Greenhouse Gas Emissions from Hydro-Québec’s “Clean” Hydro

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Sierra Club, November 21, 2019
Hager family vacations, 1998 - 2005

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Fresh Bread!
Case study: Hydro-Quebec


The net carbon footprint of a newly created boreal hydroelectric reservoir

Cristian R. Teodoru,1,2 Julie Bastien,3 Marie-Claude Bonneville,4 Maud Demarty,3 Michelle Gameau,5 Jean-Francois Hélie,5 Luc Pellerin,6,7 Nigel T. Roulet,6,7 Ian B. Strachan,4 and Alain Tremblay8

[Map of hydroelectric reservoirs]
Science to take home

• Climate impact (gCO$_{2e}$/kWh) of hydro facilities varies by a factor of 10,000
  • 3 main factors control greenhouse gas emissions
    • Area of forest flooded per kWh generated (hydro => deforestation)
      • Hydro from damming narrow, steep valleys above tree line is cleaner
      • Hydro from damming broad forested lowlands is dirtier
    • Age: New reservoirs emit ~ 5 x CO$_2$ of old reservoirs (initial rapid decay & disturbance)
    • Temperature (forest density, methane production)
      • Low T is better
      • High T is worse

• Need to evaluate specific reservoirs in making decisions
  • Power from new Hydro Québec reservoirs emits >> average CO$_2$
    • 15 - 60 times wind, 5 - 15 times solar, 0.5 – 2.5 times Combined Cycle Natural Gas
    • For HQ, CO$_2$ is the problem, not methane
My background

• Avid outdoorsman, concerned citizen, worried parent
• “Dual citizenship:” Massachusetts & Maine
• MIT Professor
  • Department of Earth, Atmospheric and Planetary Sciences
  • Co-Director, MITEI Center for Carbon Capture, Utilization, and Storage
  • Teach 12.021: Earth Science, Energy, and Environment
  • Science definition team for NASA’s Radar Satellite Mission, 2012 - 2019
    • Deformation of Earth’s surface
    • Motion of ice sheets
    • Assessment of above-ground woody biomass
Reliable sources of information?

• Peer reviewed literature – not infallible, but best available
  • Important recent citations included next slides

• White papers – not reviewed, but information can be assessed
  • Used here: International Hydropower Association - predicted footprints
    • G-Res Tool

• Statements by companies and organizations; op-eds
  • Difficult to trace accuracy
  • Easy to apply spin via half-truths, lies of omission
    • Can contradict articles in peer-reviewed literature by same authors!
Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude

Nathan Barros¹, Jonathan J. Cole², Lars J. Tranvik³, Yves T. Prairie⁴, David Bastviken⁵, Vera L. M. Huszar⁶, Paul del Giorgio⁴ and Fábio Roland¹*

Detailed measurements of Hydro-Quebec’s new Eastmain-1 reservoir

The net carbon footprint of a newly created boreal hydroelectric reservoir

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Recommended refereed articles – global statistical models

Research Article

Hydropower's Biogenic Carbon Footprint

Laura Scherer*, Stephen Pfister
Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland

Fit model to ~ 100 reservoirs;
Predict footprint of ~ 1500 reservoirs

Environmental Science & Technology

Climate Impacts of Hydropower: Enormous Differences among Facilities and over Time
Ilissa E. Ocko* and Steven P. Hamburg
Environmental Defense Fund, New York, New York 10010 United States

Further analysis of Sherer & Pfister’s ~ 1500 reservoirs
Estimated Hydro GHG emissions per facility highly variable

https://www.hydropower.org/news/study-shows-hydropower’s-carbon-footprint

International Hydropower Association: Results of GHG Reservoir (G-RES) Tool

Power density

\[ \log(W/m^2) \]

\[ W/m^2 \sim \text{Flow} \times \text{height/Area} \]

\[ \log(g \text{CO}_2/kWh) \]

\[ g\text{CO}_2 \sim \text{Area} \]
Fig. 7.29b

Narrow, deep valleys, little vegetation, large h, small Area, small Flow

Intermediate breadth valleys, more vegetation, large h, intermediate Area, intermediate Flow

Wide valleys, most vegetation, small h, largest Area, highest Flow

Switzerland, Iceland

Maine

Hydro-Québec

Switzerland

Hydro-Québec

Narrow, deep valleys, little vegetation, large h, small Area, small Flow

Intermediate breadth valleys, more vegetation, large h, intermediate Area, intermediate Flow

Wide valleys, most vegetation, small h, largest Area, highest Flow
Per facility estimates from EDF study comparable

# of reservoirs in each emissions bin

Log scale, 1 – 10,000

Linear scale, -300 - 700
Estimated CO$_2$ footprint (Scherer & Pfister, 2016)
Estimated Methane footprint (Scherer & Pfister, 2016)

Fig 1. Carbon footprints of hydropower plants across the world (a) and hydropower plants with high methane emissions (> 10 kg CH₄/MWh) and a large share of methane emissions (> 50% of the carbon footprint) (b). Country boundaries are obtained from Natural Earth (http://www.naturalearthdata.com/).

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Initially, Hydro in boreal forest ~ 2.5 global warming of Natural Gas (without CCS)

Long-term, Hydro in boreal forest ~ 1/2 global warming of Natural Gas (without CCS)
Science to take home

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Thank you! – Any questions?

Linear scale, -300 - 700
Fig 2. Carbon footprints of various energy sources (based on [32] for all energy sources other than hydropower). The lower and upper values of the dark bar for hydropower are the lower and upper quantiles for the corrected mean average (Model A0). The light diamonds represent the 10 and 90% quantiles and the red diamond marks the median.

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MA electric power generation mix

How Massachusetts generated electricity from 2001 to 2017

New Brunswick electric power generation mix