

Greenhouse Gas Emissions from Hydro-Québec's "Clean" Hydro

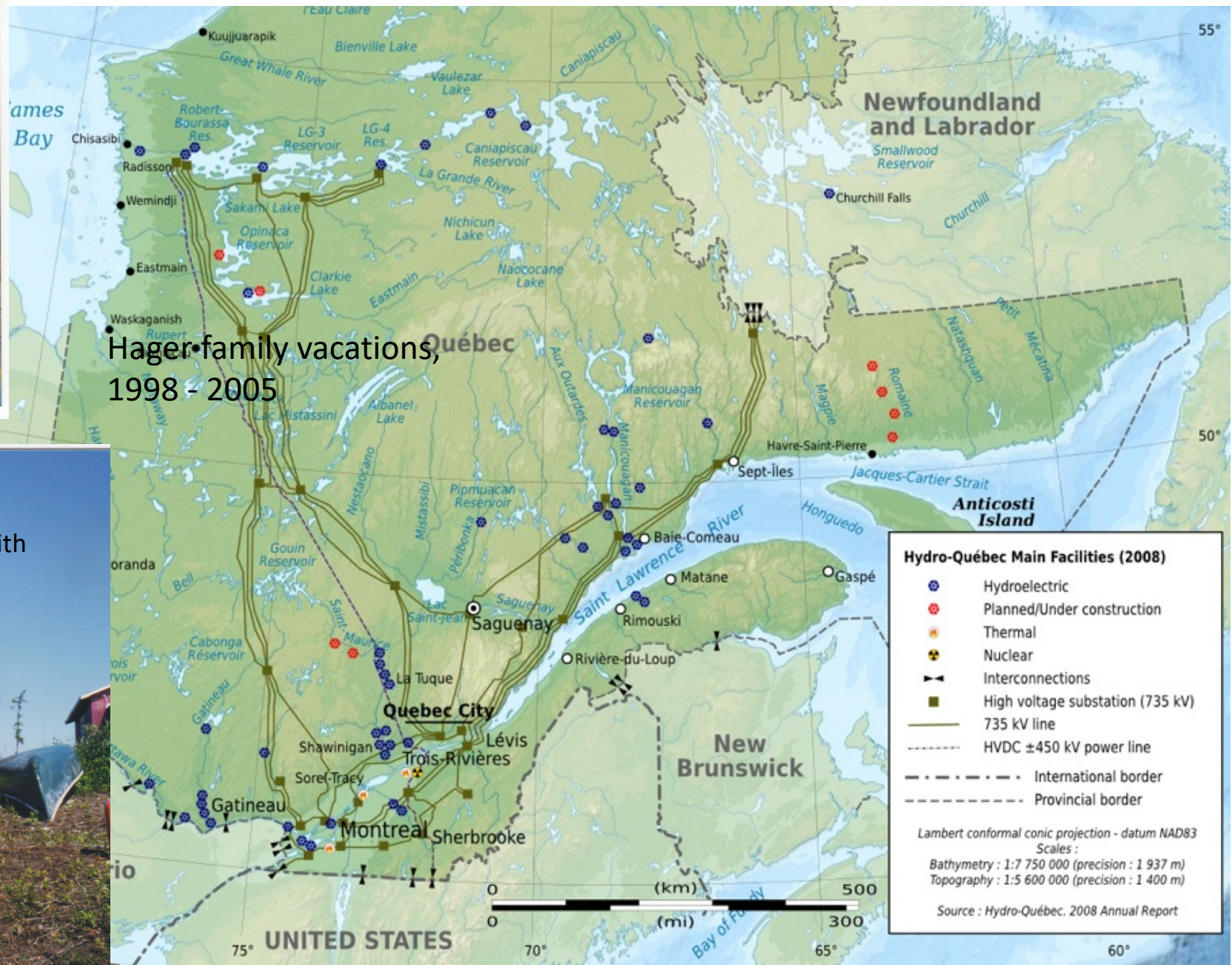
Bradford H. Hager

Cecil and Ida Green Professor of Earth Sciences

Department of Earth, Atmospheric and Planetary Sciences

MIT

Sierra Club, November 21, 2019



Hager family vacations,
1998 - 2005

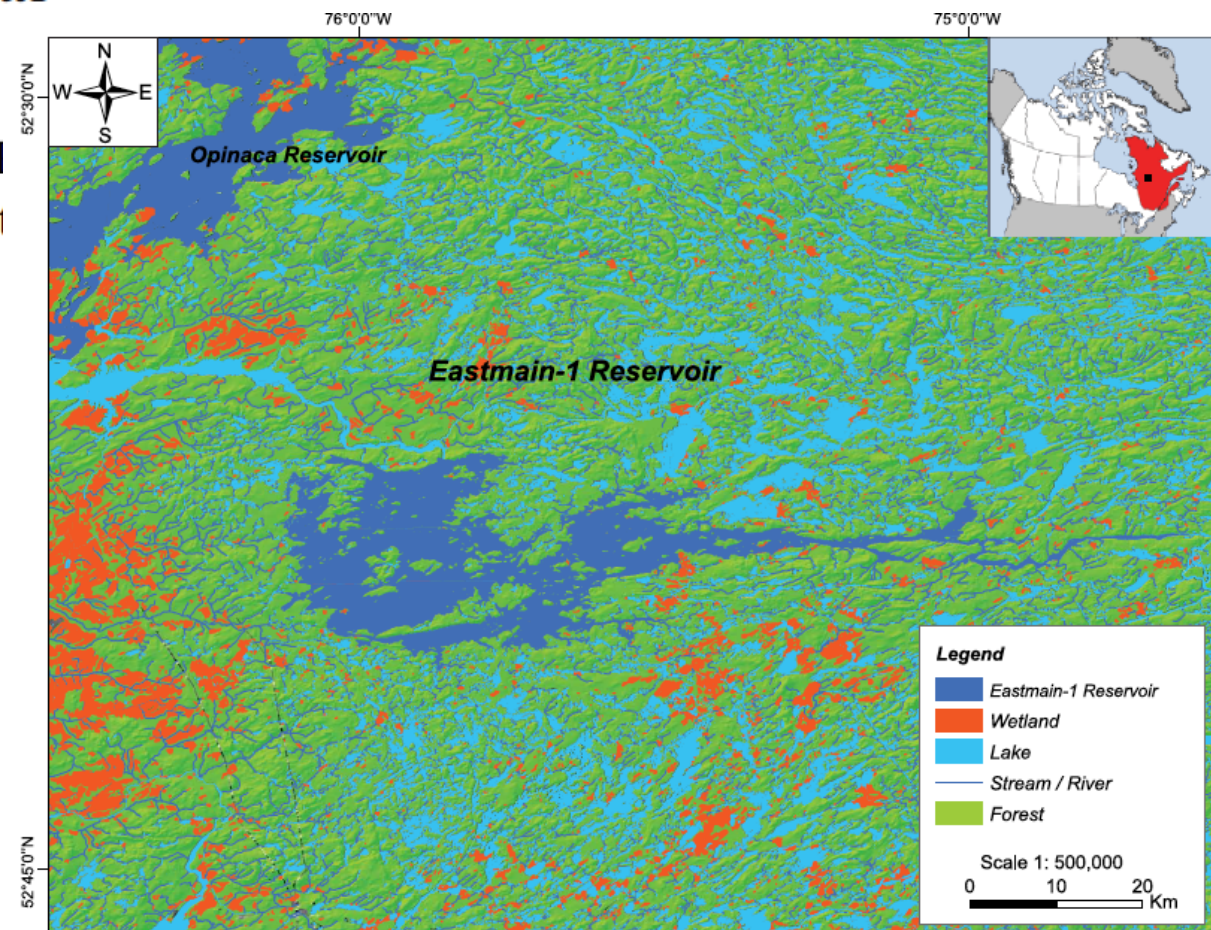
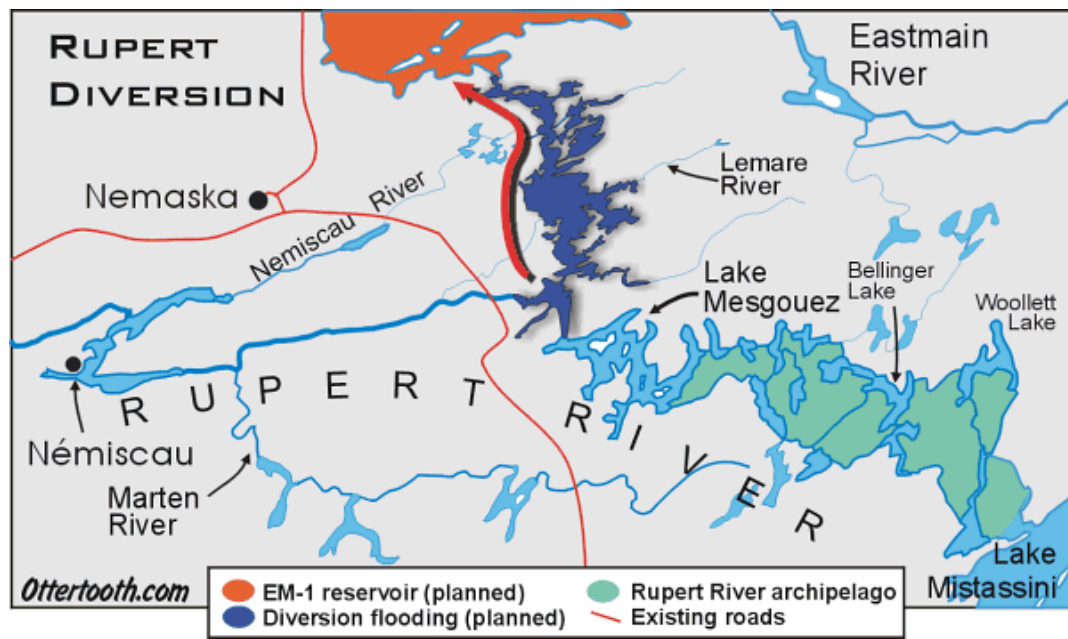


Case study: Hydro-Quebec

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 26, GB2016, doi:10.1029/2011GB004187, 2012

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 Pelletier,⁶ Nigel T. Roulet,^{6,7} Ian B. Strachan,⁴ and Alain Tremblay⁸



Science to take home

- Climate impact ($\text{gCO}_2\text{e}/\text{kWh}$) 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
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 - Age: New reservoirs emit $\sim 5 \times \text{CO}_2$ of old reservoirs (initial rapid decay & disturbance)
 - Temperature (forest density, methane production)
 - Low T is better
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- Need to evaluate specific reservoirs in making decisions
 - Power from new Hydro Québec reservoirs emits \gg 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!

Recommended refereed articles: measured footprints

nature
geoscience

LETTERS

PUBLISHED ONLINE: 31 JULY 2011 | DOI: 10.1038/NCEO1211

Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude

Data from 85 reservoirs

Nathan Barros¹, Jonathan J. Cole², Lars J. Tranvik³, Yves T. Prairie⁴, David Bastviken⁵,
Vera L. M. Huszar⁶, Paul del Giorgio⁴ and Fábio Roland^{1*}

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 26, GB2016, doi:10.1029/2011GB004187, 2012

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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Nigel T. Roulet,^{6,7} Ian B. Strachan,⁴ and Alain Tremblay⁸

Recommended refereed articles – global statistical models



RESEARCH ARTICLE

Hydropower's Biogenic Carbon Footprint

Laura Scherer*, Stephan Pfister

Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland

Citation: Scherer L, Pfister S (2016) Hydropower's Biogenic Carbon Footprint. PLoS ONE 11(9): e0161947. doi:10.1371/journal.pone.0161947

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



Cite This: *Environ. Sci. Technol.* XXXX, XXX, XXX–XXX

Article

pubs.acs.org/est

October, 2019

Climate Impacts of Hydropower: Enormous Differences among Facilities and over Time

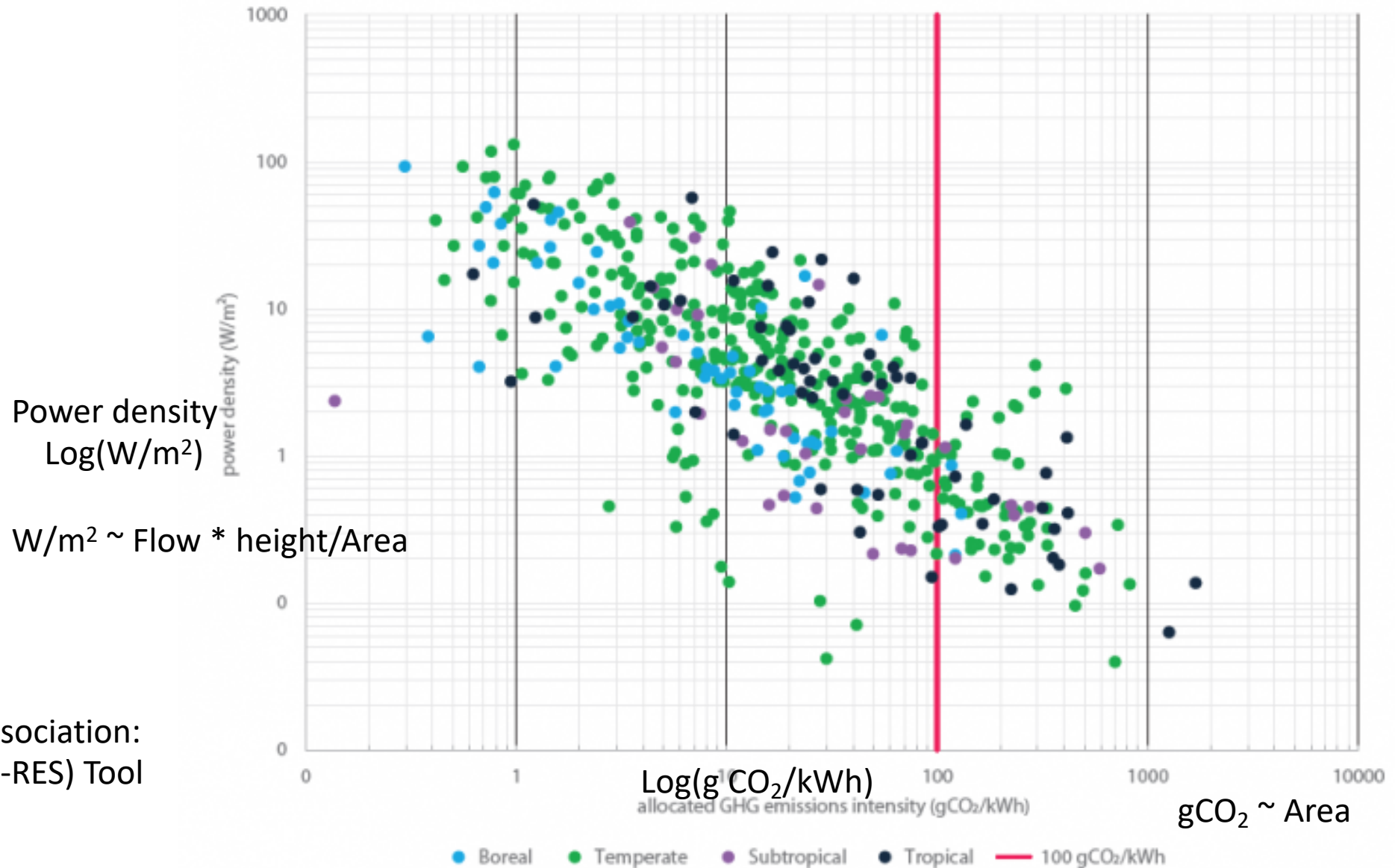
Ilissa B. Ocko*^{id} and Steven P. Hamburg

Environmental Defense Fund, New York, New York 10010 United States

Further analysis of Scherer & 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

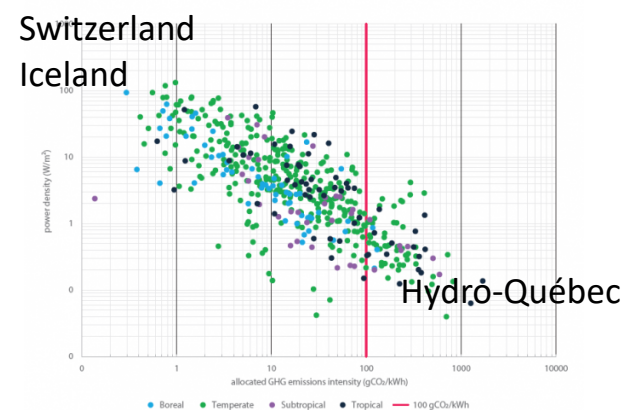
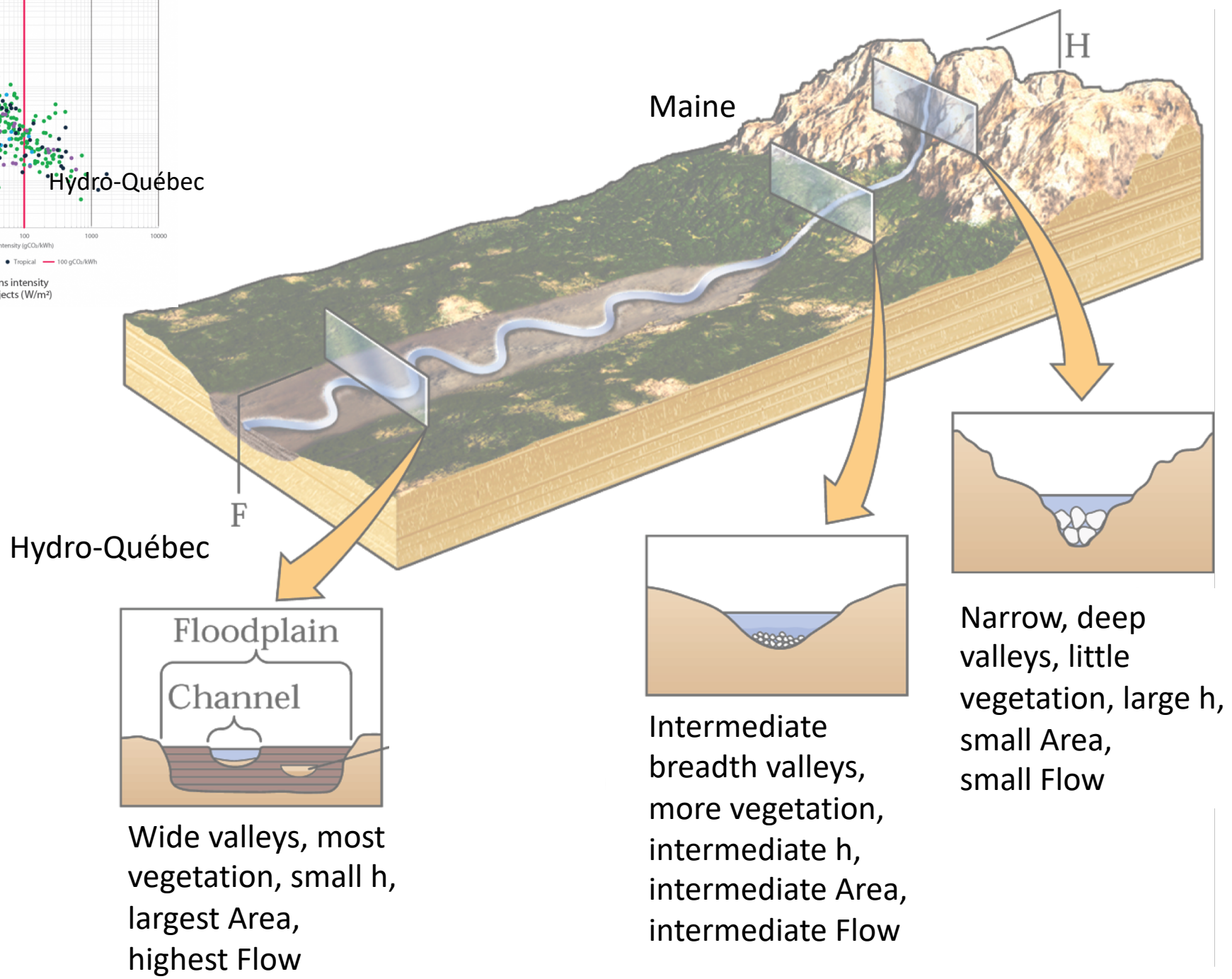
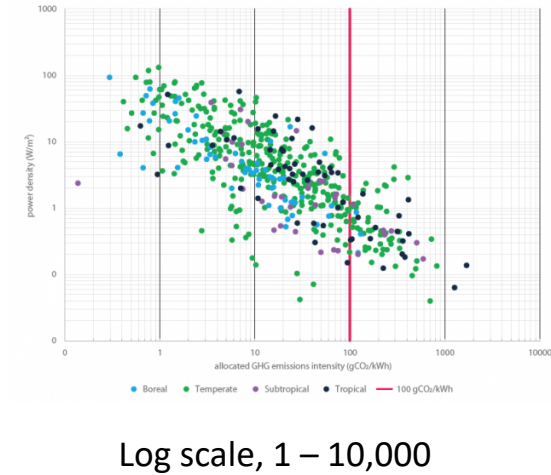
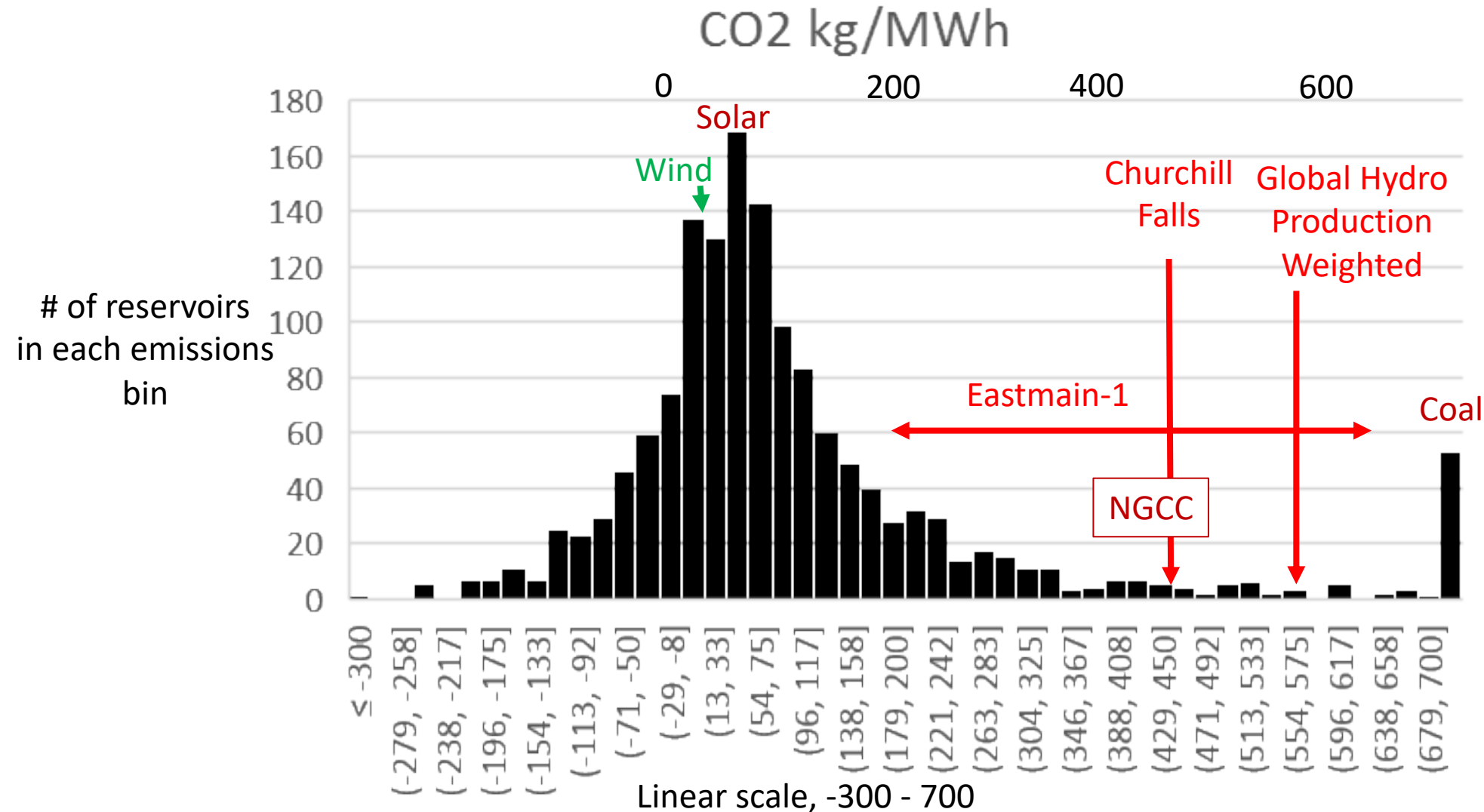


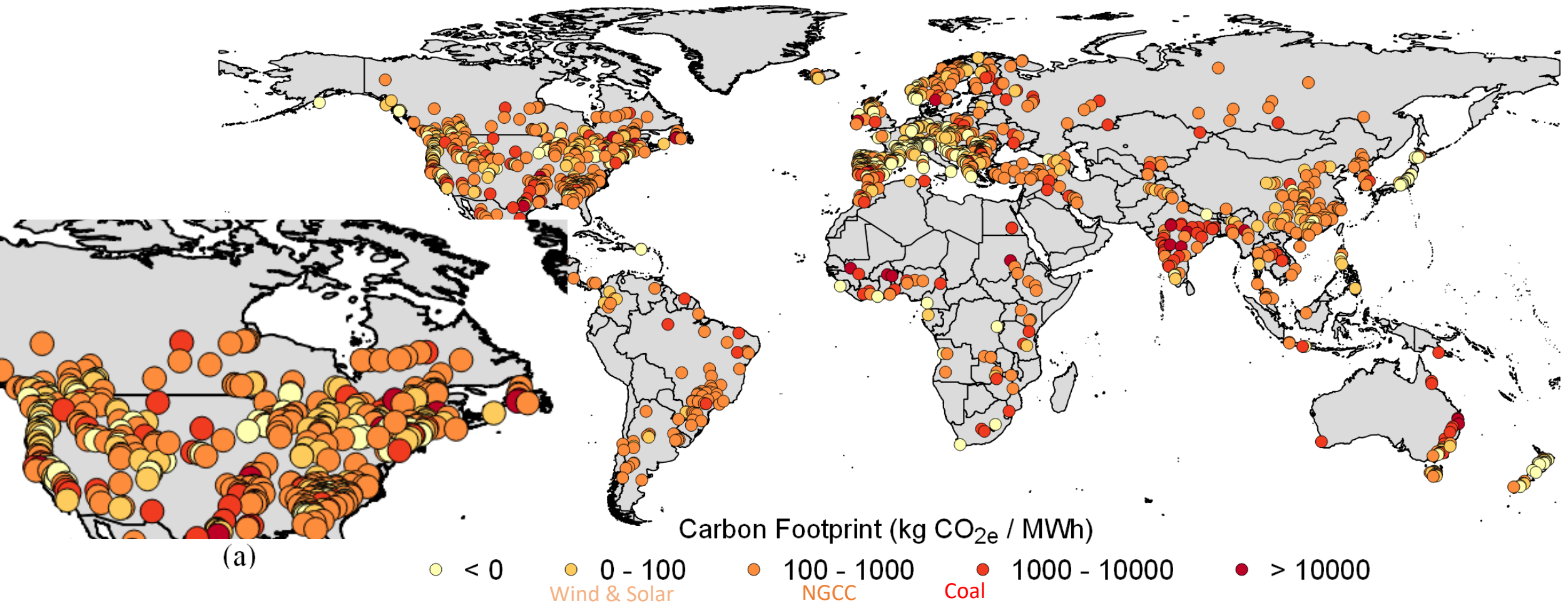
Figure 2: Relationship between GHG emissions intensity ($gCO_2\text{-eq}/kWh$) and the power density of projects (W/m^2)



Per facility estimates from EDF study comparable



Estimated CO₂ footprint (Scherer & Pfister, 2016)



Estimated Methane footprint (Scherer & Pfister, 2016)

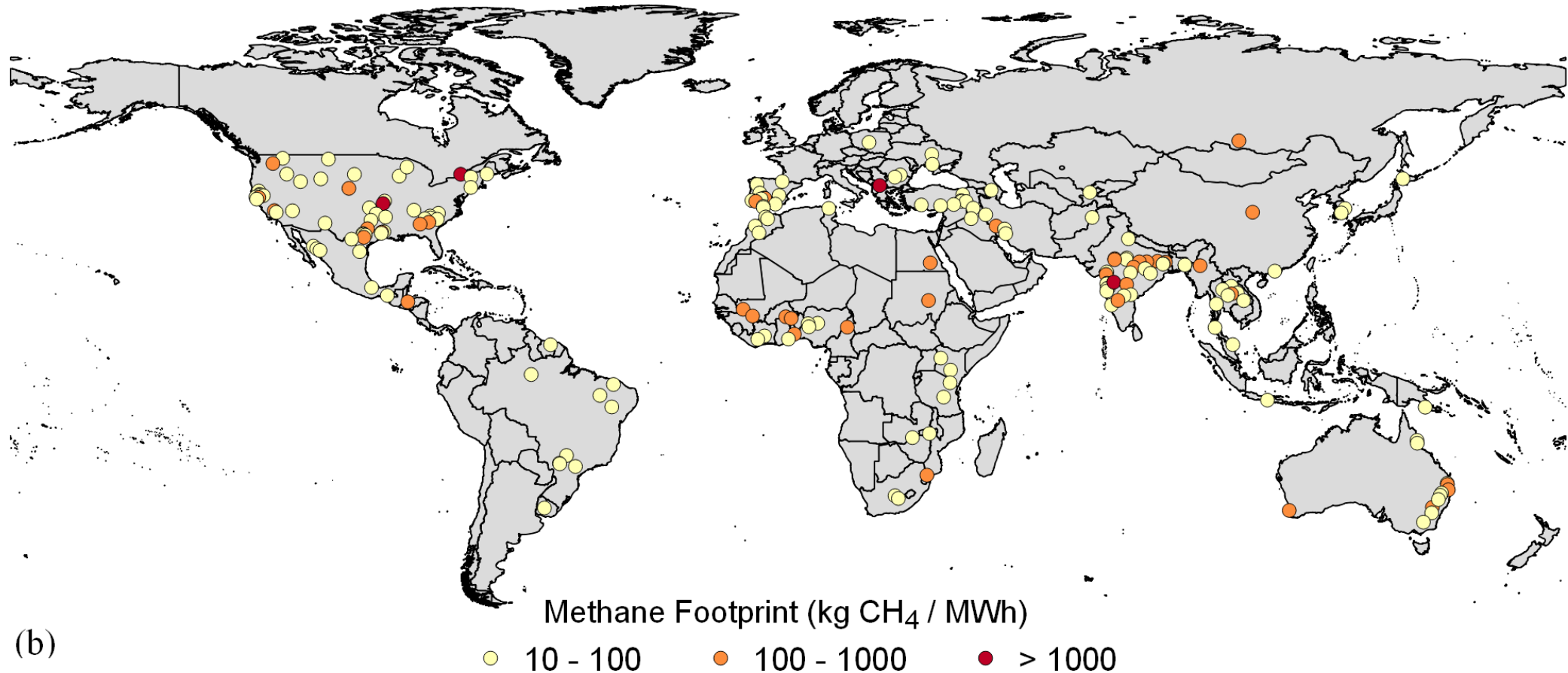
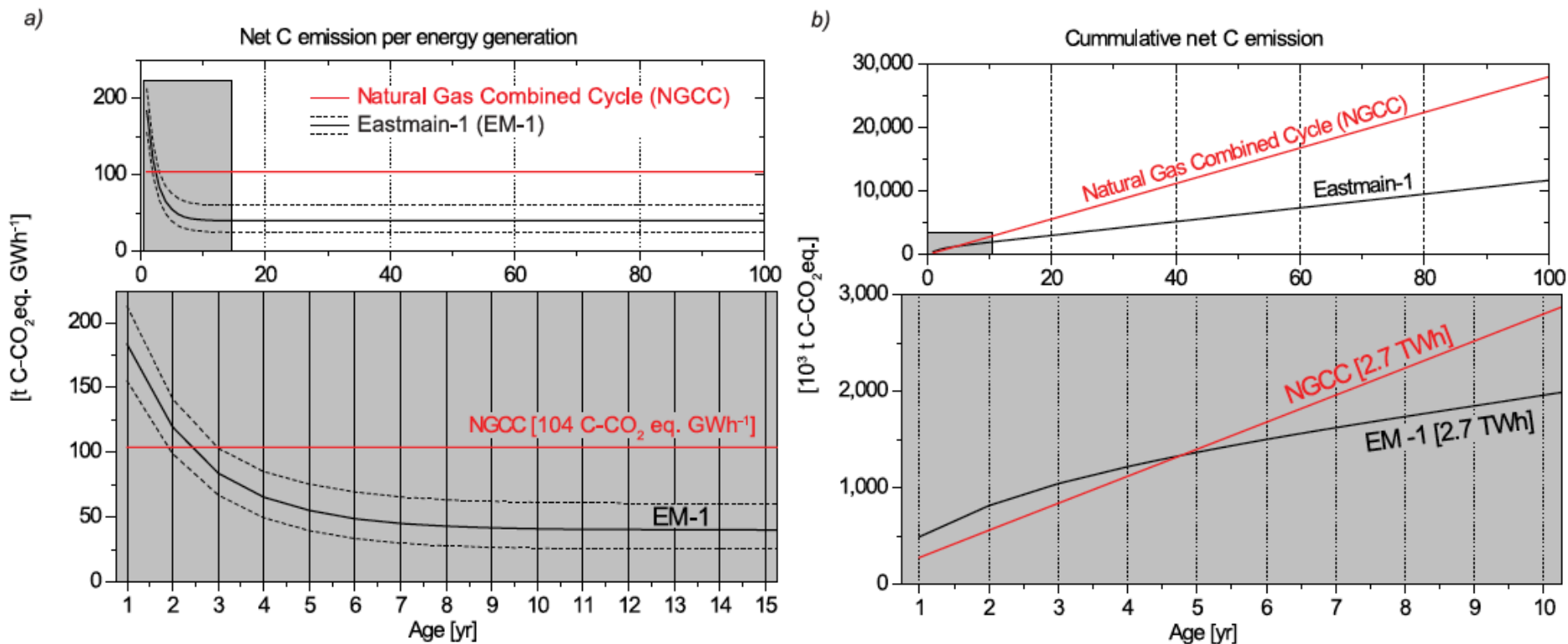


Fig 1. Carbon footprints of hydropower plants across the world (a) and hydropower plants with high methane emissions (≥ 10 kg CH₄/MWh) and a large share of methane emissions ($\geq 50\%$ of the carbon footprint) (b). Country boundaries are obtained from Natural Earth (<http://www.naturalearthdata.com/>).

The net carbon footprint of a newly created boreal hydroelectric reservoir

Cristian R. Teodoru,^{1,2} Julie Bastien,³ Marie-Claude Bonneville,⁴ Paul A. del Giorgio,¹ Maud Demarty,³ Michelle Gameau,⁵ Jean-Francois Hélie,⁵ Luc Pelletier,^{4,5} Yves T. Prairie,¹ Nigel T. Roulet,^{6,7} Ian B. Strachan,⁴ and Alain Tremblay⁸



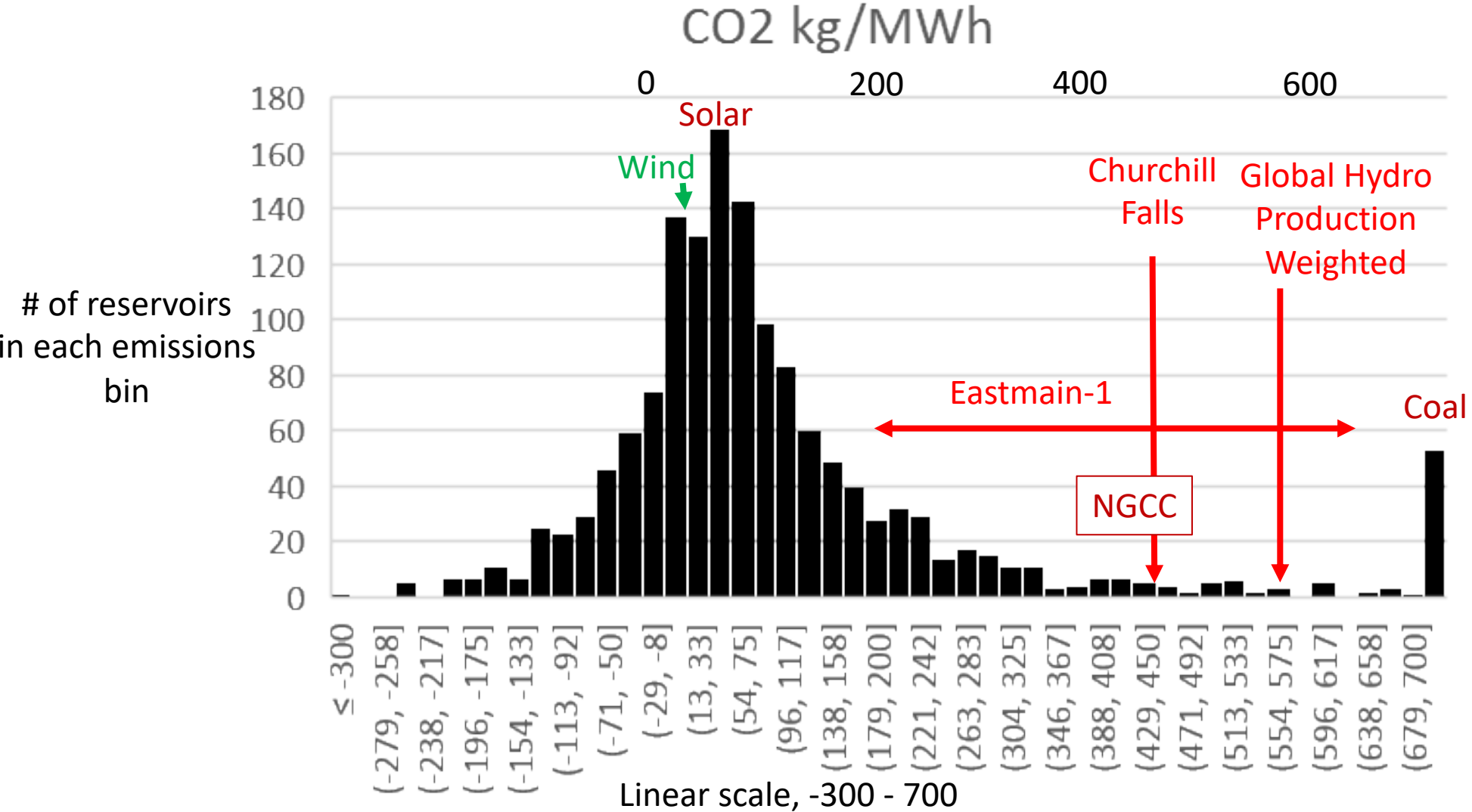
Initially, Hydro in boreal forest ~ 2.5 global warming of Natural Gas (without CCS)

Long-term, Hydro in boreal forest $\sim 1/2$ global warming of Natural Gas (without CCS)

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Thank you! – Any questions?



CO2 Footprint Comparison (Scherer & Pfister, 2016)

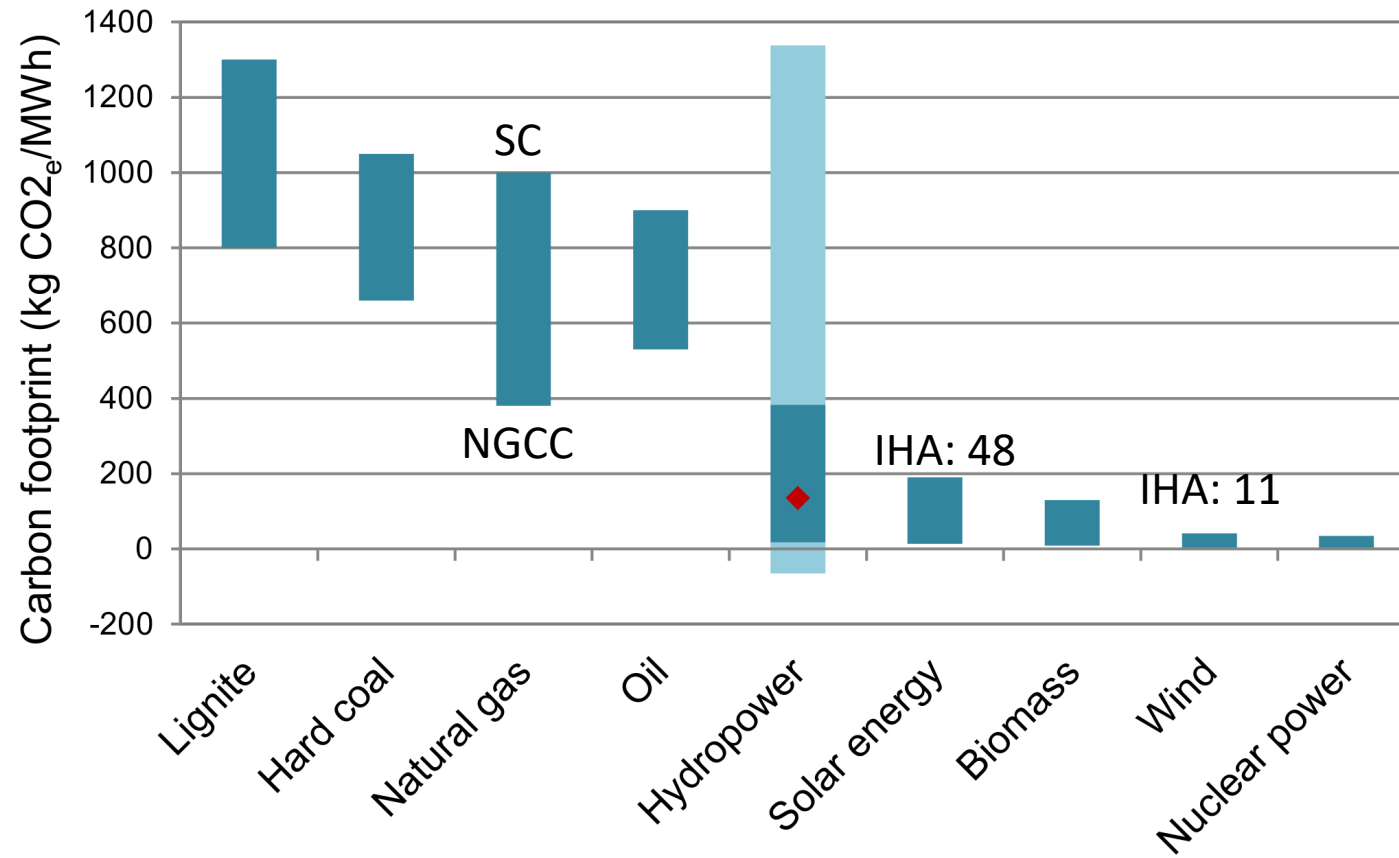


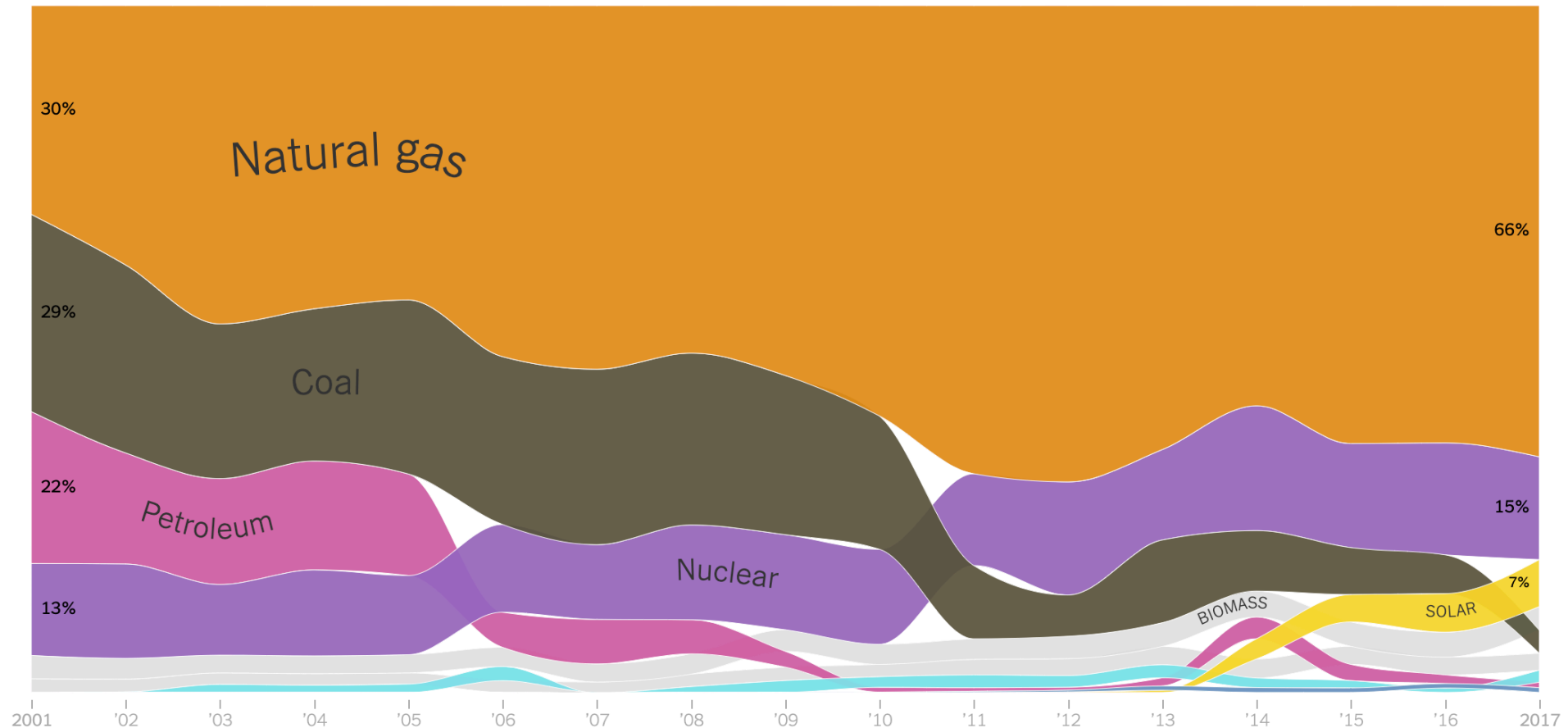
Fig 2. Carbon footprints of various energy sources (based on [32] for all energy sources other than hydropower). The lower and upper value of the dark bar for hydropower are the lower and upper quartiles for the corrected model average (Model A_c). The light extensions represent the 10 and 90% quantiles and the red diamond marks the median.

MA electric power generation mix

How **Massachusetts** generated electricity from 2001 to 2017



Percentage of power produced from each energy source <https://www.nytimes.com/interactive/2018/12/24/climate/how-electricity-generation-changed-in-your-state.html>



New Brunswick electric power generation mix

