Biological Carbon Uptake and Carbon Sinks: Role of Forests

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Western Forest Economists
Welches, OR

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Background papers:

- van Kooten, GC, 2009. Biological Carbon Sinks: Transaction Costs and Governance, *The Forestry Chronicle* In press.
- van Kooten, GC, 2009. Biological Carbon Sequestration and Carbon Trading Re-Visited, *Climatic Change* In press.
- van Kooten, GC & B Sohngen, 2007. Economics of Forest Carbon Sinks: A Review, *International Review of Environmental & Resource Economics* 1(3): 237-269.
- Manley, J, GC van Kooten, K Moeltner & DW Johnson, 2005. Creating Carbon Offsets in Agriculture through Zero Tillage: A Meta-Analysis of Costs and Carbon Benefits, *Climatic Change* 68: 41-65.
- van Kooten, GC, AJ Eagle, J Manley & T Smolak, 2004. How Costly are Carbon Offsets? A Meta-analysis of Carbon Forest Sinks, Environmental Science & Policy 7(4): 239-51.

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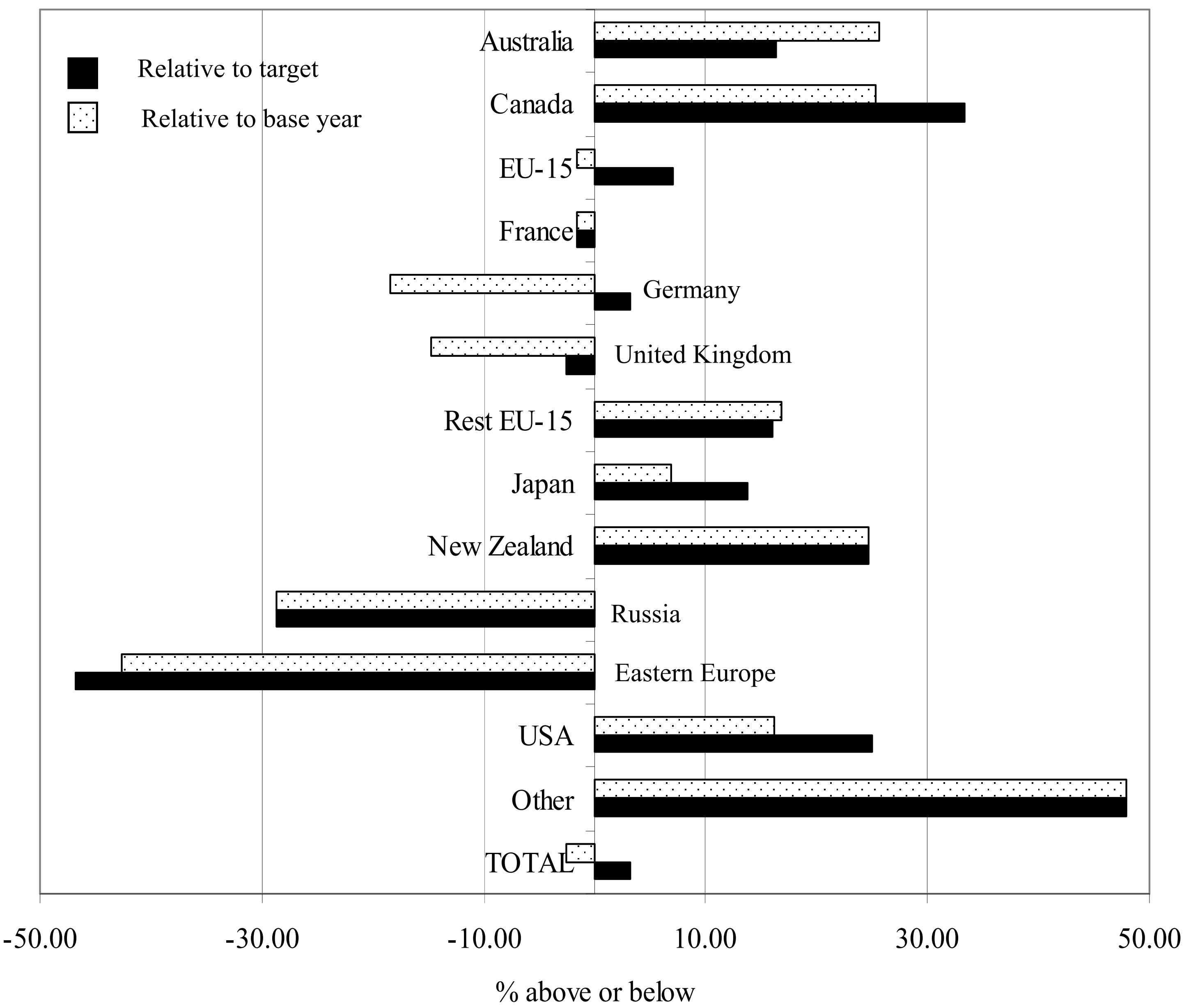
Climate: Background

- Current rush to implement climate policy
  - EU renewable energy targets
  - ETS of 2005; trading in western states (WCI)
  - US renewable energy initiatives, including subsidies for electricity renewables and notably biofuels
  - China and India using CDM funding
  - BC has implemented carbon tax

Climate Background (cont)

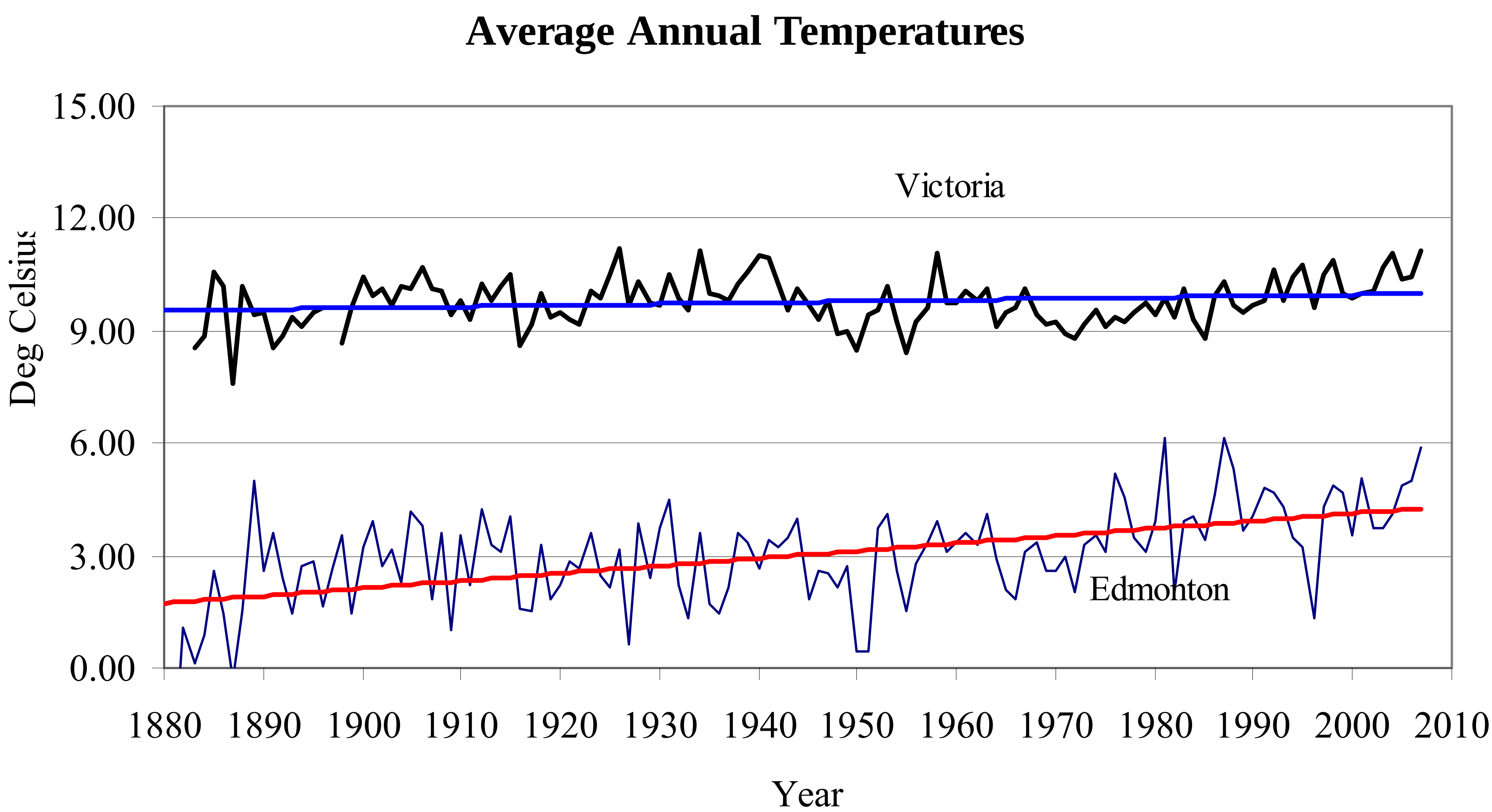
- Should something be done about climate change? Can something be done? Is Kyoto Protocol effective?
  - Chinese emissions rose 11% in each of 2005, 2006, and by 8% in 2007. China accounts for 35% of increase in global emissions
  - Norway: emissions rose 15% after carbon tax was implemented
  - Kyoto targets are not being met

Success at Meeting Kyoto Targets



Heat Island Effect of Temperature Measurement

  - US high temperatures occurred in 1930s
  - Average temperature for 1st six months of 2008 put us back 100 years
- Climate in Victoria generally warmer than Edmonton. Has gap narrowed?
- Have winter temperatures narrowed more than summer ones?
- Have night-time temps (lows) risen faster than daytime temps (highs)?



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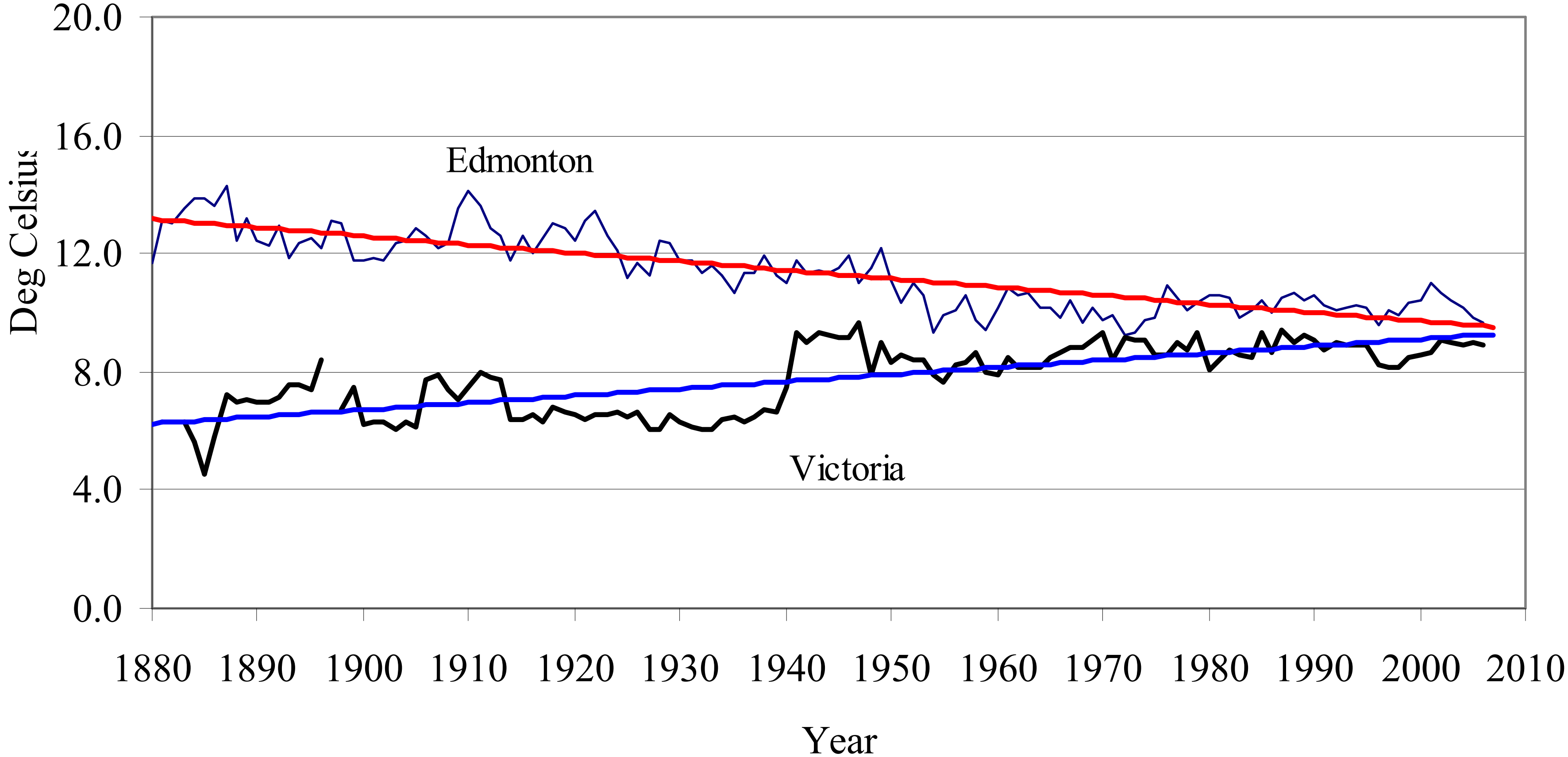
Average Maximum minus Minimum Temperatures



Indicative of human heat island effect

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What is going on?

- Summer temperatures are rising slowly in both locations; Edmonton’s winter temperatures are rising, but not those of Victoria
- KEY: the max-min difference has declined significantly in Edmonton, suggesting ‘heat island effect’
- Climate data supposedly filter out this effect, but “as much as half of the measured post-1980 land-based ‘global warming’ may be attributable to contamination of the basic data” (McKitrick & Michaels, *J Geophysical Research* 112: 2007)

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Biological Sink Activities

- Many sellers of CO_2 offsets created by sinks
  - Greenfleet, Australia will plant trees for a donation www.greenfleet.com.au/greenfleet/objectives.asp
  - Trees for Life claims to reduce your carbon footprint for a fee www.treesforlife.org.uk/tfl.global_warming.html
  - Haida Gwaii want to restore old-growth trees (must remove alder first) and is selling carbon credits (www.haidaclimate.com/)
  - Little Red River Cree and Powell River Community Assoc want carbon credits for not harvesting trees (timber markets are currently the worse they have been in years!)

How many are legitimate offset activities?

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CDM Forestry Projects

- Sequestration of CO_2 via forestry projects is popular within CDM.
- First project approved in November 2006 (UNFCC 2006): to establish 2,000 ha of multiple-use forests on degraded lands in Huanjiang County of Guangxi province of China (sponsored by Italy and Spain).
- Cost: \$4 per t CO_2
- Total sequestration over 30-year life: 773,842 tCO_2, or 25,795 tCO_2 annually
- Ignores potential loss of CO_2 in 2036, fire/disease risk, etc.

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CDM Forestry Projects

- FAO (2004) examined 49 projects then underway or proposed to create carbon offset credits:
  - 43 in developing countries and eligible for CDM credits
  - 38 forestry projects
  - 17 involve forest conservation
  - 33 provide some information on amount of carbon sequestered
  - 24 have data considered 'good'
  - 11 provided information on costs
  - None had data on the timing of carbon uptake or release

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Meta-regression Analysis

- Based on a meta-regression analysis of 68 studies, 1047 observations, we determine costs of sequestering carbon in forest ecosystems.

Region and Scenario	Study Averages (n=68)	All observations (n=1047)
Global	$28.85	$25.10
Planting	$0.26	-$4.93
Planting & opportunity cost of land	$29.80	$21.91
Planting, opportunity cost of land & fuel substitution	-$40.14	$19.88
Forest management	$88.47	$35.31
Forest management & opportunity cost of land	$118.01	$62.15
Forest management, opportunity cost of land & fuel substitution	$48.07	$60.12
Forest conservation	$158.28	$20.16
Forest conservation & opportunity cost of land	$187.82	$47.00
Europe	$173.26	$183.64
Planting & opportunity cost of land	$185.44	$180.14
Planting, opportunity cost of land & fuel substitution	$115.50	$178.11
Forest management & opportunity cost of land	$273.65	$220.38
Forest management, opportunity cost of land & fuel substitution	$203.71	$218.35
Tropics (CDM Projects)	-$26.20	$4.04
Planting & opportunity cost of land	-$25.26	$0.85
Planting, opportunity cost of land & fuel substitution	-$95.20	-$1.18
Forest management & opportunity cost of land	$62.95	$41.09
Forest management, opportunity cost of land & fuel substitution	-$6.99	$39.06
Conservation	$103.22	-$0.90
Conservation & opportunity cost of land	$132.76	$25.94
Boreal Region	$58.01	$8.77
Planting & opportunity cost of land	$70.19	$5.26
Planting, opportunity cost of land & fuel substitution	$0.25	$3.23
Forest management & opportunity cost of land	$158.40	$45.50
Forest management, opportunity cost of land & fuel substitution	$88.46	$43.47

Meta-regression Analysis

- Only 10% of studies provided data on how long carbon was held in the terrestrial sink.
- Most forest activities not competitive with emissions reduction because of high opportunity cost of land. Even when account is taken of carbon stored in wood products, costs are high.
- Some activities in some regions are worth undertaking, many are not.
- When trees are harvested and burned in place of fossil fuels to generate electricity, one gets best results, but not for all locations. More recent research suggests this needs further investigation

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Agriculture: Storing Carbon in Soil Yields Carbon Credits

- During the 1990s, farmers increasingly adopted conservation tillage practices, particularly zero tillage cropping.

Storing Carbon in Soil Yields Carbon Credits

Profit to no till = saving from reduced tillage – output price × Δyield – input price × chemicals

- zero tillage lowers yield, reduces tillage costs and increases chemical use
- during the 1990s, output prices and chemical prices were low
- increase in output price = ↑ opportunity cost of lost yield
- increased chemical prices implies costs of chemicals is higher and it is cheaper to substitute tillage for chemicals

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Storing Carbon in Soil Yields Carbon Credits

- To determine cost of sequestering carbon in soils by shifting from conventional to zero tillage, we needed two meta-regression analyses:
  - Carbon flux caused by shift to no till: we found that carbon flux narrowed with increase in soil depth (52 studies) (Baker et al. Agric., Ecosystems & Environ. 2007)
  - Cost of shifting from conventional to zero till agriculture (51 studies)

- Next table summarizes the results of the two meta-regression analyses.

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Cost of Creating Carbon Credits via Zero Tillage Agriculture, $ per metric ton of CO_2

Region	Wheat	Other Crops
U.S. South	$3 to $4	$½ to $1
Prairies	$105 to >$500	$41 to $57
U.S. Corn Belt	$39 to $51	$23 to $24

Store Carbon in Soil and get Carbon Credits

Conclusion: Conservation tillage appears a winner in some but not all cases.

Problems:

- Ephemeral nature of soil conservation

  E.g., 12 years of soil conservation can be reversed in one year (Olson et al., J of Soil & Tillage Research, 2005)
- Duration Problem: How do we compare projects of different durations?

Comparing Carbon Credit Values when Duration Differs Across Projects

- This depends on:
  - discount rate (*r*)
  - time it takes a ton of CO_2 stored in a forest ecosystem to return to the atmosphere (*n*)
  - time it takes a ton of CO_2 not emitted today to increase emissions at a future date (*N*)

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Comparing Carbon Credit Values when Duration Differs Across Projects

- Proportional value of a sink credit to an emissions reduction credit ($\boldsymbol{\alpha}$) varies depending on:
  - relationship between n and N
  - discount rate
  - growth rate (γ) in damages from atmospheric concentrations of CO_2

Comparing Carbon Credit Values when Duration Differs Across Projects

- The following slides indicate values of a temporary relative to a permanent carbon credit (α), for the following growth rates of shadow price of carbon at N=100, 200 and 500 years:
  - $\gamma = 0.00$
  - $\gamma = 0.01$

As γ increases, the value of a temporary carbon credit declines relative to a permanent credit

Value of a Temporary Relative to a Permanent Carbon Credit (α), $\gamma = 0$

n to N ratio	N=100 years			N=200 years			N=500 years		
	Discount rate			Discount rate			Discount rate		
	2%	5%	10%	2%	5%	10%	2%	5%	10%
Growth rate of shadow price of carbon, γ=0									
0.01	0.023	0.048	0.091	0.040	0.093	0.174	0.094	0.216	0.379
0.05	0.109	0.218	0.379	0.183	0.386	0.614	0.390	0.705	0.908
0.10	0.208	0.389	0.615	0.333	0.623	0.851	0.629	0.913	0.991
0.15	0.298	0.523	0.761	0.457	0.769	0.943	0.774	0.974	0.999
0.20	0.379	0.628	0.851	0.558	0.858	0.978	0.862	0.992	1.000
0.25	0.453	0.710	0.908	0.641	0.913	0.991	0.916	0.998	1.000
0.30	0.520	0.775	0.943	0.709	0.947	0.997	0.949	0.999	1.000

Value of a Temporary Relative to a Permanent Carbon Credit (α), $\gamma = 0.01$

n to N ratio	N=100 years			N=200 years			N=500 years		
	Discount rate			Discount rate			Discount rate		
	2%	5%	10%	2%	5%	10%	2%	5%	10%
Growth rate of shadow price of carbon, γ=0.01									
0.01	0.016	0.039	0.082	0.023	0.075	0.157	0.048	0.177	0.347
0.05	0.077	0.180	0.347	0.109	0.322	0.574	0.220	0.621	0.882
0.10	0.150	0.329	0.574	0.208	0.540	0.819	0.392	0.857	0.986
0.15	0.219	0.451	0.722	0.297	0.688	0.923	0.526	0.946	0.998
0.20	0.285	0.551	0.819	0.378	0.789	0.967	0.631	0.979	1.000
0.25	0.348	0.634	0.882	0.452	0.857	0.986	0.713	0.992	1.000
0.30	0.408	0.703	0.923	0.519	0.903	0.994	0.778	0.997	1.000

Discussion

Sink offset credits cannot generally be traded one-for-one for emission reduction credits, even if the latter are not considered permanent;

NOR can credits from different sink projects be traded one-for-one without some adjustment for duration (say using previous tables).

Discussion

Value of temporary carbon storage fall as the shadow price of damages from CO_2 rises.

Consequence: reduced demand for short-term sequestration as landowners will delay investing in land-use activities that create carbon credits so as to obtain a higher price in the next period

Discussion

Equivalently, landowners delay investments in carbon sink activities if opportunity cost of time falls, which essentially happens when CO_2 damages rise over time (the shadow price γ increases).

Discussion

Given great difficulty determining not only the discount rate and the growth rate in damages, but also uncertainty surrounding n and N, it will simply not be possible for the authority to determine a conversion factor between activities leading to carbon credits of differing duration.

Perhaps one can rely on the market to determine conversion rates, but even the market will have difficulty resolving all uncertainty. In the absence of a certifying authority that guarantees equivalence and thereby resolves uncertainty, sink credits will be worth a lot less.

Discussion

To judge sink projects in the absence of market data requires the analyst make arbitrary judgments about the discount rate, the rate of increase in damages, and the conversion rate between projects to remove CO_2 from the atmosphere to account for differing durations. These are over and above assumptions and uncertainty related to vegetation growth rates, uptake of carbon in soils, wildfire, disease, pests, etc.

Discussion

Some advocate for low discount rates, but low rates of discount militate against terrestrial sink activities.

Discussion

If the rate of increase in damages equals or exceeds the discount rate, CO_2 offset credits from sink activities are only worth n/N of an emissions-reduction credit. This is equivalent to assuming a zero discount rate for physical carbon. But this implies that temporary offsets from biological sink activities are overvalued because, as $N \to \infty$, the value of a temporary offset credit falls to zero. ($N \to \infty$ if an emissions-reduction policy changes behavior that cause permanent reductions in CO_2 emissions).

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Discussion

If a country relies on terrestrial carbon sinks during Kyoto's 1st commitment period and remains committed to long-term climate mitigation, it is in trouble! Suppose it relies on forest sinks for one-third of a 6% reduction in emissions and commits to a further 7% reduction for the second commitment period. In the 2nd period, it must still reduce emissions by 11%. It has only reduced emissions by 4% in 1st period, so it must reduce emissions by 9% in the 2nd period.

But as the forest sink releases its carbon to the atmosphere, it must also cover that loss, which amounts to a further 2% reduction in emissions.

Discussion

(continued)

Temporal shifting in the emissions-reduction burden caused by reliance on carbon sinks results in an onerous obligation for future generations, one which they may not be willing to accept.

Two more thoughts

1. Giving carbon credits to conservation (preventing deforestation) opens one up to corruption
2. Burning forest biomass to generate electricity is not carbon neutral.
   - Eg. Burning mountain pine beetle killed wood results in increased CO_2 emissions just as burning of coal (and likely more so). Benefits come from growing trees, not burning them.

Conclusion

Do away with the terrestrial sink option and focus on energy and real emissions reduction!

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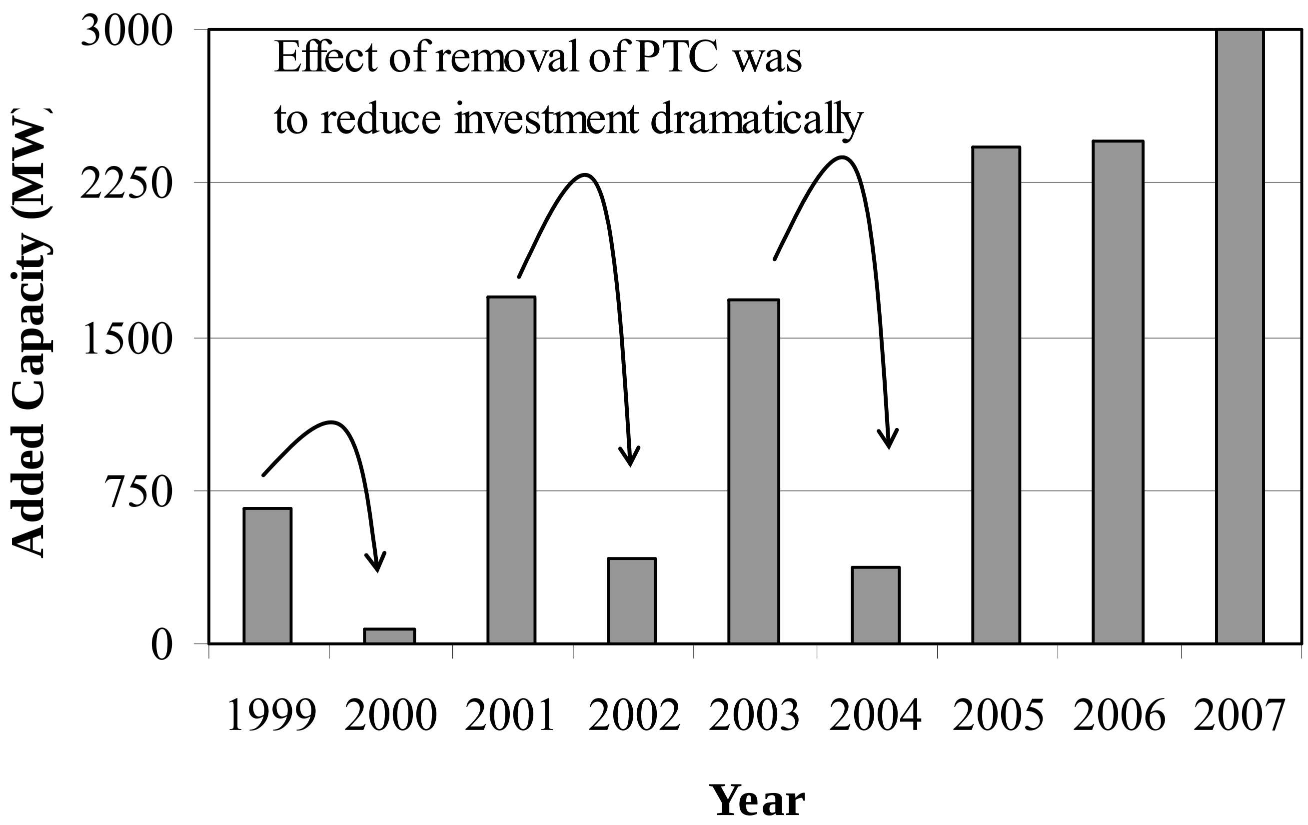
Effect of US Wind Energy Production Tax Credit (PTC) on Investment



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Costs of reducing CO_2 emissions

Generation mix/ Wind penetration	Reducing emissions per tCO_2		Increase in per MWh costs	
	10%	30%	10%	30%
High hydro (HH)	\$1,493.71	\$3,339.88	73%	245%
Typical (TT)	\$120.03	\$272.58	26%	88%
Fossil Fuel (FF)	\$42.86	\$73.63	16%	58%

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Model Conclusion:

- Intermittent power leads to added costs to the system that must be considered in project analysis
- Wind Power can displace CO_2 emissions but in a non-linear and often decreasing fashion
- Their ability to do so heavily depends on the pre-existing generating mix
- However, there may be non-marketed benefits of tidal power over wind power, and renewable power in general