Science, Technology, & Policy: Reaching for a sustainable and attainable energy future

Robert Rosner

William E. Wrather Distinguished Service Professor
Energy Policy Institute at Chicago
Harris School of Public Policy Studies

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Energy Policy Institute at Chicago
THE HARRIS SCHOOL

What will I talk about?

- Some general comments about energy, environment and human welfare …
- Some general technical comments about the state of affairs in energy technologies
- Some observations (and unsolicited opinions) about the state of energy policy and technology in Chile …
- Asides:
  - I do believe that climate change is real, and with us … based on the data, not on the modeling …
  - I am a skeptic about climate predictions and climate impact predictions
  - I believe in insurance, otherwise known as hedging your bets …

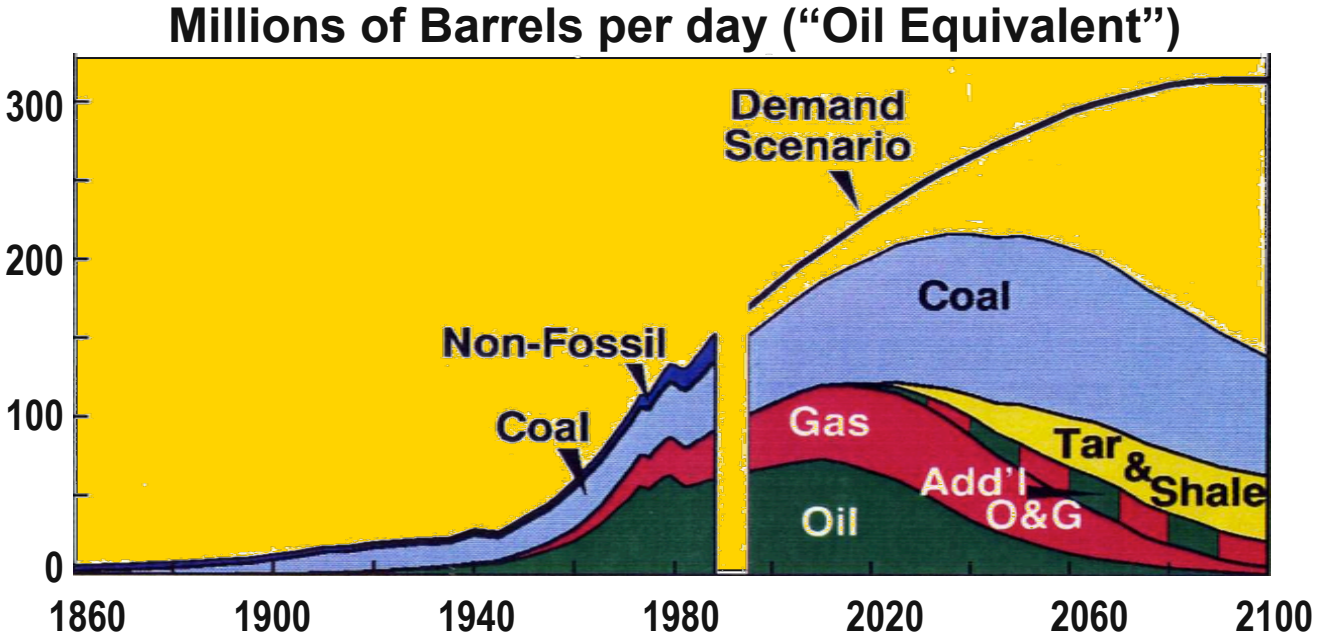
R.E. Smalley's view of Humanity's Top Ten Problems for the next 50 years …

1. **ENERGY**
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

… that was the view in 2005 … and it's much more sobering today

So, exactly how sobering is the situation today, only 6 years later?

- Population growth projections
  - 2004: ~ 6.5 billion people
  - 2011: ~ 7.0 billion people
  - 2050: ~ 10 billion people
- Energy demand growth
  - Population increase
  - **Increased expectations**



Source: John F. Bookout (President, Shell USA) ,"Two Centuries of Fossil Fuel Energy" International Geological Congress, Washington DC; July 10,1985. Episodes, vol. 12, 257-262 (1989).

… and here are some things to remember during my talk

- Our energy problems of today are NOT the same as those of the 1970s
  - It was all international politics in the ‘70s, driven by OPEC’s need to assert itself
  - It’s no longer all international politics today …

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  - It's no longer all international politics today …
- The sustainability problem with the 'business-as-usual' (BAU) energy path is not that we are running out of energy supplies …
  - It's that we are running out of cheap and easily recovered liquid fuels
  - It's that whether or not we are running out of environment, a significant aroused public segment thinks we are, and is very vocal …
  - It's that readily available supplies are now precariously balanced against sharply increased demands …

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  - It's that whether or not we are running out of environment, a significant aroused public segment thinks we are, and is very vocal …
  - It's that readily available supplies are now precariously balanced against sharply increased demands …
- Solutions for the industrialized nations may not be relevant for the developing (and undeveloped) nations …

What is the problem?

- Oil, coal and gas – fossil fuel products in general – are amazingly efficient in packaging energy in an
  - easily obtained (= technically simple and cheap), and
  - easily transportable way – and the infrastructure is in place and paid for …
- **All** of the alternatives - except for one, namely increased efficiency of energy use – are burdened with one or more relative disadvantages *at present*, which come in many flavors …
  - Environmentally not benign, or [~ coal-based synfuels; 'clean' coal]
  - Relatively costly, or [~ solar/photovoltaic/nucl. fission/wind*]
  - Geographically limited, or [~ hydro]
  - Inefficient, or [~ corn-based ethanol]
  - Ineffective (despite the hype …), or [~ hydrogen]
  - Scary, or [~ nuclear fission]
  - Does not really/yet exist, or [~ nuclear fusion/CCS/'clean' coal]
  - …
- These disadvantages are the fundamental reason that fossil fuels still dominate …

*Wind is cheap if one does not account for energy storage required because it is an intermittent energy source …

What can we conclude is: It won't be easy!

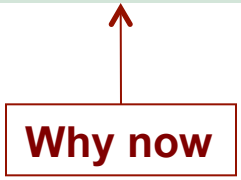
- What we want is energy that is
  - Cheap
  - "Clean" (= minimal or no environmental impact)
  - Sustainable
  - Reliable
  - Not scary …

  … and such an energy source does not exist …
- Thus we face
  - Technological challenge(s): we depend on innovation/investments …
  - Economic challenge(s): permanent subsidies cannot survive …
  - Political/policy challenge(s)
    - *In the US:*
      - Will we ever have an energy policy?
      - Can we overcome NIMBY? NIABY*? BANANA**?
    - *Internationally:*
      - Priorities …
      - Trust … a key issue for Chile

*NIABY: Not in Anyone's Back Yard
**BANANA: Build Absolutely Nothing Anywhere Near Anything

What are the pros and cons for energy technologies?

Type	Main Pros	Main Cons	Time frame
Conservation	Non-polluting; no global warming impacts; incremental; sustainable	Does not solve base power problem	Now



Why now

Why *not* now: R&D motivation

… and the pros and cons are? … continued

Type	Main Pros	Main Cons	Time frame
Conservation	Non-polluting; no global warming impacts; incremental; sustainable	Does not solve base power problem	Now
Wind/solar/tidal	Low or no pollution; no global warming impacts; sustainable	Intermittent (need storage/R&D); highly location-dependent; solar and tidal remain inefficient/ expensive (R&D needed)	Now
Geothermal	Low or no pollution; no global warming impacts; sustainable	Seismic impact highly controversial; highly location-dependent; costly	Now
Water ('hydro')	No pollution; no global warming impacts	Highly location-dependent/limited; possible environmental damage	Now
High-value bio synfuels	No global warming impact; positive for waste recycling; useful for transport; sustainable	Non-carbon pollutants (NOx, particulates); possible agriculture impacts; R&D needed for increased efficiency/lowered cost	Now
Ethanol	Can have little global warming impact; useful for transport; sustainable	Agricultural impacts; current production methods energy-inefficient	Now
'Clean' Coal	Very abundant; useful for transport	Major global warming impact in absence of effective/safe carbon sequestration; very expensive	?
Oil shale/tar sands/'tight gas'	May be very abundant	Major global warming impact in absence of carbon sequestration; recovery may be environmentally destructive; seismic issues	Now
Nuclear fission	Minimal global warming impact; potential long-term energy solution; sustainable	Operations and waste repository highly controversial; high risks require strong technical and administrative competence	Now-50 years
Nuclear fusion	Minimal global warming impact; sustainable	We don't know how to do this at present	?
Hydrogen	Depending on production mechanism, no global warming impact; transport fuel	Requires substantial primary energy source; production presently inefficient; storage and distribution major R&D issues	? for U.S.; now for Iceland (!), w/ geothermal

… and my own summary of the 'winners' in the U.S. is …

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… and my summary of the 'winners' in Chile is …

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Geothermal	Low or no pollution; no global warming impacts; sustainable	Seismic impact highly controversial; highly location-dependent; costs uncertain	Now
Water ('hydro')	No pollution; no global warming impacts	Highly location-dependent/limited; possible environmental damage	Now
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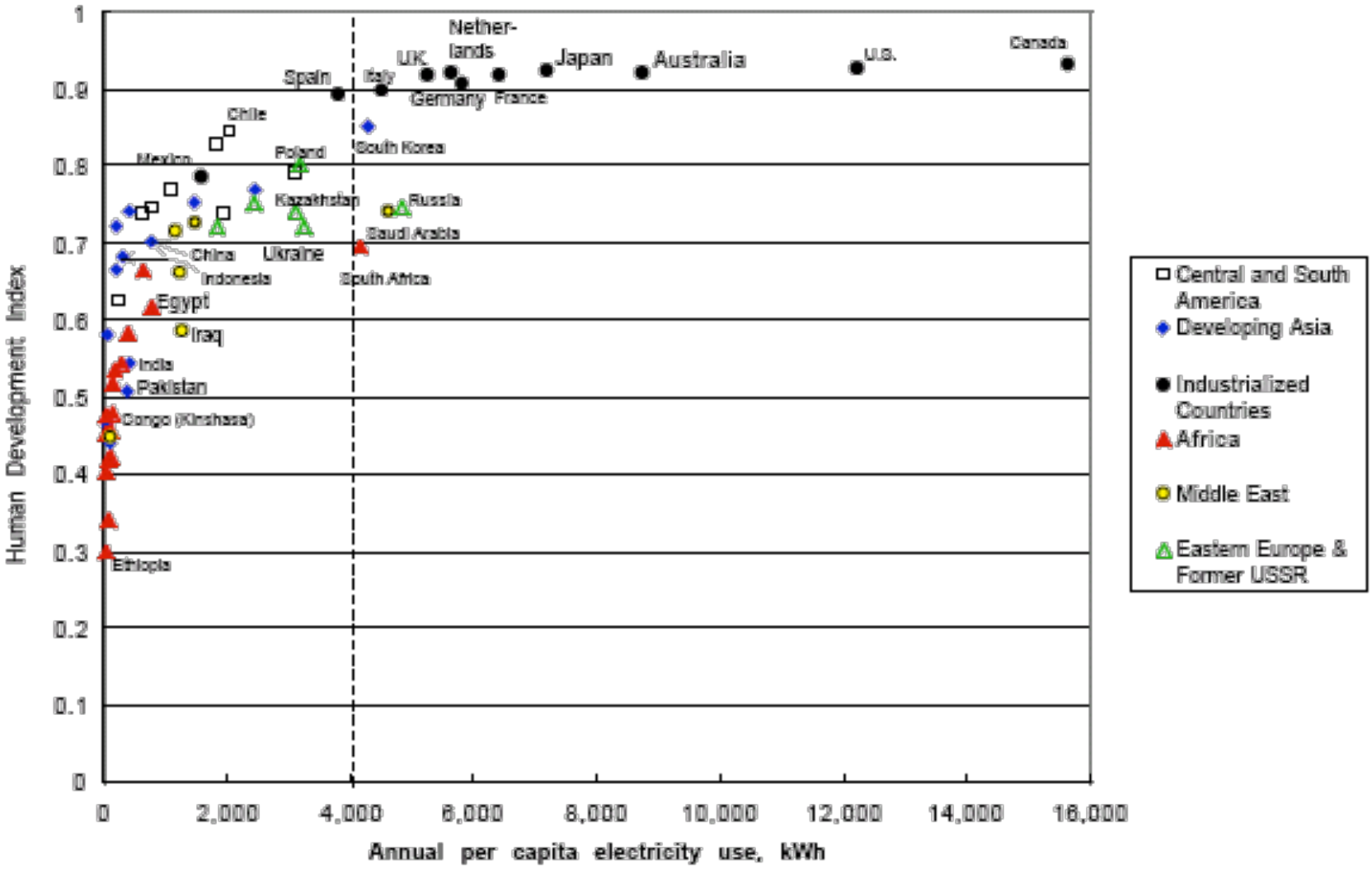
Chile has a unique energy problem …

- **Economic growth is high, and expected to continue to be high**
  - **The ambition is to make the transition to a 'developed' nation**
- **Natural gas from Argentina is not an option – considerable focus on importing LPG …**
- **Hydro is**
  - **Relatively underexploited (10's of gigawatts remain to be tapped)**
  - **Under severe attack by environmentalists**
- **Energy growth is dominated by coal-fired thermal power plants …**
  - **"Renewables" – with the exception of biofuels in the far south – are not a major player …**
- **Income inequality is large, and there is little evidence that this gap is closing**
- **Political environment is difficult**
  - **Lack of consensus on the environment/growth issue**

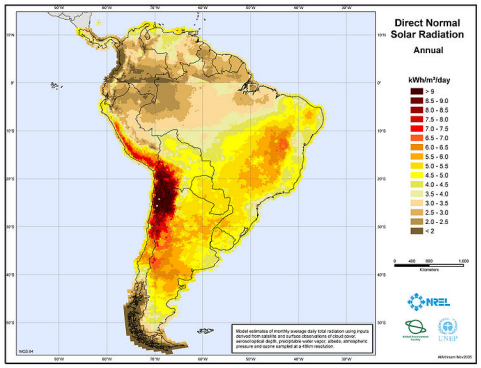
… and Chile has a key ambition to transition to the developed world

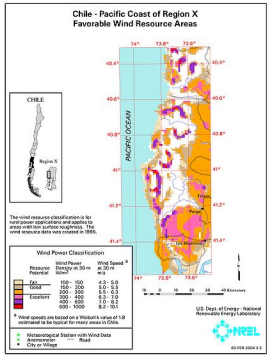


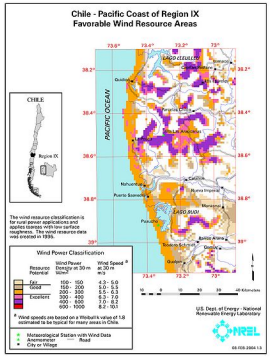
- … and this transition will require a major increase in energy supply …

Is there a way out? Some observations …

- **Wind and solar are 'naturals' for Chile, with a major caveat**
  - **Chile is – in principle – an excellent location for solar and wind renewables**
  - **The obstacle is their intermittency …**
  - **Intermittency can be dealt with by storage – but battery technologies are not sufficiently developed as yet … and costly**





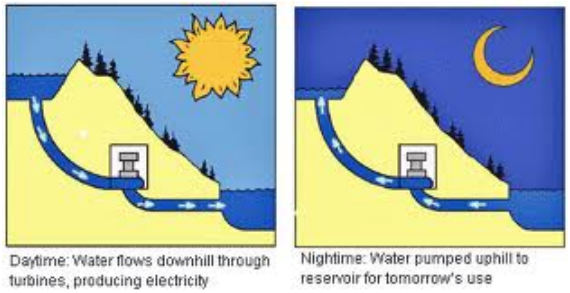


Data courtesy NREL

- **The energy market in Chile has large price fluctuations**
  - **The spot price for electricity fluctuates O(1)**
  - **This is an ideal situation for arbitrage … BUT how big is that market? (Most Chilean electricity contracts are long-term …)**

Is there a way out? A possible solution … ?

- **Chile has a unique topographic profile**
  - **The Andes are steep on the western side, and much less steep on the eastern side**
- **There is a proven storage technology ideally suited for Chile …**
  - **The Western European alpine countries have heavily invested in 'pumped storage' facilities …**
    - ***These are designed to ameliorate supply side fluctuations from renewables***



Okinawa, Japan

  - **"Pumped storage" can deal with extremely large amounts of power**
    - ***The largest facilities in Europe are ~2GW in scale***
  - **Large parts of the Chilean coast offers steep gradients ideally suited for pumping sea water up to 100s of meters above mean sea level**
    - ***Japanese have already developed this technology …***
    - ***Not sensitive to droughts, unlike hydro …***

Is there a way out? A possible solution … ?

- **The economic case for pumped storage remains to be made**
  - **The large spot price fluctuations resulting from load fluctuations offer a *potentially* large economic opportunity – pump at low demand/low cost, generate at times of high demand/high cost**
  - **The key is a hard-nosed business case analysis, based on existing Chilean infrastructure capabilities – note that the mining industry already has highly developed infrastructure for tunneling, …**
    - ***A sensible business case requires a sufficiently large market …***
    - ***European costs are ~ $1B/1-2 GW pumped storage facility***
- **Once pumped storage is in place (and economically justified primarily by the arbitrage opportunities), renewables – especially solar in the Atacama – can effectively overcome their key vulnerability, namely fluctuations in supply.**
- **Chile offers pumped storage sites in regions in which ecological impacts are minimal – in particular, the Pacific coast west of the Atacama … but that is not where the cost of electricity fluctuates …**
  - **The Chilean grid will matter …**

… and my final comments:

- So far I've focused on technology … but policy also involves politics …
- In Chile, as everywhere else, allowing the energy conversation to boil down to 'environment' vs. 'ugly power' dooms the production side …
  - In that case, the 'no' position devolves either into a 'no growth' position … or
  - Leads to arguments for renewables
    - *Highly optimistic cost estimates …*
    - *Heavy dependence on 'invention'*

Data from World Resources Institute

Country	kW/person
United States	10381
Chile	2200
Italy	4164
Portugal	3305

- Thus, moving forward will require a change in the conversation …
  - What standard of living does Chile aspire to? How does Chile plan to effectively address existing income disparities?
  - Has any society successfully dealt with income disparities without substantial economic growth?
  - How does one balance fixing social & economic disparities with environmental constraints?

… which brings us to questions and discussion