Hydropower's Contribution to Carbon Dioxide Emission Reduction

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The annual carbon dioxide emissions currently avoided by the use of hydropower in electricity generation is 142 million metric tons, and it has a carbon tax value of $7.1 billion. Developing the identified additional hydropower capacity can yield an additional 34 million tons annually of avoided carbon dioxide emissions, with a value of $1.7 billion in carbon taxes (Table 1). The total annual avoided emissions can exceed 176 million metric tons, with a value of $8.8 billion.

Table 1. Hydropower's contribution to avoiding carbon dioxide emissions

	Avoided annual carbon dioxide emissions (metric tons)	Potential carbon tax value
Current annual generation	141,986,065	$7,099,303,225
Identified additional generation	34,598,376	$1,729,918,796
Total annual contribution	176,584,441	$8,829,222,021

Current Annual Hydropower Generation - Avoided Emissions

Hydropower, by the nature of its fuel source (water) and the non-combustion way in which it captures and converts the energy of falling water into electrical energy via the water turbine and generator set, lowers the amount of carbon dioxide emitted during the production of electricity. The annual reduction in carbon dioxide emissions can be calculated as follows:

Converting the pounds of carbon dioxide per million Btu (Table 2) into the pounds per kilowatt-hour (kWh) value by multiplying Table 2 by the Btu per kWh (Table 3) and dividing by 1 million to convert to emission pounds per Btu instead of per million Btu.

207.7 x 10,296 / 1,000,000 = 2.14 pounds of emissions per kWh

Multiplying 2.14 by the average annual hydropower kWh energy (Table 4), divided by 2,000 to convert to tons and multiply by 0.9718 to convert to metric tons.

2.14 x 278,816,144,000 / 2000 x 0.90718 = 270,449,647 metric tons

It is assumed that only 52.5% of the hydropower is replacing coal generation, given that coal comprises 52.5% of the electric generation in the United States (Table 5), so the metric tons is multiplied by 52.5%.

270,449,647 x 0.525 = 141,986,065 metric tons of carbon dioxide emissions annually omitted by hydropower generation in the United States.

Given the $50 per metric ton carbon tax, the hydropower emissions has a value of $7.1 billion.

141,986,065 x $50 = $7,099,303,225

Potential Additional Avoided Hydropower Generation - Emissions Avoided

DOE has identified the potential hydropower capacity that can be developed given the various environmental, legal, and institutional development constraints as totaling 34,470 MW of capacity (Table 6). Various state natural resource, water quality, and environmental quality departments have provided input to this modeling process. Because 93% of these identified sites with undeveloped capacity are sites that already have either existing generation or at minimum a dam with no current generation, the addition of new capacity would occur at sites with current infrastructure development. Given the need to minimize carbon emissions and the absence of environmental types of constraints at these sites with undeveloped potential, a very high percentage of these sites can be successfully developed in the near term if their value in decreasing emissions is fully considered. For analysis purposes, it is assumed that only 50% of this capacity would be developed.

To convert the undeveloped capacity to kWh, the following equation is employed.

34,470 x 1,000 (convert to kWh) x 24 (hours) x 365 (days) x 0.45 (plant factor) x 0.50 (% developed) = 67,940,370,000 kWh

The 67.9 billion kWh can now be used to calculate the avoided tons of carbon dioxide emissions using the same calculations used above to calculate the current annual emissions avoided.

67,940,370,000 x 207.7 x 10,296 / 1,000,000 / 2,000 x 0.525 x 0.90718 = 34,598,376 metric tons

To find the carbon tax value of the avoided emissions multiply by $50

34,598,376 x $50 = $1,729,918,796

Table 2. Average Carbon Dioxide Emission Factors for Coal by Coal-Consuming Sector. EIA, Annual Energy Review 1995 (July 1996). Table C1.

Year	Electric Utilities - Pounds of Carbon Dioxide per Million Btu
1990	207.6
1991	207.7
1992	207.7
1993	207.8
1994	207.9
Average	207.7

Table 3. Approximate heat rates for electricity, EIA, Annual Energy Review 1995 (July 1996), Table A7. (Fossil Fuel is defined as petroleum, coal, and natural gas.)

Year	Fossil-Fueled Steam-Electric Plants (Btu per Kilowatt-hour)
1991	10,352
1992	10,302
1993	10,280
1994	10,272
1995	10,272
Average	10,296

Table 4. Conventional hydroelectric generation. EIA, Electric Power Monthly, March 1997, Table 5

Year	Thousand Kilowatt-hours
1990	283,433,659
1991	280,060,621
1992	243,736,029
1993	269,098,329
1994	247,070,938
1995	296,377,840
1996	331,935,594
Average	278,816,144

Table 5. Electric Utilities and nonutility power producers net generation. EIA, Annual Energy Review 1995 (July 1996), Table 8.2.

Year	Net Generation (billion kWh)	Coal Generation (billion kWh)	Percent from coal
1992	3,083.4	1,621.1	52.6%
1993	3,196.9	1,690.0	52.9%
1994	3,253.8	1,691.7	52.0%
Average	3,178.0	1,667.6	52.5%

Table 6. Estimate of undeveloped hydropower resources in the United States. Includes 50 states. Does not include US territories.

Status	Number of sites	FERC database (MW)	DOE/HES study (MW)	Percent of original estimate
49 states - sites with power	361	5,850	3,499	59.8%
49 states - sites without power	2,395	29,006	17,527	60.4%
49 states - sites undeveloped	2,398	26,710	9,617	36.0%
Idaho - all sites	360	7,685	3,827	49.8%
Totals	5,514	69,251	34,470	49.8%

Notes:

- FERC - Federal Energy Regulatory Commission. Hydroelectric Power Resources Assessment database
- The DOE Hydropower Program has been conducting a resource assessment of the undeveloped hydropower capacity in the United States. The undeveloped potential in Idaho has not been modeled to date. For the other 49 states, the following process has been followed:
    - The Hydropower Evaluation Software (HES) computer model was developed to perform a uniform assessment of the institutional, environmental and legal constraints to hydropower development.
    - The FERC database was used to identify the undeveloped physical potential, absent of any environmental type of development constraints.
    - The FERC data is loaded into the HES model and the environmental type of constraints are obtained from the Department of Interior's National River Inventory (NRI). The NRI provides a site's fish, scenic, recreation, wildlife, geologically, historic and cultural values; as well as the site's legal constraints to development such as wild and scenic protection and threatened and endangered protections. The FERC database contains the Federal Land Ownership, which can include park, wilderness, grasslands, military, or Indian ownership status.
    - The dam status is also identified based on if a site has current power generation, is a dam with no power generation, or if the site is totally undeveloped.
    - The model applies a development probability based on the cumulative effect of environmental, institutional and legal values present and the degree of development (dam status) that has occurred to date.
- The table contains the FERC estimated undeveloped capacity potential and the HES modeled undeveloped capacity potential for the 49 modeled states and the percent decrease in estimated potential capacity. The FERC estimate for Idaho has been extrapolated based on the results for the modeled 49 states.