Colorado Climate Project

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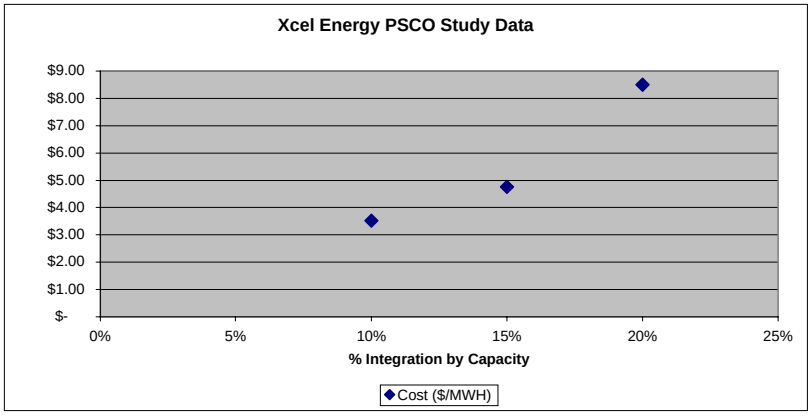
To: Colorado Energy Supply (ES) Policy Working Group (PWG)
From: CCS Project Team
Re: Renewable energy costs
Date: **REVISED** 8/14/2007

This memo summarizes information on renewable energy costs, as provided by members of the ES PWG and obtained through additional research by the CCS project team, to inform the discussion of these key assumptions on the August 15th ES PWG call. It also suggests ways that the group can approach the uncertainty associated with wind integration costs at the level of penetration suggested by ES-2. Although this memo provides suggestions, it is the PWG's responsibility to recommend appropriate inputs for the analysis to the CAP.

Thanks to everyone who provided data.

1. Wind Integration Costs

Since the August 1 CAP meeting, there has been e-mail discussion among the PWG group about wind integration costs. Xcel distributed the results of its Colorado wind integration study and proposed costs extrapolated from that. Other work group members suggested that efforts to manage integration costs could lead to costs significantly lower than Xcel's extrapolation. The chart below shows the costs identified in Xcel's study at different penetration levels. Note that penetration is measured in this study as wind capacity as a percentage of peak load. By this measure, the an RPS requirement of 25% wind energy in 2020 corresponds to a wind capacity penetration of about 40%, which is well above the range considered by Xcel.



As uncertain as these data are within the range shown, we have even less analytical basis for estimating what the range beyond 20% looks like, nor do we know what aggressive efforts to reduce the cost of wind integration would do to this curve in the future. A good approach may be to pick a conservative, middle-of-the-road number and make sure that readers understand both the uncertainty and the sensitivity of the results to this assumption. One approach to making sure readers get this message would be to put two sets of RPS numbers in the summary table – a "low integration cost" scenario and a "high integration cost" scenario.

To inform the discussion, the tables below show such a pair of integration cost functions through 2020, as well as the effects they would have on the cost of the RPS policy proposal. The first row in each table ("Low") uses costs similar to those originally analyzed by CCS. The second row ("High") is loosely based on the Xcel data (the three data points in the graph above).

Wind Integration Costs ($/MWh)

Penetration Threshold (% energy)	0%	5%	10%	15%	20%
Low:	$-	$1	$2	$3	$5
High:	$4	$6	$9	$12	$15

Integration Cost Impact on RPS Policy Costs

Cost Assumption	NPV Gross Renewables Cost (M$)	NPV (Cost) of RPS (M$)	GHG Reductions ($/ton)
Low:	4,606	480	8.32
High:	5,180	1,055	18.27

2. Proposed Changes in Renewable Energy Costs

CCS received information from PWG members and did additional research on renewables costs. Based on this, the CCS project team proposes changes to the cost of PV and solar thermal (CSP), as shown in the table below.

Proposed Renewable Energy Cost Changes

	Original Cost Numbers			Proposed Cost Numbers		
	2010	2015	2020	2010	2015	2020
Wind	50	45	45	50	45	45
Solar PV	576	409	409	See discussion below.		
Solar Thermal	254	243	243	166	115	110
Small Hydro	---	105	105	---	105	105
Biomass Co-firing	20	20	20	20	20	20
Other Biomass	67	67	65	67	67	65
Geothermal	---	78	74	---	78	74

Costs are in nominal 2005 $.

Wind – On the last call there was a proposal to assume that wind costs remain flat at $50 per MWh through the study period (net of the PTC) rather than assuming costs fall from

current levels in 2015. It is not clear how much support there was in the group for this. On the upcoming PWG call, the group needs to decide whether to make this change.

Solar PV – On the last call there was concern that the costs proposed for PV were too high, perhaps by a factor of two. One reason for this was an oversight – the federal Investment Tax Credit (ITC) had not been factored in. With the original cost assumptions, a 10% ITC brings the 2010 cost down to $473 per MWh, and a 30% ITC brings it down to $369. See the table below. The PWG needs to decide whether to assume the 30% credit is extended or the default 10% credit applies through the study period. Currently there is a 30% ITC, but it will revert back to 10% at the end of 2007 unless lawmakers extend it.

If the PWG decides to lower the original 2010 capital cost assumption from $8,500 to $7,000 per kW, the resulting energy cost is $391 per MWh with a 10% ITC and $305 with a 30% ITC. It could be argued that the current rate of PV deployment will result in this kind of cost reduction.

CCS also reviewed three additional sources on PV costs. First, data from the CA Self Generation Incentive Program places the average cost of PV arrays deployed in that program at about $8,700 per kW – slightly higher than the capital cost originally proposed. (Recall that the original cost proposal was based largely on Bolinger and Wiser's statistical analysis of PV costs in California, along with data on installations in Massachusetts.) However, cost estimates from the WGA Solar Task Force and EIA are well below this level. The WGA task force estimates current small PV costs to be in the range of $200 to $300 per MWh and falling to $100 to $150 in 2015. The assumptions behind these costs are not available, but these costs are probably net of a 30% ITC. The U.S. EIA uses capital costs of about $4,600 per kW in the NEMS model. Using our financial assumptions, this yields an energy cost of $259 per MWh with a 10% ITC and $203 with a 30% ITC. Thus, the EIA numbers are in line with the WGA numbers, assuming WGA is factoring in a 30% ITC.

There is a wide range of PV cost data out there. Note that the higher numbers tend to be from actual installations, while the lower ones from non-empirical projections. This may suggest that the non-empirical projections are not including certain project costs or that actual project costs simply tend to be higher than projected. Certainly, we see the latter dynamic in the realm of large fossil plant cost estimates.

The PWG needs to agree on an outlook for PV capital costs and an assumption about what level of ITC is available over the period. To inform the discussion, the table below shows estimated levelized energy costs at different capital cost and ITC levels.

Levelized PV Energy Costs Under Different Assumptions

	10% ITC	30% ITC
$8,500/kW	$473/MWh	$369/MWh
$7,000/kW	$391/MWh	$305/MWh
$4,600/kW	$259/MWh	$203/MWh

Concentrating Solar -- Tom McKinnon and Chuck Kutscher directed us to three reports on concentrating solar power costs. Two of the three (Stoddard and Western Governor's Association) provided very consistent numbers. The new numbers proposed in the table above are based on these reports. These reports appear to assume a 10% ITC. The third report is older and estimates costs to be significantly lower than the other two reports.

- Stoddard, et. al., *Economic, Energy and Environmental Benefits of Concentrating Solar Power in California*, National Renewable Energy Laboratory, May 2005 – April 2006, NREL/SR-550-39291.
- Western Governor's Association Solar Task Force, *Clean and Diversified Energy Initiative*, Western Governor's Association, January, 2006.
- Sargent & Lundy LLC Consulting Group, *Assessment of Parabolic Trough and Power Tower Solar Technology and Cost Performance Forecasts*, National Renewable Energy Laboratory, October 2003, NREL/SR-550-35060.

Biomass Cofiring – no change proposed.

CFB Biomass – no change proposed.

Geothermal – no change proposed. Chuck Kutscher sent the current cost assumptions to Martin Vorum at NREL. Based on his response (below), CCS proposes leaving the geothermal costs where they are.

> It [the proposed geothermal costs] compares reasonably to the results of the Western Governors' Association CDEAC study of 2005. We arrived at LCOE estimates in a range of roughly $80 to $100 per MWh without accounting for PTC, or just under $60 to just under $80 per MWh with the PTC captured. These results were for (a) current technology, (b) 2005 "$", (c) and resources of moderately well known character. I haven't kept current with EIA values and don't know the B&V source you cited below. Absent other qualifiers, your LCOE tabulation falls in a reasonable range for geothermal power in the given timeframe.