

Renewable Energy and Climate Change

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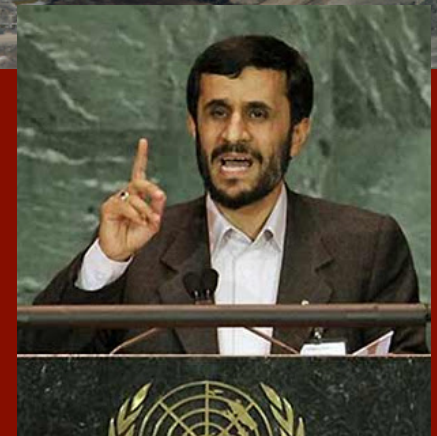
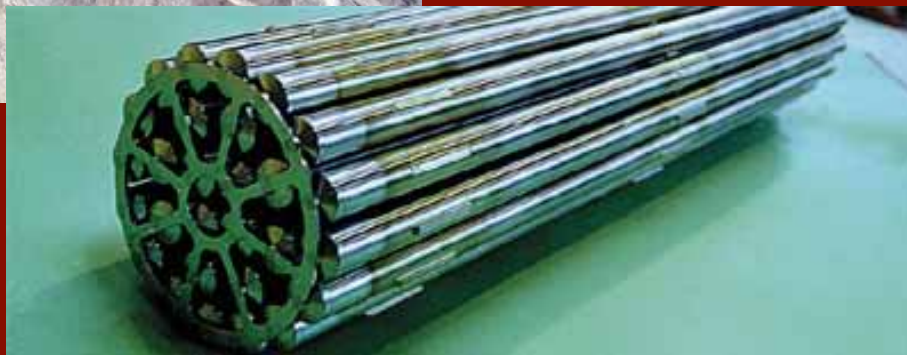
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September 2012

Renewable Energy Advantages

- Avoidance of fuel cycle impacts, costs and risks (except biomass)



Advantages

- Low operational impacts relative to non-renewables
- Compatibility with other land uses
 - (wind, solar, small hydro, biomass)



GHG Emission Estimates (University of Sydney 2006)

Electricity technology	Energy intensity (kWh _{th} /kWh _{el})	Greenhouse gas intensity (g CO ₂ -e/kWh _{el})
Light water reactors	0.18 (0.16 – 0.40)	60 (10 – 130)
Heavy water reactors	0.20 (0.18 – 0.35)	65 (10 – 120)
Black coal (new subcritical)	2.85 (2.70 – 3.17)	941 (843 – 1171)
Black coal (supercritical)	2.62 (2.48 – 2.84)	863 (774 – 1046)
Brown coal (new subcritical)	3.46 (3.31 – 4.06)	1175 (1011 – 1506)
Natural gas (open cycle)	3.05 (2.81 – 3.46)	751 (627 – 891)
Natural gas (combined cycle)	2.35 (2.20 – 2.57)	577 (491 – 655)
Wind turbines	0.066 (0.041 – 0.12)	21 (13 – 40)
Photovoltaics	0.33 (0.16 – 0.67)	106 (53 – 217)
Hydroelectricity (run-of-river)	0.046 (0.020 – 0.137)	15 (6.5 – 44)

Renewable Energy Disadvantages/Challenges

- Intermittency and grid integration
 - Capacity Factors
 - Wind 20-40%
 - Solar 12-15%
- Integration of up to 20% of supply possible without major disruption



Social Conflicts

- Visual and noise impacts of wind turbines
 - Noise, Low frequency sound, Infrasound, and vibration
 - Flicker
 - Ice Throw
 - Structural Hazards
 - Bird and bat kills



Protesters hold a demonstration against wind turbines at Queen's Park on Wednesday April 28, 2010. (CP24/Aaron Adetuyi)

Barriers: Cost

Technology	Costs (cents/kwh)
Natural Gas	3.9-8
Coal	3.8-5.5
Nuclear	11.1-30+
Wind	4-10+
Geothermal	4.5-30
Hydro	5.1-11.3
Solar	15-30+

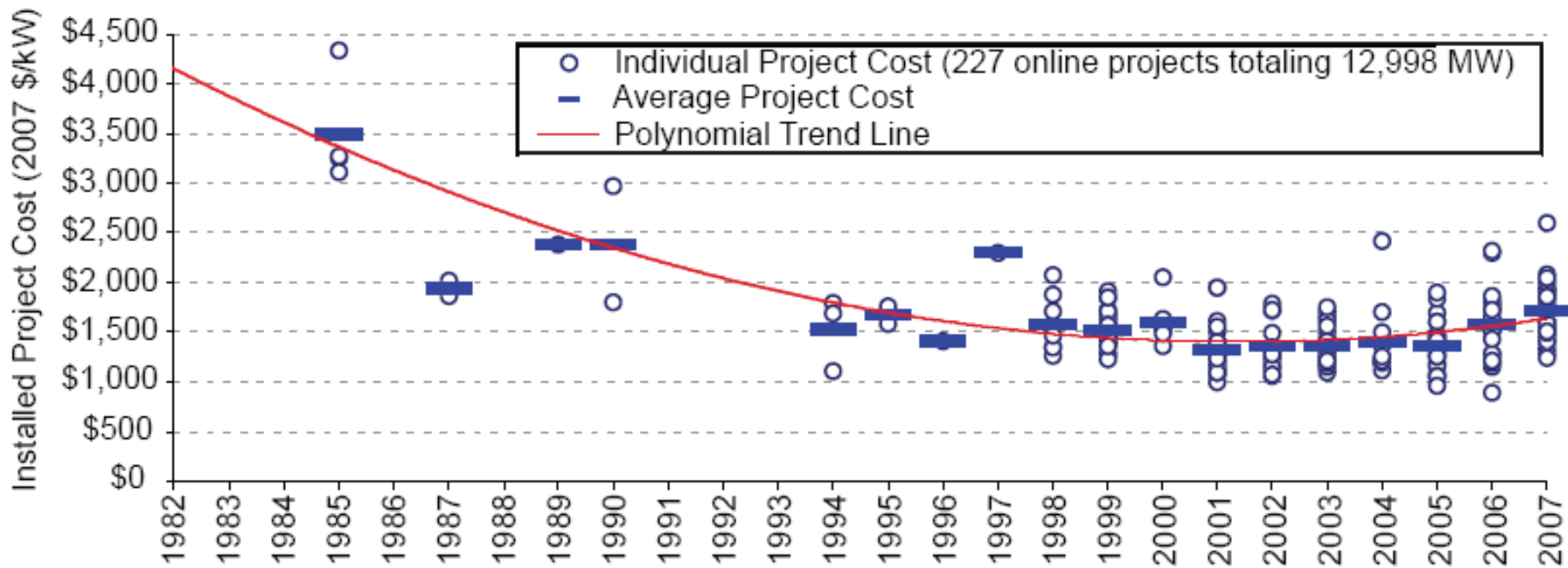
Source: http://peswiki.com/index.php/Directory:Cents_Per_Kilowatt-Hour and others

Table 2: Ontario's Electricity Options: A Cost Comparison¹⁹

Energy Efficiency	Water Power from Quebec	Natural Gas-Fired Combined Heat and Power	Existing Nuclear Reactors	Ontario Water Power Feed-in-Tariff	Ontario Wind Power (Onshore) Feed-in-Tariff	Ontario Biogas Feed-in-Tariff	Darlington Re-Build Project	Ontario Solar Feed-in-Tariff*
2.3 – 4.6 cents per kWh	5.8 cents per kWh	6 cents per kWh	8.0 – 9.1 cents per kWh	12.2 – 13.1 cents per kWh	13.5 cents per kWh	10.4 – 19.45 cents per kWh	19 – 37 cents per kWh	44.3 – 80.2 cents per kWh

**FIT solar pricing is currently being reviewed and will likely decrease*

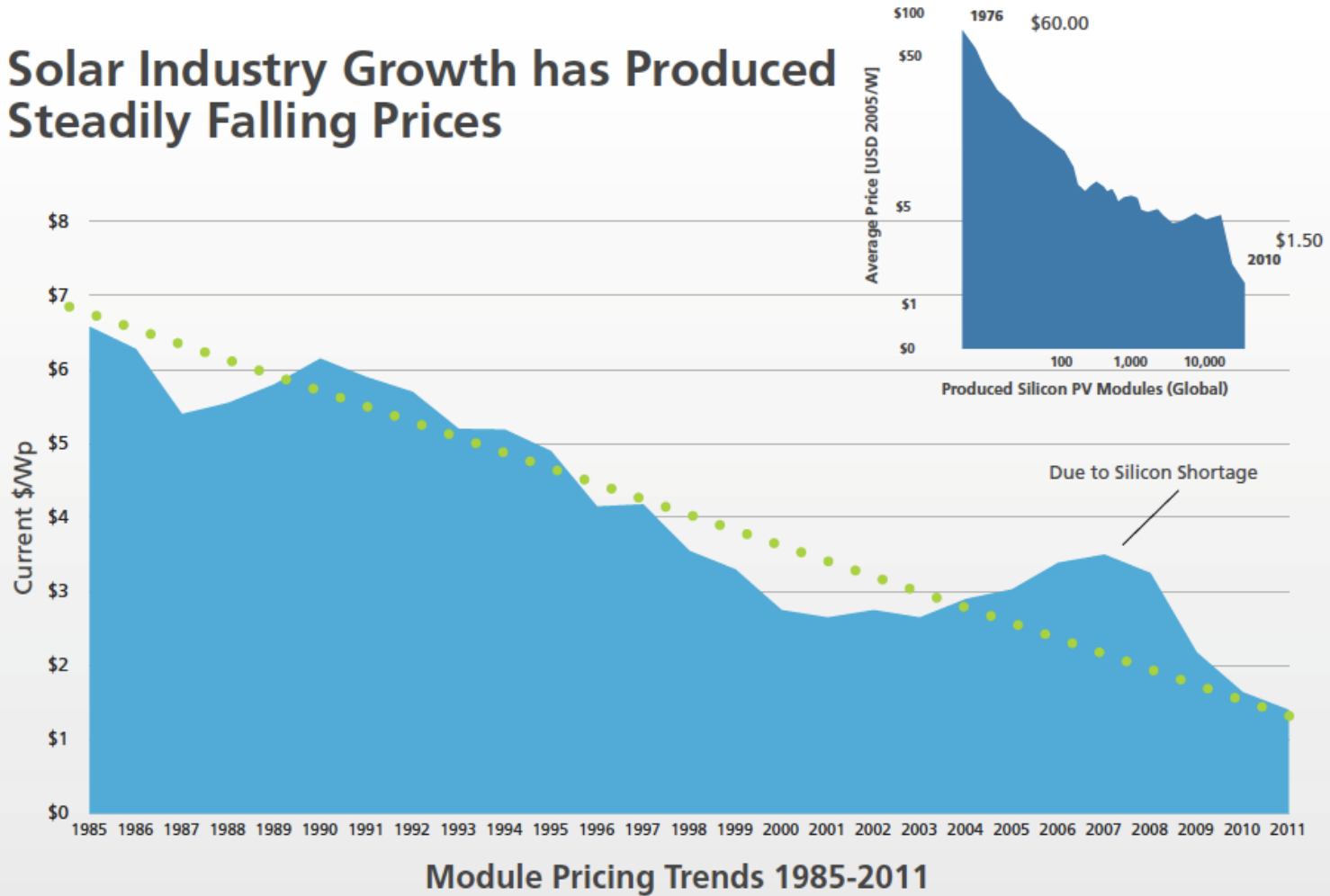
Barriers: Costs



Source: Berkeley Lab database (some data points suppressed to protect confidentiality).

Barriers: Costs

Solar Industry Growth has Produced Steadily Falling Prices



Sources: 1976 -1985 data from IPCC, Final Plenary, Special Report Renewable Energy Sources (SRREN), May 2011; 1985-2010 data from Paula Mints, Principal Analyst, Solar Services Program, Navigant; 2011 numbers based on current market data

Barriers

- Embedded 'hard' path systems and path dependency



OPG

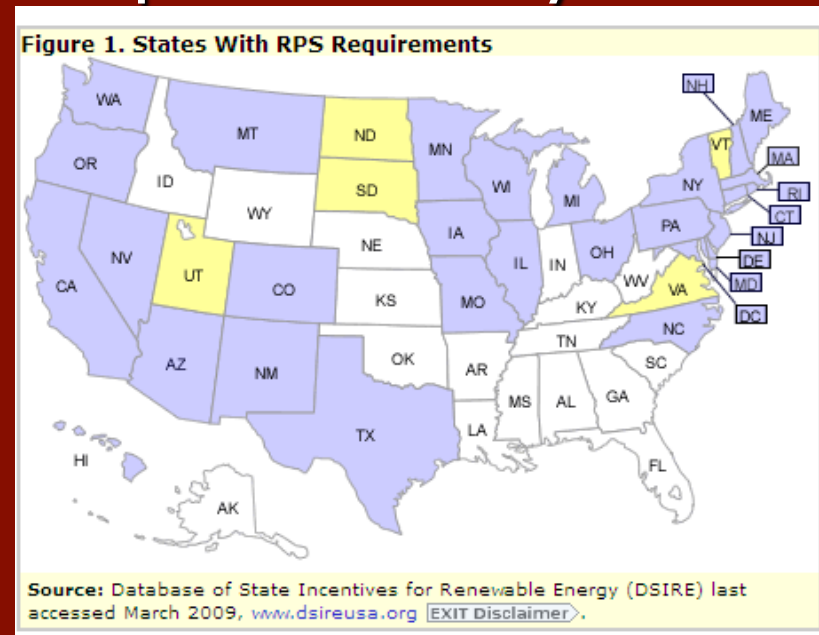
Renewable Energy Responses: Intermittency

- Distributed generation and 'smart' grids
- Storage
 - Batteries
 - Thermal (water, sodium)
 - Compressed air
 - Hydro and pumped storage



Renewable Energy Policy Responses:

- Quotas/Renewable Portfolio Standards
 - UK Renewables Obligation
 - 3% 2002/03 - 11% 2010/11
 - 24 US States – 8%-40% requirements by 2012- 2030
 - California 33% by 2030
 - New York 24% by 2013
 - Maine 40% by 2017



Renewable Energy Policy Responses: Feed-in-Tariffs

- Employed
 - Denmark
 - Germany
 - Spain
 - Ontario (2009)
- Fixed Price Per kwh produced
 - Varies by technology
- Guarantees of grid access