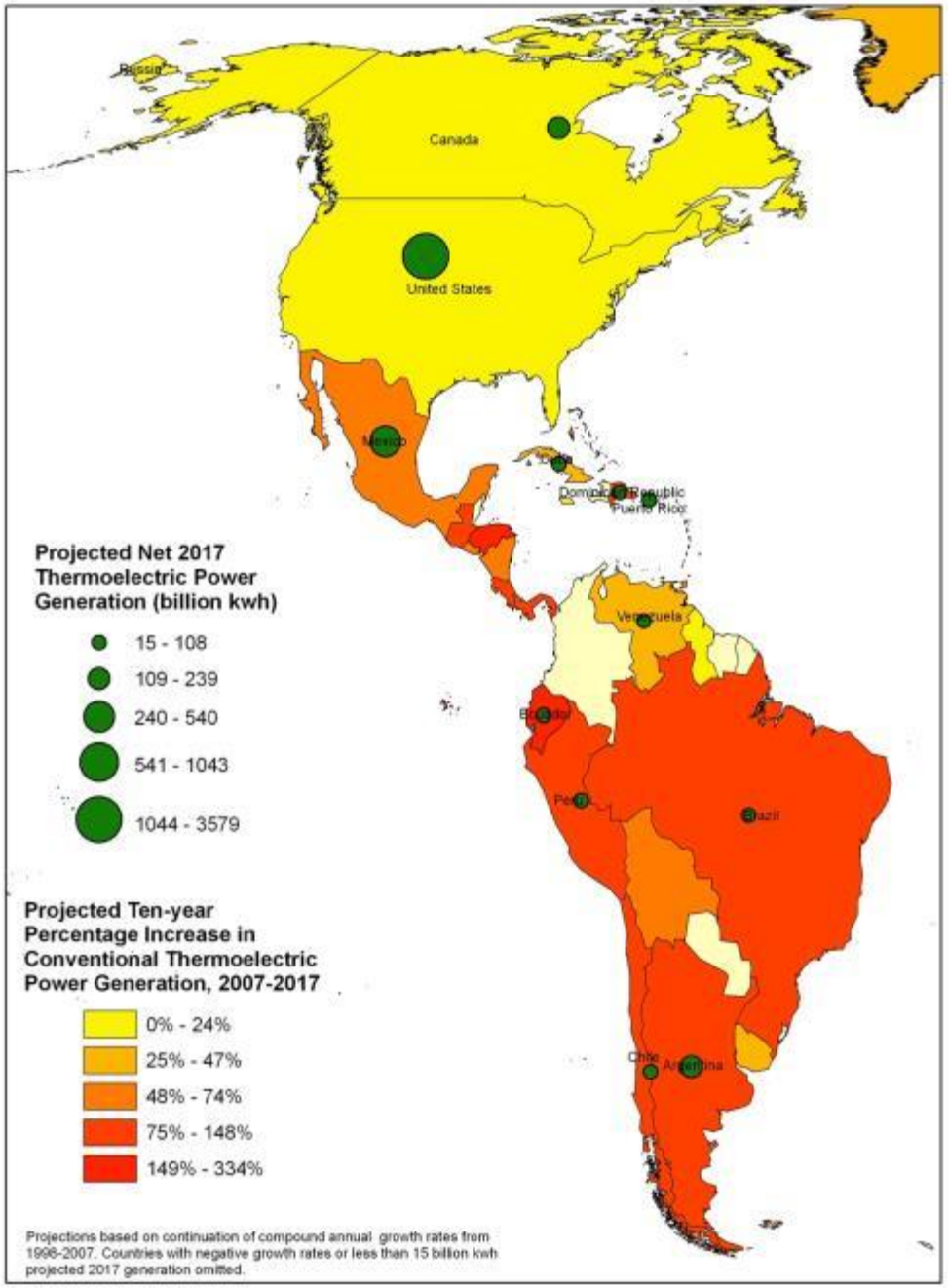
S. American countries and Canada highly reliant on hydropower.



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

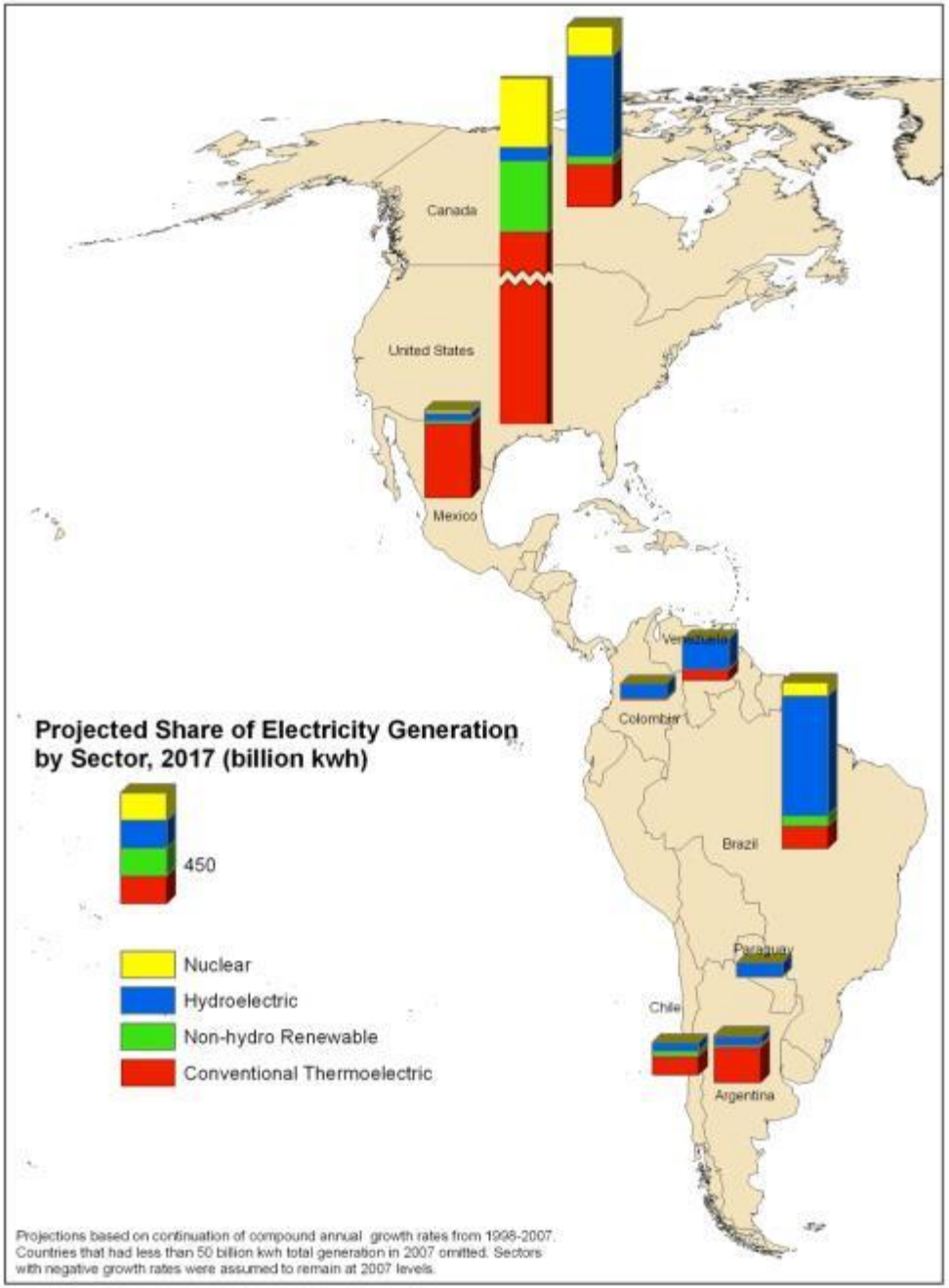
Last 10 years saw growth in renewables and hydropower in S. American countries,

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



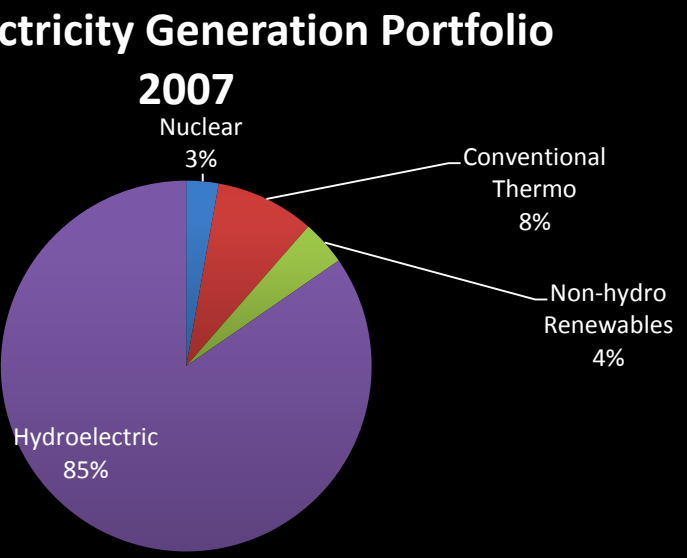
The U.S. and China will remain by far the biggest producers of thermal electric power. However, based on recent growth rates, several Central and South American nations are likely to experience substantial increases in thermal power generation by 2017 relative to the 2007 baseline.

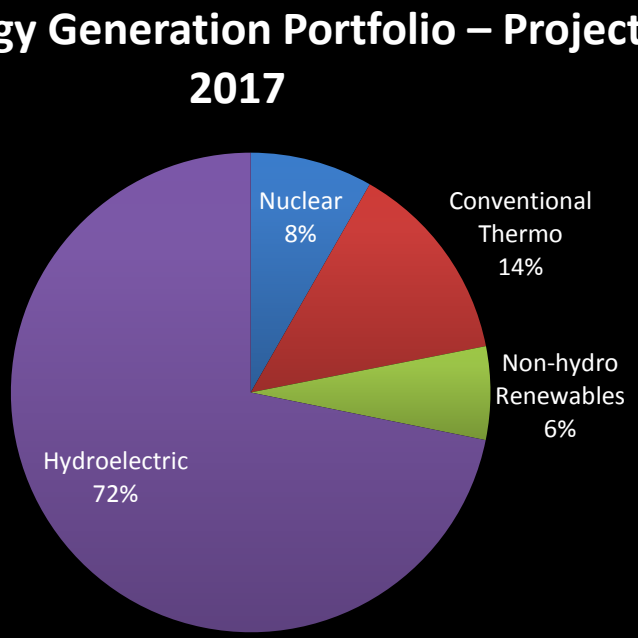
Potential Energy Future Portfolios



- 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.

Brazil





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

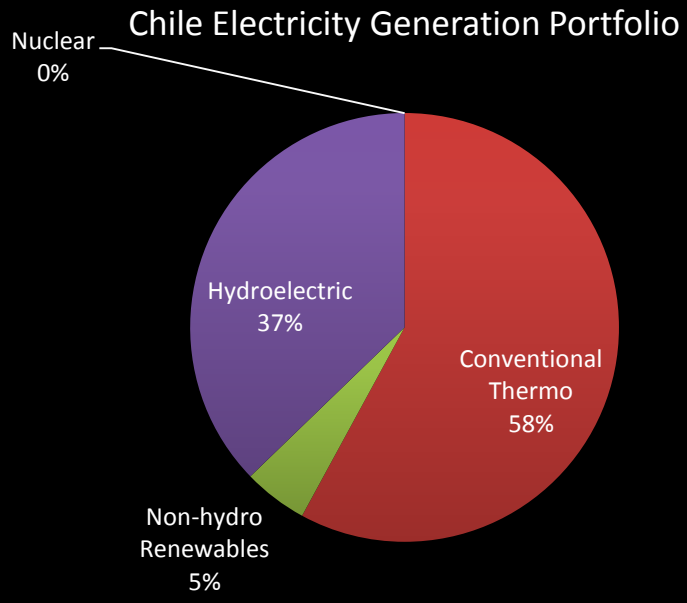
Based on CAGR 1997-2008 and total generation for 2008

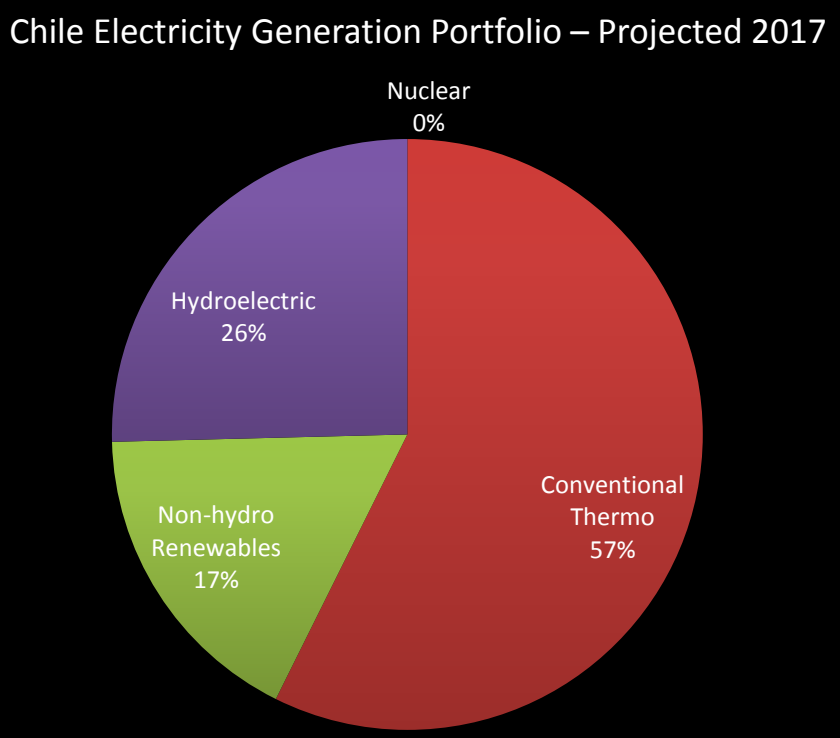
Brazil: Key future tradeoff questions

- 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)

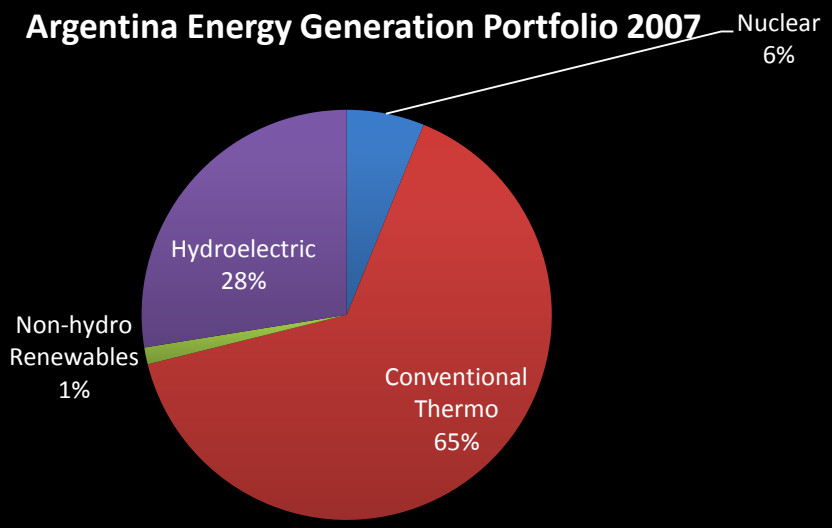


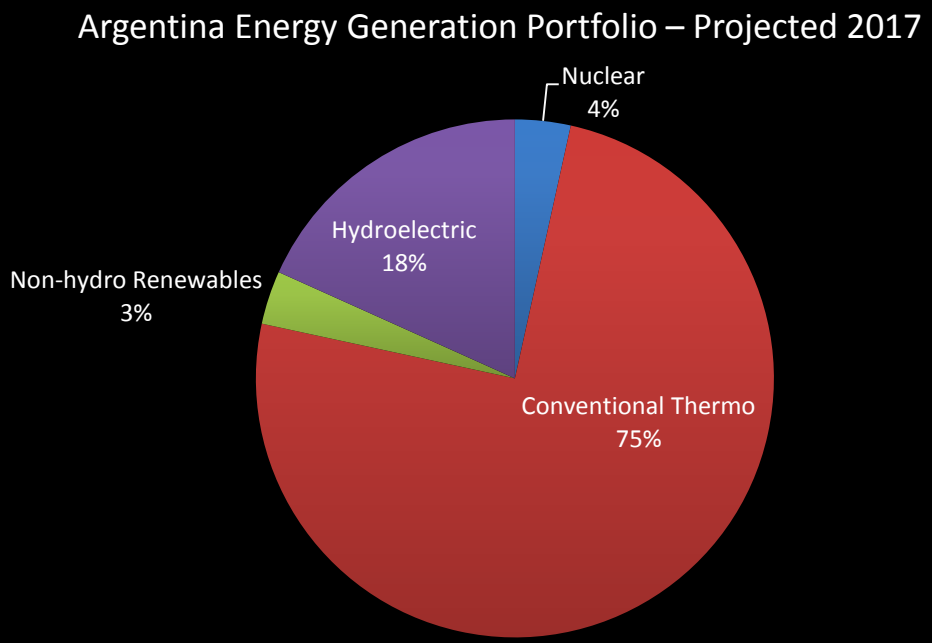


*http://www.guardian.co.uk/environment/2011/may/10/chile-hydroelectric-dam
*http://www.guardian.co.uk/environment/2011/may/10/chile-patagonia-dams-hydroelectricity

Argentina

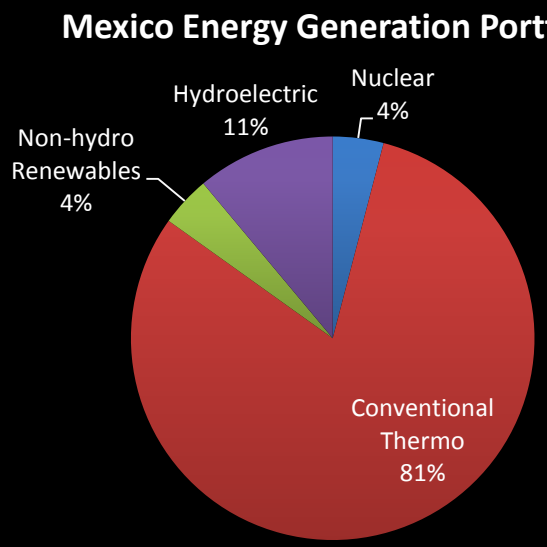
- Overall electricity growth increase lower than neighbors
- Conventional thermo increase
  - GHG and water implications are important
- Hydro constant (decreased share of national generation)

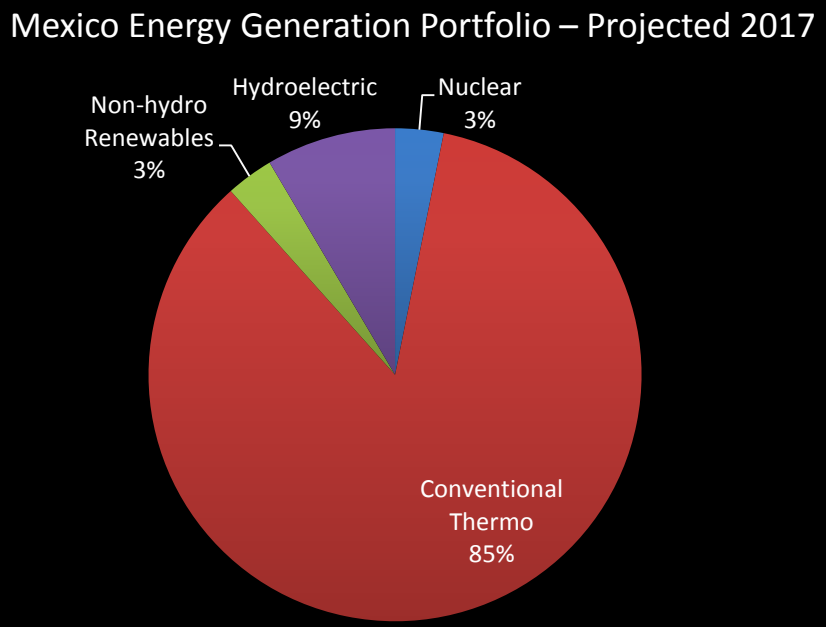




Mexico

- 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





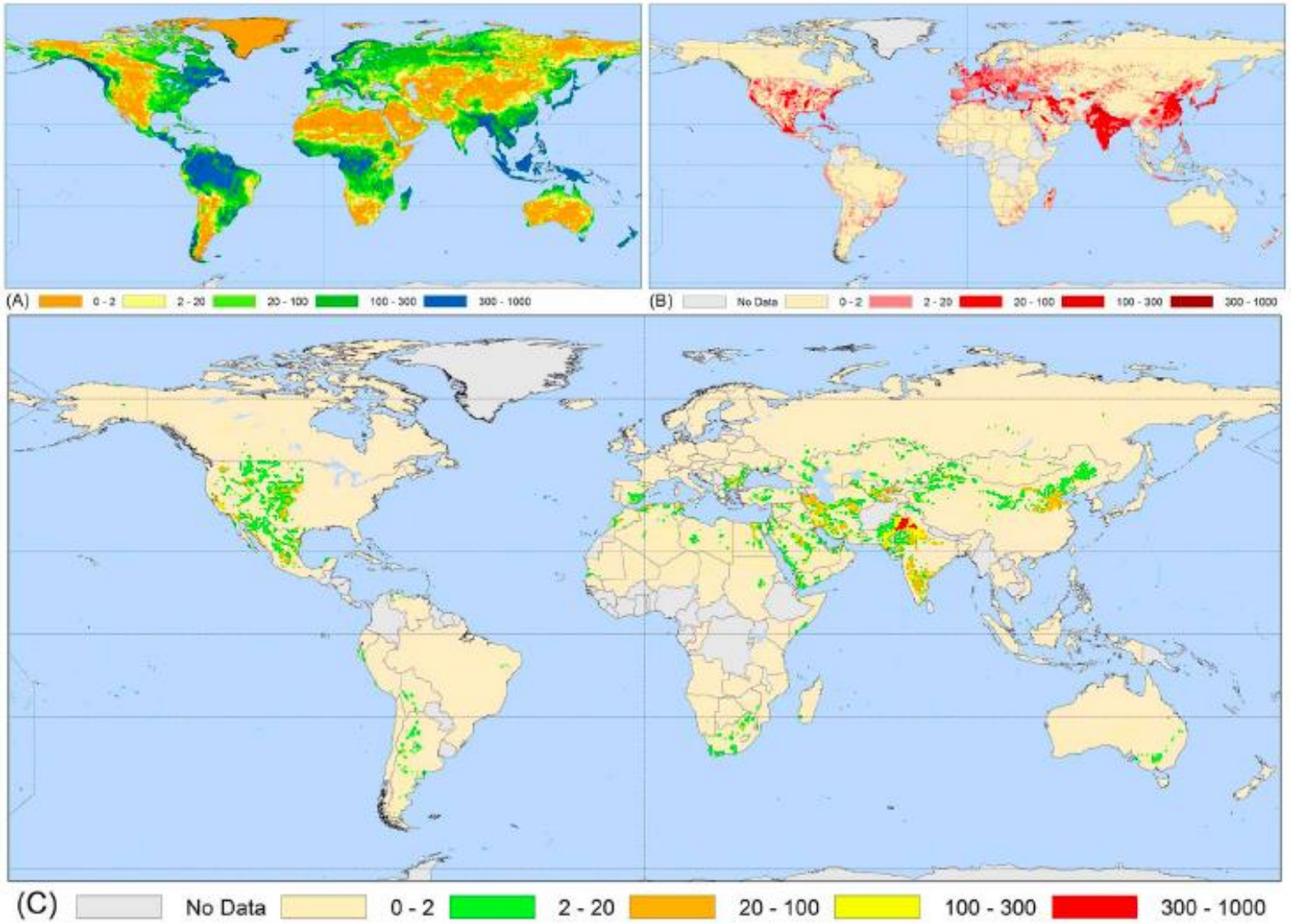
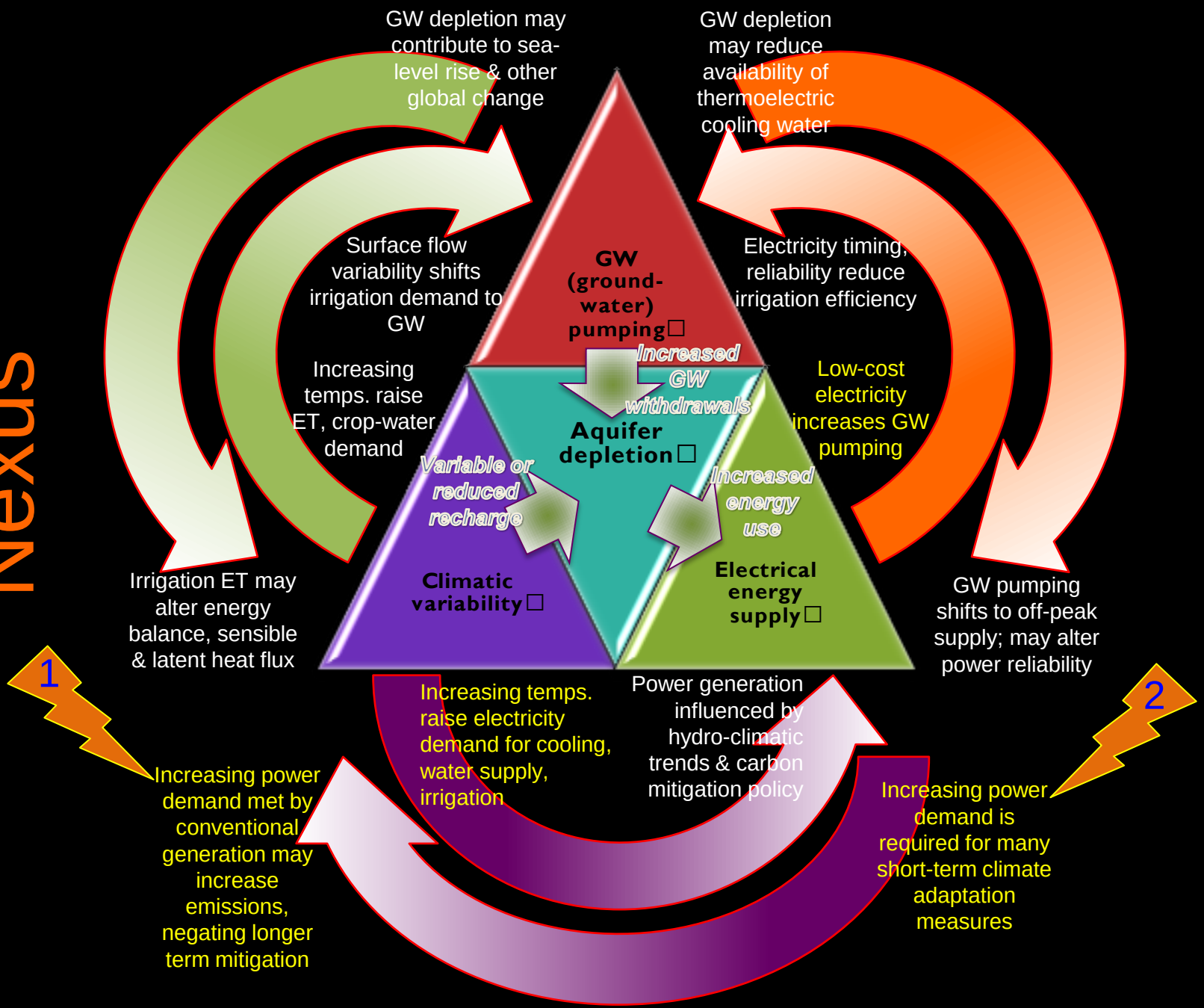


Figure 1. (a) Simulated average groundwater recharge by PCR-GLOBWB, (b) total groundwater abstraction for the year 2000 and (c) groundwater depletion for the year 2000 (all in mm a^{-1}).

Source: Wada et al. 2010. Global depletion of groundwater resources. *Geophys. Res. Lett.*, 37, L20402.

Groundwater-Energy Nexus



GW-E Nexus Over Time

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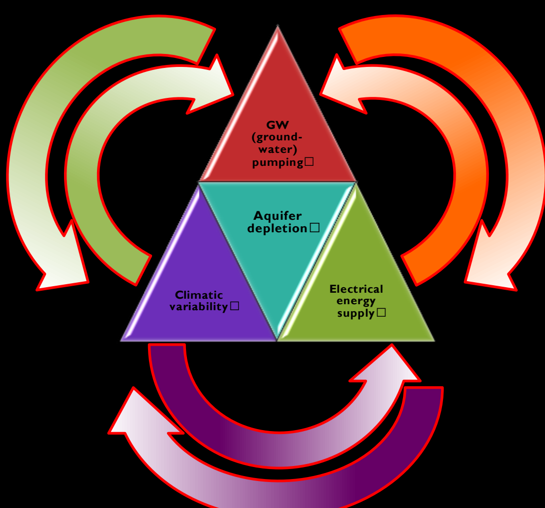
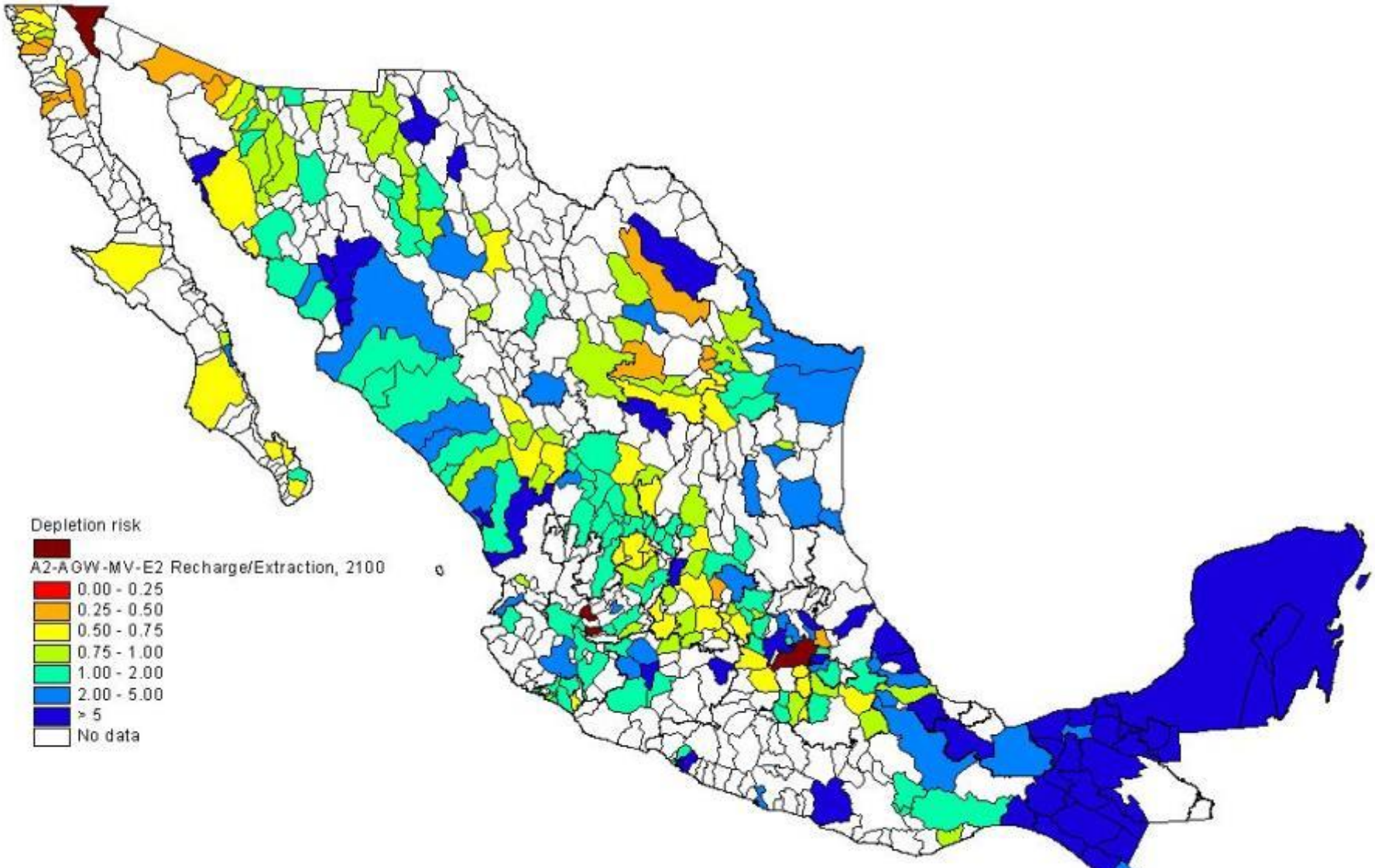


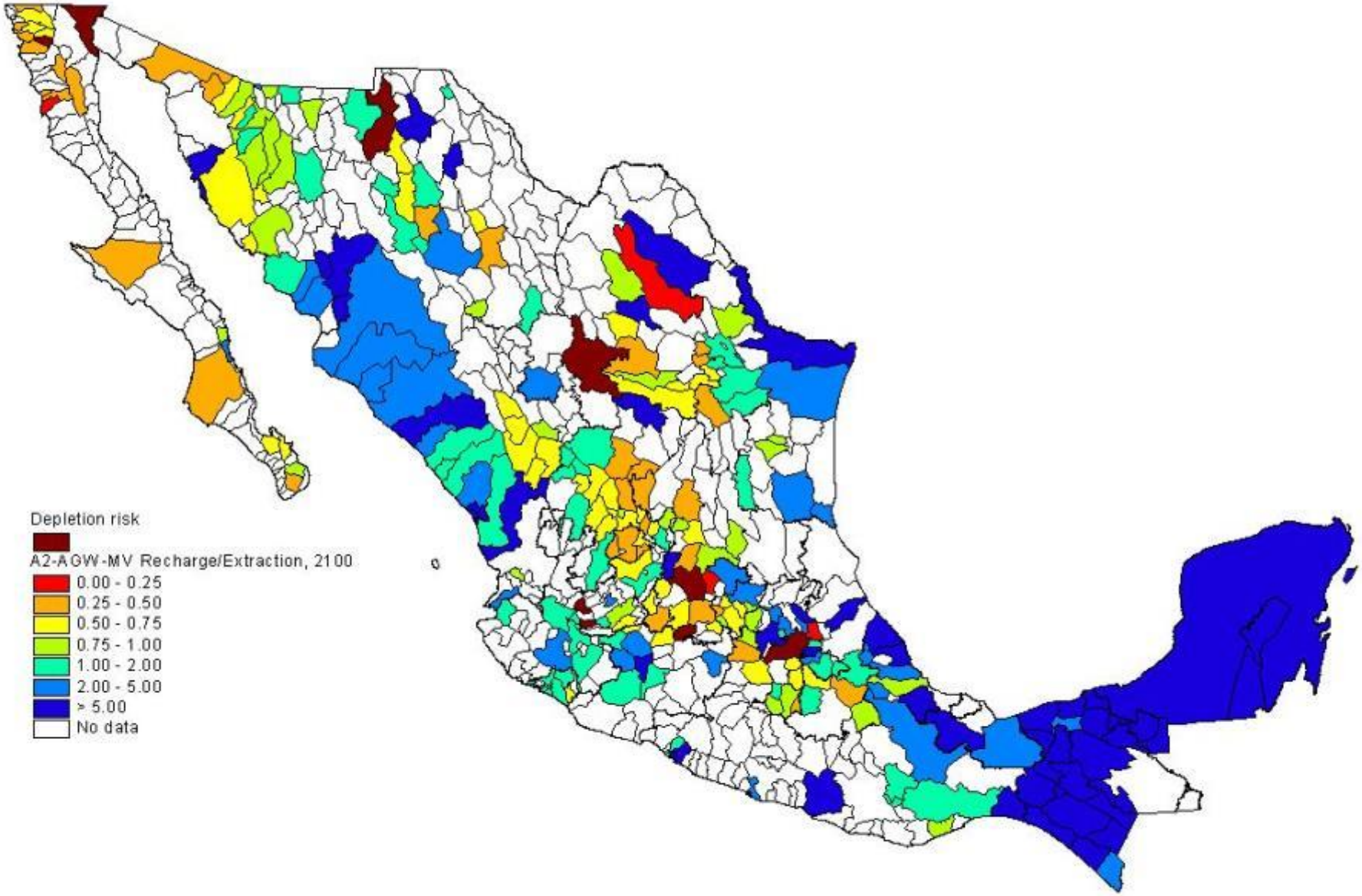
?

With 2% annual increase in *tarifa 09*



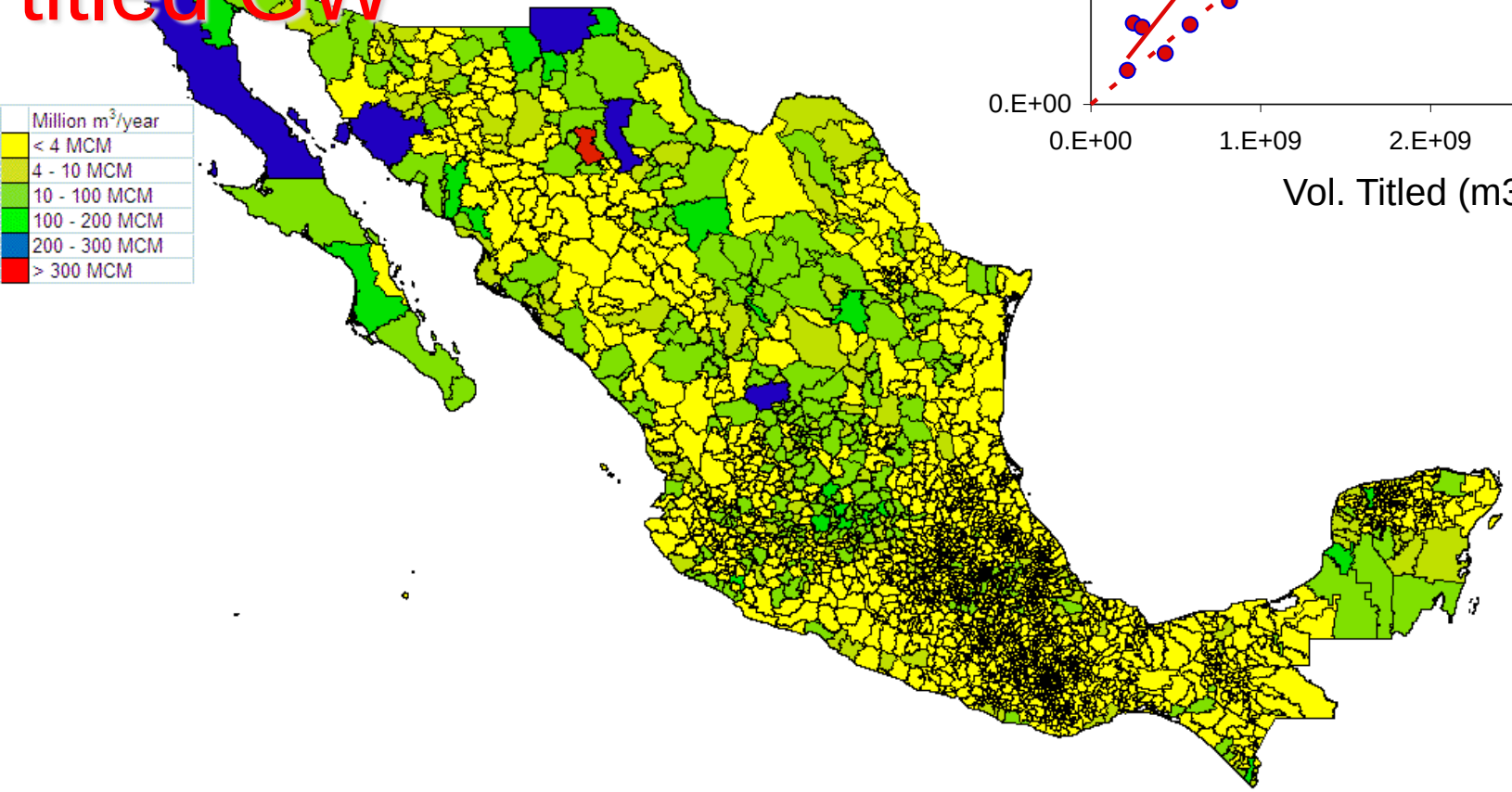
2% annual ***increase*** over 21st Century means *tarifa 09* in 2100 would reach current 2010 tariffs for domestic high-consumption or public service users (in constant 2010 pesos). Instead, from 1999-2009, tariffs ***fell*** at a compound rate of 0.94% annually.

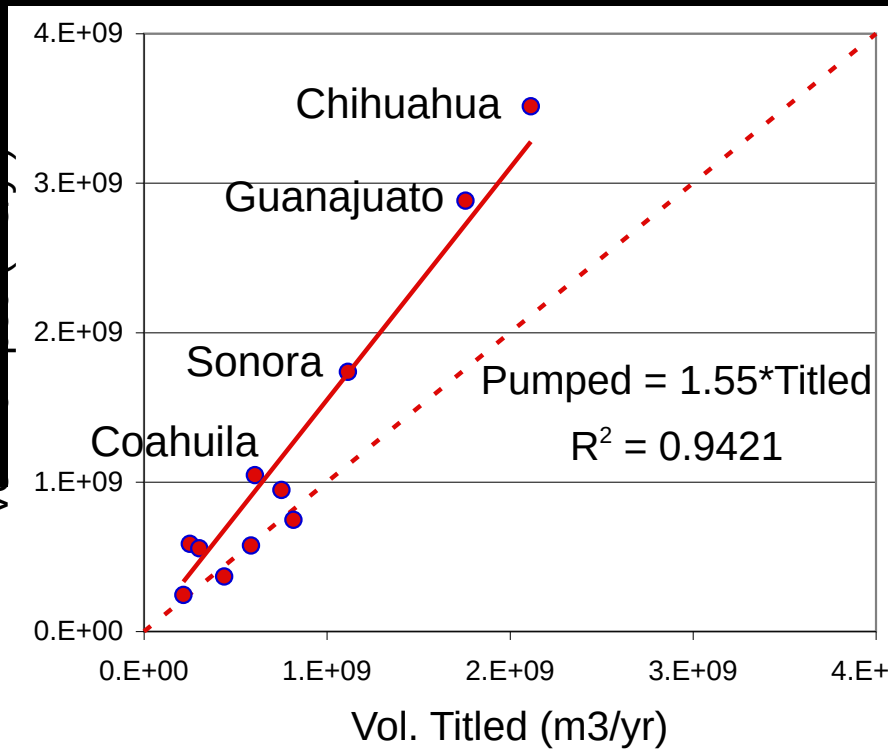
Without 2% annual increase in *tarifa 09*



unsuccessful

Drilling bans (*vedas*) and concession titles alone are inadequate; pumped GW exceeds titled GW

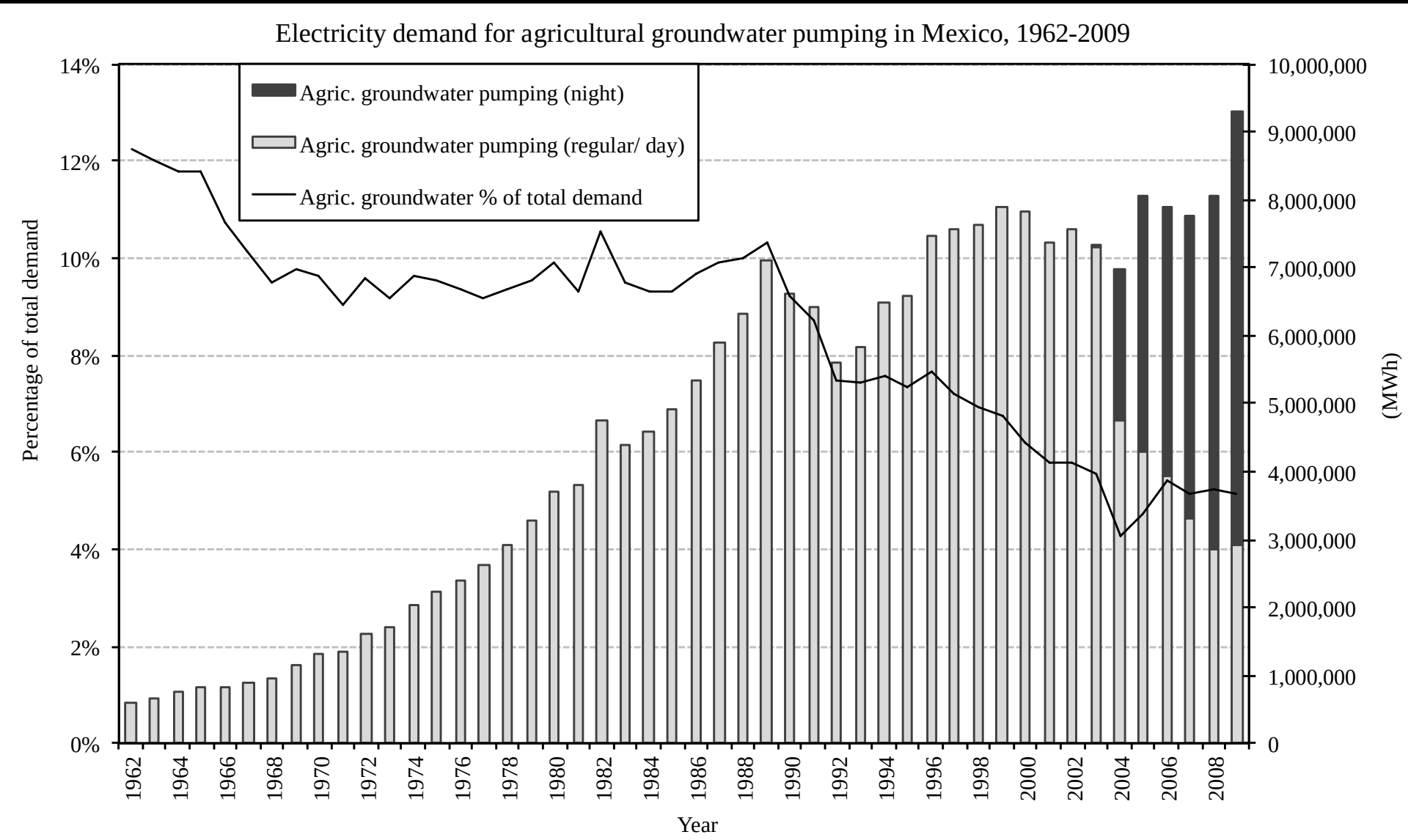




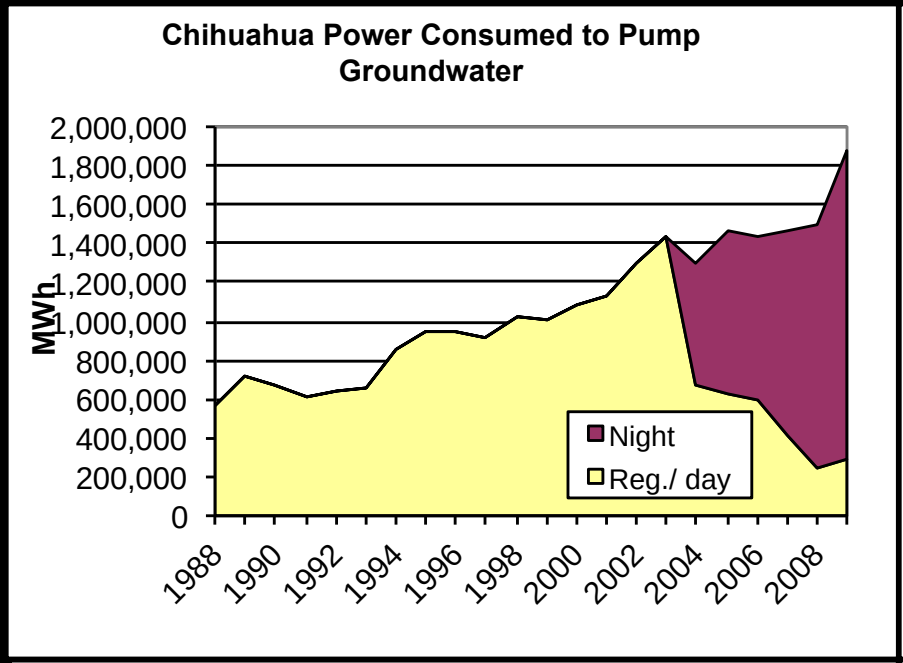
Legal and regulatory approaches must focus on the nexus

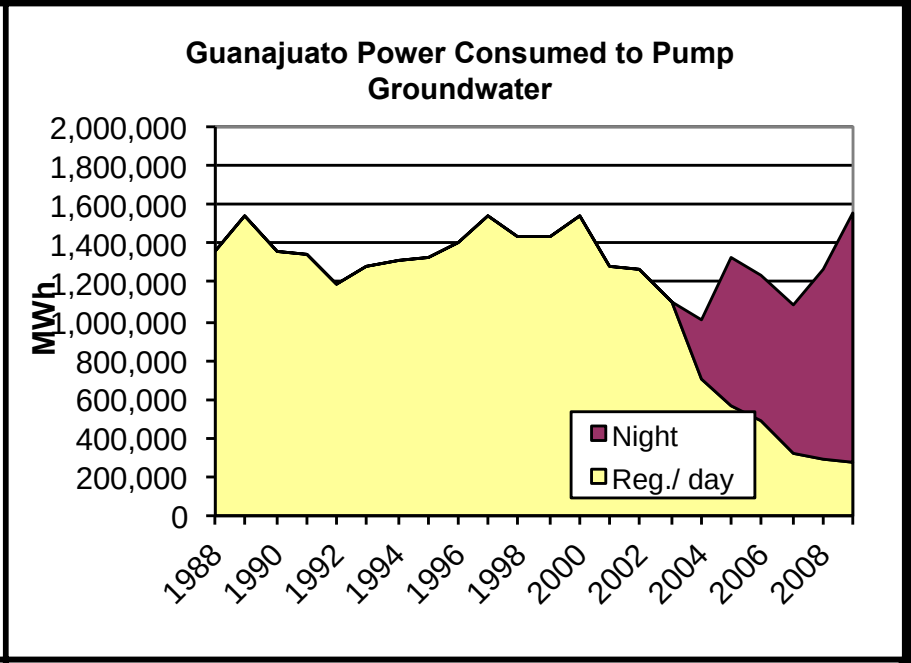
- *Ley de Energía para el Campo* (2002) a good attempt, but strongly opposed
  - *Límite de energía anual* based on concessioned volume
  - This ***nexus-based regulation*** was supplanted in 2003 by night-time *tarifa 9N* (50% day-time rate)
  - 2006 farmers secured a Mex$ 0.10 per kWh subsidy on daytime tariffs (SAGARPA, Mex$ 686 million = US$ 62 million)

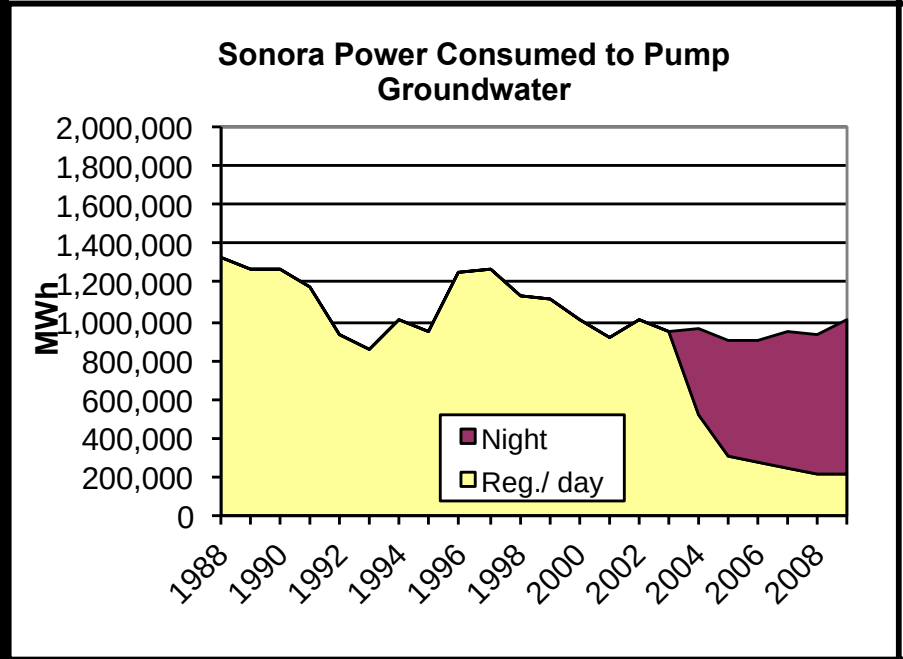
Agricultural power sales by CFE

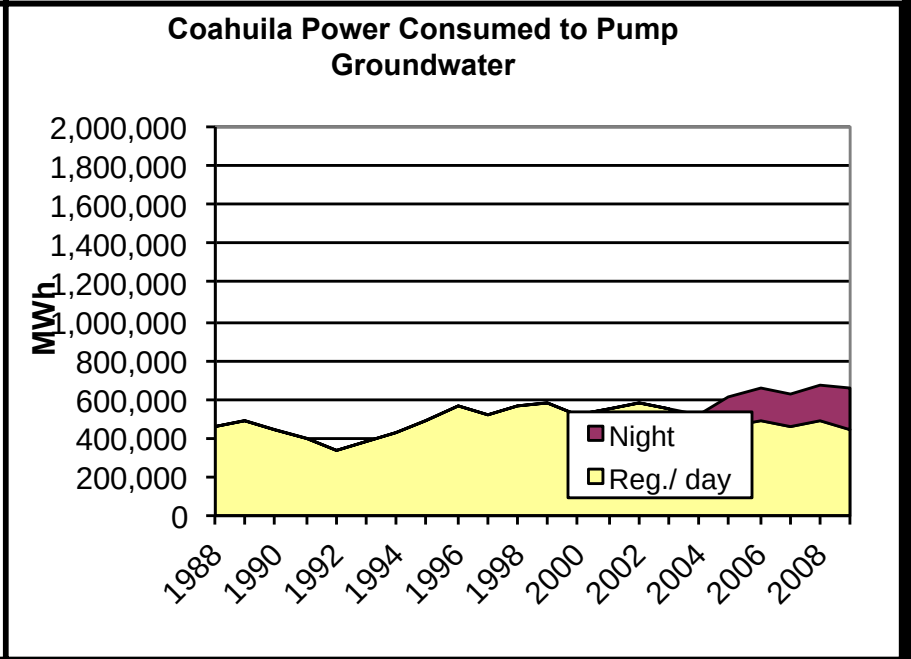


High *tarifa 09* states are increasing pumping





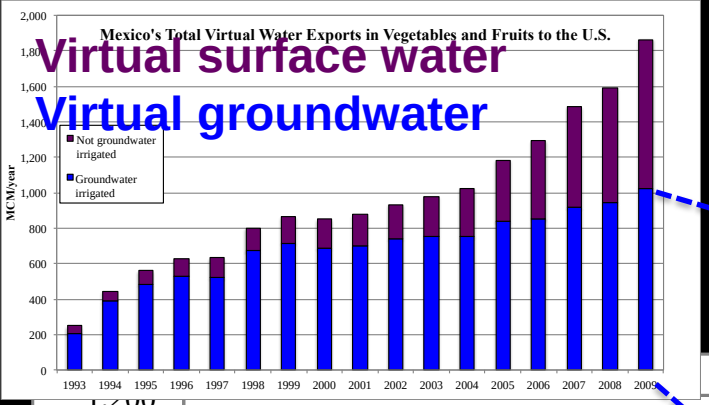


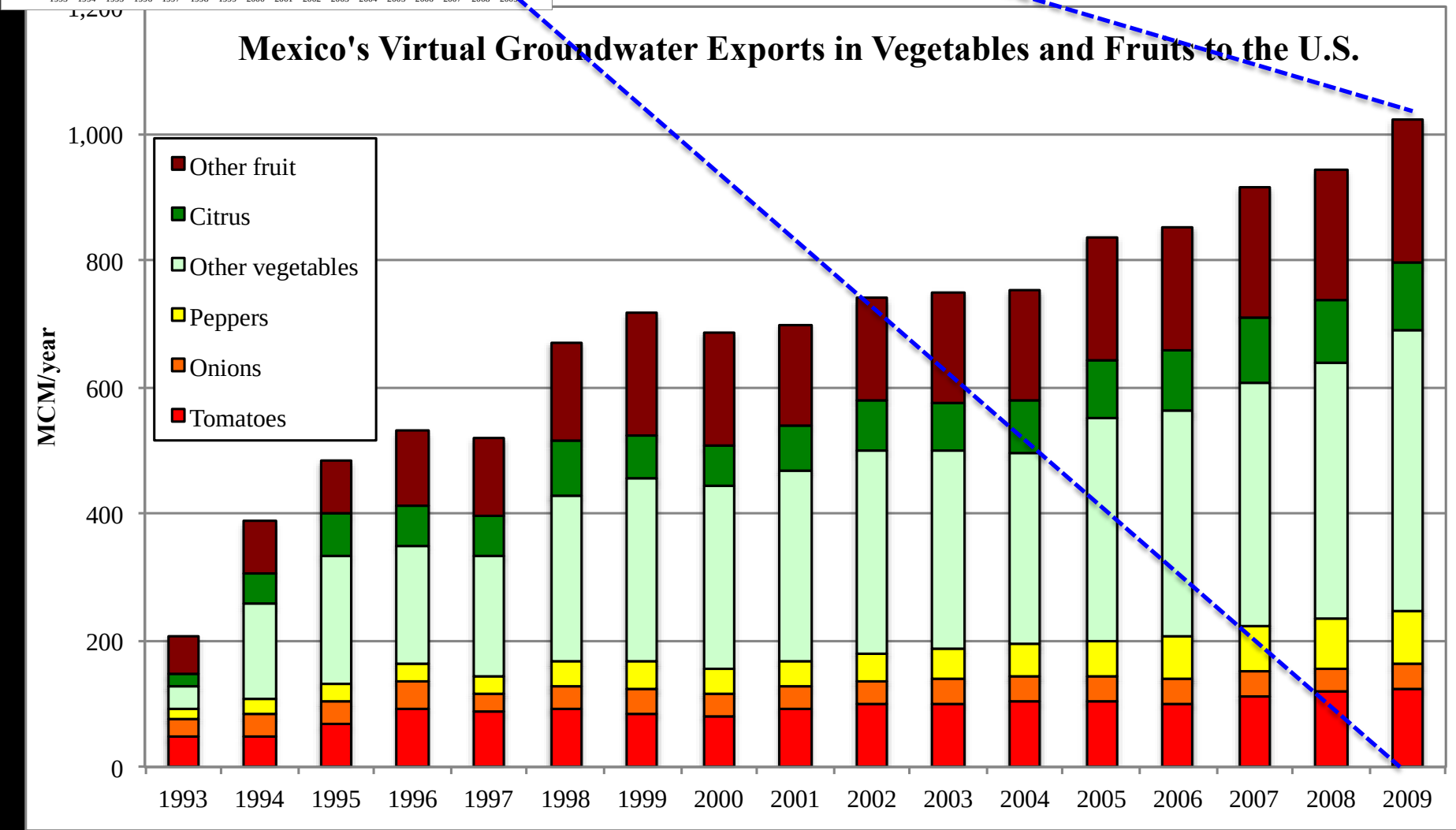


GW pumping driven by virtual water (export veg/fruit)

Virtual surface water

Virtual groundwater





CONAGUA – National Water Commission
CFE – Federal Electricity Commission

- Contentious rivalry must move to collaborative relationship
- Need extensive data sharing for informed decision-making
- Water demand for power generation will only increase
- Hydropower – another nexus opportunity lost

GW users self-regulation COTAS

- Groundwater technical committees
- CONAGUA model
  - coordination platform centered on federal authority
- Guanajuato state model
  - IWRM but without legal mandate
  - Lack incentive mechanisms

Policy choices

- Trend towards renewables: some are quite water intensive (e.g. biomass, concentrating solar thermal), while others are not (PV solar, wind, wave)
- What is the future of hydropower, nuclear, and fossil electricity? (carbon vs. water tradeoffs)

Water-energy-climate futures

- Water, energy, interlinked with climate – the environmental challenges that define our era
- Growing attention paid to water-energy nexus
- Propositions:
  - technological obstacles are surmountable
  - resource conservation is inevitable, driven by financial limitations and efficiency gains
  - institutional arrangements a seemingly intractable constraint to the virtuous water-energy-climate cycle

Thank you

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http://aquasec.org/wrpg/