Comment

Supplementary information to:

Floating solar power: evaluate trade-offs

A Comment published in *Nature* **606**, 246–249 (2022)
https://doi.org/10.1038/d41586-022-01525-1

Rafael M. Almeida, Rafael Schmitt, Steven M. Grodsky, Alexander S. Flecker, Carla P. Gomes, Lu Zhao, Haohui Liu, Nathan Barros, Rafael Kelman & Peter B. McIntyre

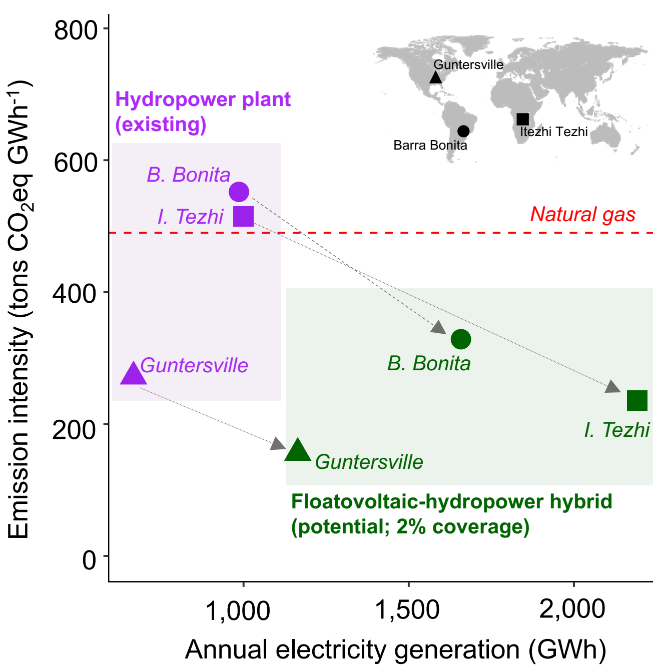

Figure S1. To evaluate whether floatovoltaics could hold promise in mitigating carbon-intensive hydropower operations, we performed a simple exercise with three similarly sized (~300 km^2) carbon-intensive hydropower plants in Brazil, Zambia, and the United States. Small coverages of floatovoltaics (~2%) may sharply reduce the greenhouse-gas footprint of these carbon-intensive hydropower plants while nearly doubling electricity output.

Methods

To determine national floatovoltaic potentials, we used a database of 7,320 large reservoirs worldwide[1]; natural lakes regulated with dams ($n = 119$) were not considered. We then calculated the full floatovoltaic generation potential of each reservoir ($EG_{solar,100\%}$; GWh yr^{-1}) as:

$$EG_{solar,100\%} = PVOUT_r \times A_r \times PD_{FPV} \qquad \text{(Eq. 1)}$$

where $PVOUT_r$ is the annual photovoltaic power potential (GWh/GWp) at each reservoir, extracted from a gridded global map[2]; A_r is the reservoir area; and PD_{FPV} is the power density of floatovoltaics (0.1 GW km^{-2}; ref. 3).

Knowing the floatovoltaic generation potential per unit reservoir area, we calculated the percent coverage of a country's reservoirs that would be needed to meet country-scale goals for solar energy generation by 2050. We first obtained country-level electricity generation by source as of 2018 and the projected annual electricity growth rates by region by 2050[4]. We used this information to calculate the total electricity generation in each country in the year 2050. The share of solar power in total electricity generation in 2050 was taken from a net-zero scenario ("Transforming Energy Scenario") projected in IRENA's Global Renewables Outlook 2020[5]. From the projected total electricity generation in 2050 and the share of solar power specified in the net-zero scenario, we calculated the required per-country increase in solar energy generation by 2050. Finally, we calculated the fractional coverage of a country's reservoirs needed to meet 2050 solar-energy demands. Summary data for Canada are illustrated below:

- Country: Canada
- Total electricity generation, 2018: 645 TWh
- Solar electricity generation, 2018: 3.5 TWh
- Annual growth rate in electricity generation, reference scenario, 2020–2050: 1.2% a.a.
- Projected total electricity generation in 2050: 945 TWh
- Projected share of solar power in total electricity generation in 2050: 29%
- Projected solar electricity generation in 2050: 274 TWh
- Demand for additional solar electricity generation in 2050 (2050 minus 2018): 270.5 TWh
- Total area of reservoirs: 37,736 km^2
- Percent coverage of reservoirs needed to generate 270.5 TWh of solar: 5.5%

To build Figure S1, we first obtained areal emission rates of carbon dioxide and methane from the surface of those three reservoirs[6]; methane emissions were converted to CO_2-equivalents considering a 100-year Global Warming Potential of 34 for methane[7]. Emission intensities (tons CO_2eq GWh^{-1}) of those three hydropower facilities were computed by dividing annual CO_2-equivalent emissions by annual hydropower generation at each dam. We then assumed a hypothetical 2% coverage of the reservoir with floating solar panels and estimated the emission intensity of the hybrid floatovoltaic-hydropower system (EI_{hybrid}, tons CO_2eq GWh^{-1}) as follows:

$$EI_{hybrid} = \frac{(EI_{hydro} * EG_{hydro}) + (EI_{solar} * EG_{solar,2\%})}{(EG_{hydro} + EG_{solar,2\%})} \quad \text{(Eq. 2)}$$

where EI_{hydro} is the emission intensity of the hydropower facility (tons CO_2eq GWh^{-1}); EG_{hydro} is the annual energy generation of the hydropower facility (GWh yr^{-1}); EI_{solar} is the average emission intensity of solar power (48 tons CO_2eq GWh^{-1}; ref. 8); and $EG_{solar,2\%}$ is the annual generation of the floatovoltaic system based on 2% coverage of the reservoir (GWh yr^{-1}), computed using a modification of Eq. 1 (i.e., Eq. 1 considers 100% coverage). Summary data are presented in the table below.

	Barra Bonita	Guntersville	Itezhi Tezhi
Country	Brazil	US	Zambia
Reservoir area (km^2)	324 (ref. 6)	279 (ref. 6)	365 (ref. 6)
Reservoir $CH_4 + CO_2$ emissions ($tCO_2eq/km^2/day$)	4.6 (ref. 6)	1.8 (ref. 6)	3.9 (ref. 6)
Floatovoltaic area, 2% coverage (km^2)	6.48	5.58	7.30
Power density of floatovoltaic systems (GW/km^2)	0.1 (ref. 3)	0.1 (ref. 3)	0.1 (ref. 3)
Floatovoltaic technical potential, 2% coverage (GWp)	0.65	0.56	0.73
Daily PVOUT (GWh/GWp)	4.40 (ref. 2)	4.08 (ref. 2)	4.97 (ref. 2)
$EG_{solar,2}$% (GWh/yr)	1,041	831	1,324
EG_{hydro} (GWh/yr)	986 (ref. 9)	667 (ref. 10)	1,000 (ref. 11)
EI_{hydro} (tCO_2eq/GWh)	552	272	516
EI_{solar} (tCO_2eq/GWh)	48 (ref. 8)	48 (ref. 8)	48 (ref. 8)
EI_{hybrid} (tCO_2eq/GWh)	293	148	249

1. Global Reservoir and Dam Database (GRanD v1.3). http://globaldamwatch.org/grand/ (Access date: January 2022).
2. "Photovoltaic Power Potential" obtained from the "Global Solar Atlas 2.0", a free, web-based application developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info (Access date: January 2022).
3. Spencer, R. S. *et al*. Floating Photovoltaic Systems: Assessing the Technical Potential of Photovoltaic Systems on Man-Made Water Bodies in the Continental United States. *Environ. Sci. Technol.* **53**, 1680–1689 (2019).
4. U.S. Energy Information Administration. *International Energy Outlook 2021*. Washington, DC: U.S. Department of Energy (2021).
5. IRENA. *Global Renewables Outlook: Energy transformation 2050*. Abu Dhabi: International Renewable Energy Agency (2020).
6. Deemer, B. R. *et al*. *Greenhouse gas emissions from reservoir water surfaces: a new global synthesis BioScience* **66**, 949–964 (2016).
7. Myhre, G. *et al*. *Anthropogenic and natural radiative forcing* (Cambridge, UK and New York, USA, 2013).
8. Schlömer, S. *et al*. in *Climate Change 2014: Mitigation of Climate Change* (eds Edenhofer, O. *et al*.), Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, 2014).
9. Brazil's National Electric System Operator (ONS). Mean annual hydropower generation 2000-2020. http://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/geracao_energia.aspx (Access date: January 2022).
10. World Bank. *Zambezi Hydropower Sustainability Assessment Protocol*. The Itezhi-Tezhi Hydropower Project. (Washington, DC, 2018).
11. Hydropower Reform Coalition. Guntersville Dam, Alabama. https://hydroreform.org/hydro-project/guntersville/ (Access date: January 2022).