The Electricity Journal 30 (2017) 17–22

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/tej

Re-evaluating the implied cost of CO_2 avoided by clean energy investments[☆]

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ARTICLE INFO

Keywords:
CO_2
GHG
Abatement cost
Abatement value
Clean energy investment
Renewable investment
Cost-effective policy
Willingness-to-pay
Displacement
Implied cost

ABSTRACT

The authors present a graphical framework to evaluate the implied CO_2 abatement costs that can be used by policymakers and resource planners to provide clarity on cost-effective policy design, and on the implications of planning decisions for meeting future de-carbonization goals. The framework would allow for comparison of alternative investments, while distinguishing the extent, type and timing of resources they would displace since those factors are system-specific and can substantially impact abatement costs.

1. Implied cost of CO_2 abatement

In this article, we describe the implied cost of CO_2 abatement as the cost premium incurred for clean energy over traditional or market-based resource alternatives.[1] Planners and customers would be willing to pay this cost if they believe the traditional or market-based mechanisms do not appropriately internalize the societal costs of emissions. In that sense, the implied cost metric can be alternatively viewed as some form of an implied "CO_2 externality value," reflecting a willingness-to-pay for the CO_2 reductions, expressed as dollars per ton.[2]

We apply a straightforward formula to calculate the implied cost, as shown below:

($/MWh cost of clean resource – $/MWh cost of displaced resource) ÷ tons/MWh emissions displaced = $/ton implied cost of CO_2 abatement

Although it is mechanically simple to calculate implied CO_2 abatement costs, it can be particularly involved to identify which resources would be displaced by the clean energy resource. As discussed later in this article, the cost and emissions characteristics of the displaced resources are as important as the characteristics of the clean energy resource itself, and they can vary over time and across areas.

2. Drivers of CO_2 abatement cost

In the past several years, a number of market and policy changes have shown that the cost of CO_2 abatement continues to be a moving and often confusing target. Abatement costs can vary quite a lot depending on a specific area's technology costs and performance characteristics. Installed costs of wind and solar resources have declined and their performance has improved materially, creating lower-cost CO_2 abatement opportunities than before. At the same time, however, natural gas prices have remained low (albeit with increased volatility in some regions), keeping the costs of renewables still relatively high compared to natural-gas-fired generation in most parts of the country. Abatement costs depend quite a bit on the alternative resources displaced and their cost and performance characteristics, which can change dramatically over time due to market conditions and public

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[1] This is a simplification since policies to build renewables, such as renewables portfolio standards, can have multiple objectives and benefits beyond emissions abatement. For more discussion please see G. Barbose et al., "Costs and Benefits of Renewables Portfolio Standards in the United States," Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-187516, July 2015, Available at https://emp.lbl.gov/sites/all/files/lbnl-187516.pdf. See also Ryan Wiser et al., "A Retrospective Analysis of the Benefits and Impacts of U.S. Renewable Portfolio Standards," Lawrence Berkeley National Laboratory and National Renewable Energy Laboratory, TP-6A20-65005, January 2016, available at https://emp.lbl.gov/sites/all/files/lbnl-1003961.pdf.

[2] Please see our 2012 article for additional discussion: Philip Q Hanser and Mariko Geronimo, "What Price, GHGs? Calculating the implied value of CO_2 abatement in green energy policies," *Public Utilities Fortnightly* 150(10) (October 2012): 12.

http://dx.doi.org/10.1016/j.tej.2017.08.006

Available online 04 October 2017

		Displaced Technology					
		Existing Coal	Existing Gas CC	New Gas CC	Blend of Gas CC and Coal (Existing Only)	Blend of Gas CC and CT (Existing Only)	Blend of Gas CC and CT (Existing & New)
$/MWh displaced resource →		*$36*	*$33*	*$47*	*$35*	*$43*	*$52*
ton/MWh displaced resource →		*1.13*	*0.41*	*0.37*	*0.77*	*0.51*	*0.49*
Wind							
Unsubsidized	$/MWh						
25% CF	*$100*	**$57**	**$164**	**$146**	**$85**	**$113**	**$98**
30% CF	*$84*	**$42**	**$123**	**$101**	**$64**	**$80**	**$64**
35% CF	*$72*	**$31**	**$94**	**$68**	**$48**	**$57**	**$39**
40% CF	*$63*	**$24**	**$72**	**$44**	**$36**	**$39**	**$21**
45% CF	*$56*	**$17**	**$55**	**$25**	**$27**	**$26**	**$7**
50% CF	*$50*	**$12**	**$41**	**$10**	**$20**	**$15**	**($5)**
With PTC							
25% CF	*$79*	**$37**	**$111**	**$87**	**$57**	**$70**	**$53**
30% CF	*$62*	**$23**	**$70**	**$41**	**$35**	**$37**	**$19**
35% CF	*$50*	**$12**	**$41**	**$9**	**$20**	**$14**	**($5)**
40% CF	*$41*	**$4**	**$19**	**($16)**	**$8**	**($3)**	**($24)**
45% CF	*$34*	**($2)**	**$2**	**($34)**	**($1)**	**($17)**	**($38)**
50% CF	*$28*	**($7)**	**($12)**	**($50)**	**($8)**	**($28)**	**($49)**
Solar PV							
Unsubsidized							
15% CF	*$150*	**$100**	**$285**	**$280**	**$149**	**$210**	**$198**
20% CF	*$112*	**$67**	**$193**	**$179**	**$101**	**$136**	**$122**
25% CF	*$90*	**$48**	**$138**	**$117**	**$72**	**$92**	**$76**
30% CF	*$75*	**$34**	**$102**	**$77**	**$52**	**$63**	**$46**
35% CF	*$64*	**$25**	**$76**	**$48**	**$38**	**$42**	**$24**
With ITC							
15% CF	*$109*	**$64**	**$185**	**$169**	**$96**	**$130**	**$115**
20% CF	*$82*	**$40**	**$119**	**$95**	**$61**	**$76**	**$60**
25% CF	*$65*	**$26**	**$79**	**$51**	**$40**	**$44**	**$26**
30% CF	*$55*	**$16**	**$52**	**$21**	**$26**	**$23**	**$4**
35% CF	*$47*	**$9**	**$33**	**$0**	**$16**	**$8**	**($12)**

Fig. 1. Implied CO_2 abatement costs of new wind and solar investments (assumes direct resource cost only and no system integration costs).

policies. Over the past several years since we published our first article on this topic, the alternative resources that are displaced by renewables have gradually shifted from coal-fired to natural-gas-fired generation in most regions, and from new to existing plants in regions with excess capacity.

Fig. 1 demonstrates a wide range of possibilities for the implied CO_2 abatement costs of new wind and solar projects.[3] The table shows several (but not all) dimensions and variants to the cost calculation, and thus illustrates how difficult it can be to draw conclusions that are helpful for planning decisions. The rows show wind and solar resources under various levels of capacity factors, with and without federal subsidies. The columns show potential displaced resources. Values in italic font reflect the characteristics of the underlying resources, including cost, emissions, and capacity factors. Values in bold font are the resulting implied CO_2 abatement costs, ranging from −$50/ton to +$285/ton depending on the combination of clean energy resources and displaced resources, as well as the federal subsidies.

In Fig. 1, looking down the rows within one column illustrates the impact of varying costs in wind and solar technologies. For simplicity, our assumed costs include the capital and operating costs of the plants, but they do not consider any additional system costs needed for integrating renewable generation. Also, costs in Fig. 1 vary by assumed capacity factor and tax credits but they assume the same fixed $/kW capital costs by plant type. In reality, capital costs can vary a great deal due to a number of factors including location and vintage of the installation. With all of the factors combined, actual costs may fall outside of the range shown in the figure. For example, the Department of Energy (DOE) has reported that wind power purchase agreements (PPAs) are currently priced at approximately $20/MWh in Texas and the Great Plains portion of the Midwest.[4] These low PPA prices likely reflect reductions from federal production tax credits (PTCs). But even without tax credits, and even with low natural gas prices, new wind generation in these areas may be competitive with existing natural-gas-fired CCs from a total cost perspective. This would yield implied CO_2 abatement costs that are very low or even negative.

Looking across columns within a single row in Fig. 1 illustrates the impact of displacing different types of resources. If existing resources are displaced, the cost premiums of wind and solar projects are calculated relative to the operating costs of these resources. If new resources are displaced, the calculations of cost premiums take into account the capital costs that would be avoided. Since new plants tend to have a higher all-in costs compared to existing resources (but not always), displacing new resources tends to put downward pressure on the

[3] Some states have recently considered or adopted subsidies to a broader range of no-emissions resources like existing nuclear plants. We do not explicitly discuss nuclear generation in this article but zero energy credit (ZEC) payments to support existing nuclear plants could fall within the same framework we present in the following sections.

[4] R. Wiser and M. Bolinger, "2015 Wind Technologies Market Report," Lawrence Berkeley National Laboratory, August 2016, available at https://emp.lbl.gov/publications/2015-wind-technologies-market-report