Department of Energy

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208-3621

In reply refer to: FOIA #2024-00643-F

October 2, 2025

SENT VIA EMAIL ONLY TO: miles@columbiariverkeeper.org

Miles Johnson, Legal Director
Columbia Riverkeeper
P.O. Box 950
Hood River, OR 97031

Dear Mr. Johnson,
This communication is the Bonneville Power Administration's (BPA) first partial response to your request for agency records made under the Freedom of Information Act, 5 U.S.C. § 552 ("FOIA"). Your FOIA request was received on December 13, 2023, and formally acknowledged on January 4, 2024.

Request
"…all records within BPA's control related to emissions of methane or carbon dioxide from reservoirs. The date range for this request is from January 1, 2010, to the date when BPA receives this request."

Response
BPA has searched for and gathered 1,922 pages of responsive agency records from the agency's Outlook email system and knowledgeable subject matter experts in the agency's Environmental Planning & Analysis, Environmental Fish & Wildlife, Energy Efficiency, and Intergovernmental Affairs offices. This collection includes 1,576 pages that comprise the "Columbia River System Operations Environmental Impact Statement – Chapter 3" that is publicly available at this link: https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/14959. Due to the size of the document and fact it is already available publicly it is not included in the records that accompany this communication. There are 346 pages of records that accompany this communication, with the following redactions applied:

- 82 redactions applied under 5 U.S.C. § 552(b)(5) (Exemption 5)
- 14 redactions applied under 5 U.S.C. § 552(b)(6) (Exemption 6)

Explanation of Exemptions
The FOIA generally requires the release of all agency records upon request. However, the FOIA permits or requires withholding certain limited information that falls under one or more of nine statutory exemptions (5 U.S.C. §§ 552(b)(1-9)). Further, section (b) of the FOIA, which contains

the FOIA's nine statutory exemptions, also directs agencies to publicly release any reasonably segregable, non-exempt information that is contained in those records.

Exemption 5
Exemption 5 protects "inter-agency or intra-agency memorandums or letters which would not be available by law to a party other than an agency in litigation with the agency" (5 U.S.C. § 552(b)(5)). In plain language, the exemption protects privileged records.

The deliberative process privilege protects records showing the deliberative or decision-making processes of government agencies. Records protectable under this privilege must be both pre-decisional and deliberative. A record is pre-decisional if it is generated before the adoption of an agency policy. A record is deliberative if it reflects the give-and-take of the consultative process, either by assessing the merits of a particular viewpoint, or by articulating the process used by the agency to formulate a decision. Here, BPA relies on Exemption 5 to protect internal discussions related to Columbia River System operations, how to respond to a draft report, and staff notes taken for internal discussion purposes prior to a final decision, the release of which would cause public confusion. Records protected by Exemption 5 may be discretionarily released. BPA has considered and declined a discretionary release of some pre-decisional and deliberative information in the responsive records set because disclosure of that information would harm the interests and protections encouraged by Exemption 5.

The attorney work-product privilege protects agency records prepared in anticipation of foreseeable litigation, including civil, criminal, and administrative proceedings. In this case, BPA asserts Exemption 5 to protect documents created in anticipation of litigation related to Columbia River System operations and related injunction motions communications.

The attorney-client privilege protects confidential communications between an attorney and a client relating to a legal matter for which the client has sought professional advice. The privilege encompasses facts provided by the client and opinions provided by the attorney. In this case, BPA asserts Exemption 5 to protect communications between attorney-advisors within BPA's Office of General Counsel and with the program offices they advise, related to Columbia River System operations.

Exemption 6
Exemption 6 serves to protect Personally Identifiable Information (PII) contained in agency records when no overriding public interest in the information exists. BPA does not find an overriding public interest in the release of the information redacted under Exemption 6—specifically, leave plans, personal cell phone numbers, conference call passcodes, and Webex passcodes. This information sheds no light on the executive functions of the agency and BPA finds no overriding public interest in its release. BPA cannot waive these redactions, as the protections afforded by Exemption 6 belong to individuals and not to the agency.

Lastly, as required by 5 U.S.C. § 552(a)(8)(A), information has been withheld only in instances where, (1) disclosure is prohibited by statute, or (2) BPA foresees that disclosure would harm an interest protected by the exemption cited for the record. When full disclosure of a record is not possible, the FOIA statute further requires that BPA take reasonable steps to segregate and release nonexempt information. The agency has determined that in certain instances partial disclosure is possible and has accordingly segregated the records into exempt and non-exempt portions.

Fees

There are no fees associated with processing your FOIA request.

Certification

Pursuant to 10 C.F.R. § 1004.7(b)(2), I am the individual responsible for the search and information released above. Your FOIA request BPA-2024-00643-F is now closed with responsive agency information provided.

Appeal

Note that the records release certified above is final. Pursuant to 10 C.F.R. § 1004.8, you may appeal the adequacy of the records search, and the completeness of this final records release, within 90 calendar days from the date of this communication. Appeals should be addressed to:

Director, Office of Hearings and Appeals
HG-1, L'Enfant Plaza
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585-1615

The written appeal, including the envelope, must clearly indicate that a FOIA appeal is being made. You may also submit your appeal by e-mail to OHA.filings@hq.doe.gov, including the phrase "Freedom of Information Appeal" in the subject line. (The Office of Hearings and Appeals prefers to receive appeals by email.) The appeal must contain all the elements required by 10 C.F.R. § 1004.8, including a copy of the determination letter. Thereafter, judicial review will be available to you in the Federal District Court either (1) in the district where you reside, (2) where you have your principal place of business, (3) where DOE's records are situated, or (4) in the District of Columbia.

Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire about the FOIA mediation services they offer. The contact information for OGIS is as follows:

Office of Government Information Services
National Archives and Records Administration
8601 Adelphi Road-OGIS
College Park, Maryland 20740-6001
E-mail: ogis@nara.gov
Phone: 202-741-5770
Toll-free: 1-877-684-6448
Fax: 202-741-5769

Questions about this communication or the status of your FOIA request may be directed to James King, FOIA Public Liaison, at jjking@bpa.gov or 503-230-7621. Questions may also be directed to E. Thanh Knudson, Case Coordinator (ACS Staffing Group), at etknudson@bpa.gov or 503-230-5221.

Sincerely,

Candice D. Palen
Freedom of Information/Privacy Act Officer

Responsive agency records accompany this communication.

From:	Grimm,Lydia T (BPA) - A-7
Sent:	Monday, February 6, 2017 12:27 PM
To:	Francis,Rose (BPA) - LN-7; Connolly,Kieran P (BPA) - PG-5; Senters,Anne E (BPA) - LN-7; Sweet,Jason C (BPA) - PGB-5
Cc:	Olive,J Courtney (BPA) - LP-7
Subject:	RE: reference methane study?

(b)(5) [redacted]

From: Francis,Rose (BPA) - LN-7
Sent: Monday, February 06, 2017 11:55 AM
To: Connolly,Kieran P (BPA) - PG-5; Grimm,Lydia T (BPA) - A-7; Senters,Anne E (BPA) - LN-7; Sweet,Jason C (BPA) - PGB-5
Cc: Olive,J Courtney (BPA) - LP-7
Subject: reference methane study?

Confidential attorney client communication/attorney work product; FOIA-exempt

(b)(5) [redacted]

Rose Francis
Office of General Counsel
Bonneville Power Administration
503-230-4967 | rmfrancis@bpa.gov
http://www.bpa.gov

From: Doumbia,Julie A (BPA) - PGB-5
Sent: Sunday, February 05, 2017 8:50 PM
To: Francis,Rose (BPA) - LN-7; Sweet,Jason C (BPA) - PGB-5
Subject: RE: methane study for Kieran dec

Confidential; FOIA-exempt

(b)(5)

[redacted]

From: Francis,Rose (BPA) - LN-7
Sent: Sunday, February 05, 2017 10:53 AM
To: Sweet,Jason C (BPA) - PGB-5; Doumbia,Julie A (BPA) - PGB-5
Subject: methane study for Kieran dec

Confidential; FOIA-exempt

(b)(5)

[redacted]

Rose Francis
Office of General Counsel
Bonneville Power Administration
503-230-4967 | rmfrancis@bpa.gov
http://www.bpa.gov

From: Doumbia,Julie A (BPA) - PGB-5
Sent: Friday, October 07, 2016 3:50 PM
To: Francis,Rose (BPA) - LN-7
Cc: Leary,Jill C (BPA) - LN-7; Koehler,Birgit G (BPA) - A-7; Sweet,Jason C (BPA) - PGB-5; Johnson,Kimberly O (BPA) - PGA-6; McDonald,Katie M (BPA) - EWP-4
Subject: RE: new study

Quick update, now that the article is out... also the article, and the article supplementary information.

(b)(5)

[redacted]

From: Doumbia,Julie A (BPA) - PGB-5
Sent: Thursday, October 06, 2016 12:04 PM
To: Francis,Rose (BPA) - LN-7
Cc: Leary,Jill C (BPA) - LN-7; Koehler,Birgit G (BPA) - A-7; Sweet,Jason C (BPA) - PGB-5 (jcsweet@bpa.gov); Johnson,Kimberly O (BPA) - PGA-6; McDonald,Katie M (BPA) - EWP-4; Lut,Agnes (BPA) - BDP-3
Subject: RE: new study

Confidential; FOIA-exempt

Hello Rose,

(b)(5)

[redacted]

Julie

From: Francis,Rose (BPA) - LN-7
Sent: Thursday, October 06, 2016 10:39 AM
To: Doumbia,Julie A (BPA) - PGB-5
Subject: new study

Confidential; FOIA-exempt

Hi Julie,

(b)(5)
[redacted]

Rose Francis
Office of General Counsel
Bonneville Power Administration
503-230-4967 | rmfrancis@bpa.gov
http://www.bpa.gov

From: Francis,Rose (BPA) - LN-7
Sent: Wednesday, May 23, 2018 3:16 PM
To: Olive,J Courtney (BPA) - LP-7; Kaseweter,Alisa D (BPA) - DI-7; Leary,Jill C (BPA) - LN-7
Subject: RE: carbon free vs carbon neutral (again)

Confidential; FOIA-exempt

(b)(5) [redacted]

Rose Francis
Office of General Counsel
Bonneville Power Administration
503-230-4967 | rmfrancis@bpa.gov
http://www.bpa.gov

From: Olive,J Courtney (BPA) - LP-7
Sent: Wednesday, May 23, 2018 2:10 PM
To: Kaseweter,Alisa D (BPA) - DI-7; Leary,Jill C (BPA) - LN-7; Francis,Rose (BPA) - LN-7
Subject: RE: carbon free vs carbon neutral (again)

Thanks Alisa for bringing us all up to speed on the reservoir issue (I learned a lot!).

Jill, everything you've said below sounds spot on. As long as y'all are looped in with Alisa you're in exactly the right hands.

Best,
Courtney

J. Courtney Olive
Attorney || LP-7
Bonneville Power Administration
905 NE 11th Avenue
Portland, OR 97208
503.230.5085

From: Kaseweter,Alisa D (BPA) - DI-7
Sent: Wednesday, May 23, 2018 2:02 PM
To: Leary,Jill C (BPA) - LN-7; Olive,J Courtney (BPA) - LP-7; Francis,Rose (BPA) - LN-7
Subject: RE: carbon free vs carbon neutral (again)

I would just add a couple things on reservoir emissions as this tends to come up every now and then. In response to a 2016 WSU study, the Corps released a memo (attached) concluding that the CRS projects generally do not release methane gas due to the high oxygen levels, greater levels of circulation, and relatively low organic matter in the system. In 2017, the Council also made a statement concluding that it was unlikely the CRS projects emit large levels of methane gas (https://www.nwcouncil.org/sites/default/files/2017-6_2.pdf at p.28). I would cite these if needed.

However, I do note there are other studies out there that have measured methane emissions from reservoirs under certain conditions and times of year (including a PNNL study that looked at Priest Rapids and Lower Monumental) so I would caution against saying it is settled science.

From: Leary,Jill C (BPA) - LN-7
Sent: Wednesday, May 23, 2018 1:33 PM
To: Olive,J Courtney (BPA) - LP-7; Francis,Rose (BPA) - LN-7
Cc: Kaseweter,Alisa D (BPA) - DI-7
Subject: RE: carbon free vs carbon neutral (again)

(b) (5)
[redacted]

From: Olive,J Courtney (BPA) - LP-7
Sent: Tuesday, May 22, 2018 2:25 PM
To: Leary,Jill C (BPA) - LN-7; Francis,Rose (BPA) - LN-7
Subject: RE: carbon free vs carbon neutral (again)

(b) (5)
[redacted]

Thanks,
Courtney

J. Courtney Olive
Attorney || LP-7
Bonneville Power Administration
905 NE 11th Avenue
Portland, OR 97208
503.230.5085

From: Leary,Jill C (BPA) - LN-7
Sent: Tuesday, May 22, 2018 11:32 AM
To: Francis,Rose (BPA) - LN-7; Olive,J Courtney (BPA) - LP-7
Subject: RE: carbon free vs carbon neutral (again)

(b) (5) [redacted]

From: Francis,Rose (BPA) - LN-7
Sent: Tuesday, May 22, 2018 11:06 AM
To: Olive,J Courtney (BPA) - LP-7
Cc: Leary,Jill C (BPA) - LN-7
Subject: RE: carbon free vs carbon neutral (again)

Great, thanks.

From: Olive,J Courtney (BPA) - LP-7
Sent: Tuesday, May 22, 2018 10:59 AM
To: Francis,Rose (BPA) - LN-7
Cc: Leary,Jill C (BPA) - LN-7
Subject: RE: carbon free vs carbon neutral (again)

(b) (5) [redacted]

Best,
Courtney

J. Courtney Olive
Attorney || LP-7
Bonneville Power Administration
905 NE 11th Avenue
Portland, OR 97208
503.230.5085

From: Francis,Rose (BPA) - LN-7
Sent: Monday, May 21, 2018 5:21 PM
To: Olive,J Courtney (BPA) - LP-7
Cc: Leary,Jill C (BPA) - LN-7
Subject: carbon free vs carbon neutral (again)

Hi Courtney,

(b)(5) [redacted]

Rose Francis
Office of General Counsel
Bonneville Power Administration
503-230-4967 | rmfrancis@bpa.gov
http://www.bpa.gov

From:	Reller,Mark D (BPA) - DIR-MSGL
Sent:	Monday, April 15, 2019 2:17 PM
To:	Warner,Joshua P (BPA) - DIR-7; Mainzer,Elliot E (BPA) - A-7; James,Daniel M (BPA) - D-7; Armentrout,Scott G (BPA) - E-4; Welch,Dorothy W (BPA) - E-4; Zelinsky,Benjamin D (BPA) - E-4; Jule,Kristen R (BPA) - EWP-4; Key,Philip S (BPA) - LN-7; Cogswell,Peter (BPA) - DI-7; Pruder Scruggs,Kathryn M (BPA) - E-4; Bettin,Scott W (BPA) - EWP-4; Simms,Scott R (BPA) - DK-7; Hansen,Michael S (BPA) - DKP-7; Wilson,David B (BPA) - DKP-7; Carnes,Karrie L (BPA) - DKP-7; Helms,Michelle R (BPA) - DKP-7; Helwig,Heidi Y (BPA) - DKE-7; ADL_DI_ALL; Godwin,Mary E (BPA) - LN-7
Cc:	Ball,Crystal A (BPA) - DIR-7; Kavanagh,Maureen A (BPA) - EWP-4
Subject:	RE: Artifishal Screening
Attachments:	PNNL-22297_Greenhouse_gases_Arntzen_etal_2013.pdf

Josh
I wanted to respond to the comment in your email regarding NW reservoirs and greenhouse gases. I have attached the most recent report I am aware of that sampled reservoirs in the NW for GHG. That report is attached and key quotes are below.
Mark

"The objectives of PNNL's study were to contribute to the Department of Energy's national effort by sampling Northwest reservoirs in order to 1) determine whether CO_2 and CH_4 emissions varied among different environments within representative hydroelectric dam complexes on the Columbia and Snake Rivers in Washington and 2) estimate GHG fluxes from those environments while placing them in context relative to GHG emissions from other temperate hydroelectric dam complexes."

"The surface fluxes of methane we report here are small compared to those observed by others in similar temperate reservoirs."

"The reservoirs we sampled were sinks for CO_2, with mean flux rates ranging from –48.5 mg m^{-2} d^{-1} to –262 mg m^{-2} d^{-1}."

From: Warner,Joshua P (BPA) - DIR-7
Sent: Monday, April 15, 2019 2:24 PM
To: Mainzer,Elliot E (BPA) - A-7; James,Daniel M (BPA) - D-7; Armentrout,Scott G (BPA) - E-4; Welch,Dorothy W (BPA) - E-4; Zelinsky,Benjamin D (BPA) - E-4; Jule,Kristen R (BPA) - EWP-4; Key,Philip S (BPA) - LN-7; Cogswell,Peter (BPA) - DI-7; Pruder Scruggs,Kathryn M (BPA) - E-4; Bettin,Scott W (BPA) - EWP-4; Simms,Scott R (BPA) - DK-7; Hansen,Michael S (BPA) - DKP-7; Wilson,David B (BPA) - DKP-7; Carnes,Karrie L (BPA) - DKP-7; Helms,Michelle R (BPA) - DKP-7; Helwig,Heidi Y (BPA) - DKE-7; ADL_DI_ALL; Godwin,Mary E (BPA) - LN-7
Cc: Ball,Crystal A (BPA) - DIR-7; Kavanagh,Maureen A (BPA) - EWP-4
Subject: Artifishal Screening

Crystal, Maureen and I went to a screening for *Artifishal*, the new Patagonia documentary about hatcheries and aquaculture. The screening was the North American premier and was viewed at the Patagonia store on Burnside by about 250-300 people. Store employees had to turn people away when the store filled to capacity. The film is having screening in cities across the country. There will likely be a lot of interest in this film.

BPA is not the focus of this film. It is well done and dramatic. It covers hatcheries in California and the NW. It includes historical footage from the 1800s. It tries to explain the human impact on salmon and the human choice to pursue hatchery supplementation, but it asserts hatcheries are really bad for wild fish and the prey and cultures that rely on them. There is a quick scene outside a hatchery that shows a number of state and federal agency logos, including BPA's. The film mentions BPA's F&W program and states that 40% of the $15+ billion invested in the program was spent on hatcheries. There is also a connection between orca and chinook with the idea that more hatchery fish will be bad for the orca mainly because hatchery salmon are smaller than wild salmon.

For a tribal perspective they used a storyline of the Yurok on the Klamath. That was about dam removal and the desire by at least some tribal members to not use hatcheries to supplement salmon numbers once the dams are removed.

The Patagonia ambassador who is featured in the film and who is largely responsible for convincing Patagonia to produce this film took questions from the audience when the screening was over. In response to a question about hydropower, he said hydropower is clean but reservoirs behind dams create GHGs.

The Native Fish Society and Wild Fish Conservancy tabled at the event. Let me know if you have any questions.

Thanks,
Josh

Josh Warner

Constituent Account Executive, Public Interest Organizations
Bonneville Power Administration
905 N.E. 11th Ave., Portland, OR 97232
(503) 230-5857
jpwarner@bpa.gov

PNNL-22297

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Evaluating greenhouse gas emissions from hydropower complexes on large rivers in Eastern Washington

FINAL REPORT

EV Arntzen
BL Miller
AC O'Toole
S Niehus
M Richmond

March 2013

Pacific Northwest
NATIONAL LABORATORY

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PNNL-22297

Evaluating greenhouse gas emissions from hydropower complexes on large rivers in Eastern Washington

EV Arntzen
BL Miller
AC O'Toole
S Niehus
M Richmond

March 2013

Prepared for
U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Abstract

Inland water bodies, such as freshwater lakes, are known to be net emitters of carbon dioxide (CO_2) and methane (CH_4). In recent years, significant greenhouse gas (GHG) emissions from tropical, boreal, and mid-latitude reservoirs have also been reported. At a time when hydropower is increasing worldwide, better understanding of seasonal and regional variation in GHG emissions is needed in order to develop a predictive understanding of such fluxes within man-made impoundments. We examined reservoir impoundments created by power-producing dam complexes within xeric temperate locations in the northwestern United States. Sampling environments on the Snake (Lower Monumental Dam Complex) and Columbia Rivers (Priest Rapids Dam Complex) included tributary, mainstem, embayment, forebay, and tailrace areas during winter and summer 2012. At each sampling location, GHG measurements included multiple exchange pathways: surface gas flux, degassing as water passed through dams during power generation, ebullition within littoral embayments, and direct sampling of hyporheic pore-water. Measurements were also carried out in a free-flowing reach of the Columbia River (the Hanford Reach) to estimate unaltered conditions. Surface flux resulted in very low emissions, with reservoirs acting as a sink for CO_2 (up to -262 mg m^{-2} d^{-1}, which is within the range previously reported for similarly located reservoirs). Surface flux of CH_4 remained below 1 mg CH_4 $m^{-2}d^{-1}$, a value well below fluxes reported previously for temperate reservoirs. Water passing through hydroelectric projects acted as a sink for CO_2 during winter and a small source during summer, with mean degassing fluxes of -117 and 4.5 t CO_2 d^{-1}, respectively. Degassing of CH_4 was minimal, with mean fluxes of 3.1×10^{-6} and -5.6×10^{-4} t CH_4 d^{-1} during winter and summer, respectively. Gas efflux due to ebullition was greater in coves located within reservoirs than in coves within the free flowing Hanford Reach, and CH_4 efflux exceeded that of CO_2. CH_4 ebullition varied widely across sampling locations, ranging from 10.5 to 1039 mg CH_4 m^{-2} d^{-1}, with mean fluxes of 324 mg CH_4 m^{-2} d^{-1}in Lower Monumental Dam reservoir and 482 mg CH_4 $m^{-2}d^{-1}$ in the Priest Rapids Dam reservoir. The magnitude of CH_4 efflux due to ebullition was relatively high, falling within the range recently reported for other temperate reservoirs around the world, further suggesting that this CH_4 source should be considered in estimates of global greenhouse gas emissions. Methane flux from sediment pore-water within littoral embayments averaged 4.2 mg m^{-2} d^{-1} during winter and 8.1 mg m^{-2} d^{-1} during summer, with a peak flux of 19.8 mg $m^{-2}d^{-1}$ (at the same location where CH_4 ebullition was also the greatest). Carbon dioxide flux from sediment pore-water averaged approximately 80 mg $m^{-2}d^{-1}$ with little difference between winter and summer. Similar to emissions from ebullition, flux from sediment pore-water was higher in reservoirs than in the free flowing reach. The findings reported in this investigation are consistent with recent discoveries of substantial CH_4 emissions from temperate Swiss and Chinese reservoirs. There is an apparent global need to better understand CH_4 emissions from littoral embayments of temperate hydroelectric reservoirs when estimating the impact of CH_4 emissions on climate change.

Acknowledgments

Arthur Stewart, Mark Bevelhimer, Jennifer Mosher, Jana Phillips, and Allison Fortner (Oak Ridge National Laboratory) provided guidance and advice through all phases of the project. Mark Reller and Janelle Schmidt (Bonneville Power Administration), Gregg Carrington and Janel Duffy (Chelan County Public Utilities District), Tom Kahler (Douglas County Public Utility District), Tom Dresser (Grant County Public Utility District), Kimberly Johnson, Brad Bird, and Rebecca Weiss (U.S. Army Corps of Engineers), and Eric Corbin (U.S. Bureau of Reclamation) served on an advisory group that helped identify important regional issues and assisted with reservoir selection. Kenneth Ham and Katherine Klett (PNNL) assisted with project implementation. Tom Resch (PNNL) completed carbon analyses. Chris Thompson (PNNL) supervised gas chromatography analyses. Brenda Ben James (Cascade Aquatics LLC) helped collect field samples. This work was supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy—Wind and Water Power Program. Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy under Contract DE-AC05-76RL01830.

Contents

Figures

Tables

1.0 Introduction

Atmospheric concentrations of carbon dioxide (CO_2) have risen from 315 parts per million (ppm) in 1959 to 385 ppm today (IPCC 2007; Taub 2010). The Intergovernmental Panel on Climate Change (IPCC 2007) projects that atmospheric CO_2 concentrations will increase to between 500 and 1000 ppm by 2100, raising questions about how this will effect carbon (C) cycling between the atmosphere and hydrosphere (Taub 2010). CO_2 supersaturation in freshwater lakes relative to atmospheric concentrations has been widely documented, implicating inland waters as one source of this greenhouse gas (GHG) to the atmospheric sink (Cole et al. 1994). Furthermore, Butman et al. (2012) has shown several temperate and Arctic rivers to be saturated with CO_2 in excess of atmospheric levels. At the same time, researchers have become increasingly aware of the extent to which the greenhouse gases CO_2 and methane (CH_4) may be produced within the lacustrine environments created by hydroelectric dam complexes. As a GHG, CH_4 has a warming potential in the atmospheric sink that is approximately 25 times greater than CO_2 per 100 years (Forster et al. 2007). Consequently, hydroelectricity's long-presumed carbon neutrality has been increasingly re-examined (Bastviken et al. 2004; Soumis et al. 2004; Tremblay et al. 2005).

With only 17% of potential hydroelectric sites utilized globally, dam construction is on the rise in developing countries (Bednarek 2001; Barros et al. 2011). In recent years, sizeable GHG efflux from newly constructed hydroelectric dam reservoirs in tropical and boreal latitudes has been measured, and efforts have been made to effectively model emissions (Huttunen et al. 2002; Santos et al. 2005; Tremblay et al. 2005; Galy-Lacaux et al. 1997; Barros et al. 2011). However, CO_2 and CH_4 flux rates vary among these studies by orders of magnitude. Furthermore, there is uncertainty regarding the relative contribution of greenhouse gases from reservoirs in temperate latitudes. For example, Barros et al. (2011) found that reservoir GHG emissions decreased with reservoir age and distance from the equator. This conflicts with the relatively recent discovery of "extreme" CH_4 emissions (>150 mg m^{-2} d^{-1}) from a temperate latitude Swiss reservoir that is 90 years old (Del Sontro et al. 2010).

Hydroelectric dams alter riverine systems to create lacustrine conditions, and block the downstream transport of organic and inorganic C (Wetzel 2001; Bastviken et al. 2004). In addition to dissolved inorganic carbon, which may occur as CO_2, rivers export dissolved and particulate organic carbon (DOC and POC) from throughout their catchments. While this DOC and POC may be respired by aerobic heterotrophs to produce CO_2, POC accumulations in littoral embayments of hydroelectric dam complexes can also become anoxic substrates for methanogenesis (Wetzel 2001; Del Sontro et al. 2010; Butman et al. 2012). Additionally, methanogensis can take place in the hyporheic zone, the shallow subsurface zone of streambeds where microbial activity and anoxia can prevail within pore-waters (Schindler and Krabbenhoft 1998; Huttunen et al. 2006). Under low hydrostatic pressures (e.g., when surface water depths are less than 10 m), hyporheic CH_4 can rise to the surface in large, ebullated bubbles (Del Sontro et al. 2010).

Previous studies within temperate reservoirs of the United States report varying exchange of CO_2 and CH_4 with the atmosphere via surface flux. Soumis et al. (2004) evaluated six reservoirs in Washington and California during September 2001, and concluded that four were sinks for CO_2 and all were emitters of CH_4 (3.2 to 9.5 mg m^{-2} d^{-1}). Working in reservoirs located in semi-arid Utah, Arizona, and New Mexico, Therrien et al. (2005) reported mean CO_2 emissions of 664 mg CO_2 m^{-2} d^{-1}. In still another study, St. Louis et al. (2000) listed CO_2 and CH_4 emissions in three of five Wisconsin reservoirs (3 to 11 mg CH_4 m^{-2} d^{-1} and 220 to 1300 mg CO_2 m^{-2} d^{-1}). All of these studies evaluated surface emissions only and were focused in the mainstem environments of reservoirs. Recent results show CO_2 surface efflux for Tennessee's Lake Douglas was generally within the range reported by the IPCC for other, moist temperate reservoirs (<0 to 6.00E+03 mg m^{-2} d^{-1}), while CH_4 surface efflux was generally similar to previous results for the temperate United States (<10 mg m^{-2} d^{-1}), although emissions were much greater, exceeding 50 mg m^{-2} d^{-1} in Nolichucky Cove, a local littoral embayment (Mulholland et al. 2010).

Hydroelectric dam complexes include many distinct environments, including tributaries, littoral embayments, the hyporheic zone, the mainstem reservoir, the forebay, and the tailrace. The dynamics related to GHG emissions are known to vary spatially and temporally across these environs (IHA 2010). While GHG emissions from the surface of hydroelectric reservoirs and from water passing through hydroelectric projects (i.e., outgassing) have been documented, studies of GHG fluxes from the littoral environments associated with these projects are less represented (Chen et al. 2009; Del Sontro et al. 2010, Mulholland et al. 2010). Understanding such littoral fluxes is important, especially since they have been previously underestimated in studies of temperate hydroelectric dam complexes (Chen et al. 2009). For example, littoral embayments occupy 10% of surface area in the impoundment created by the Three Gorges hydroelectric dam complex, however contribute nearly 20% of CH_4 surface efflux. It is generally accepted that CH_4 efflux occurs from vegetated littoral embayments of small boreal streams, where the vascular tissues of emergent macrophytes convey dissolved CH_4 directly from anoxic substrates to the atmosphere (Kelker and Chanton 1997; Juutinen et al. 2003; Kankaala et al. 2004; Bergstrom 2007). These studies estimate that CH_4 efflux per unit area is highest in such vegetated littoral embayments, but do not sample from or provide data on CH_4 fluxes from large temperate rivers impounded by hydroelectric dams (Kelker and Chanton 1997; Juutinen et al. 2003; Kankaala et al. 2004; Bergstrom 2007).

In order to provide greater understanding of the spatial and temporal resolution of GHG flux from the temperate United States reservoirs it regulates, the U.S. Department of Energy (DOE) initiated a study of Southeastern U.S. reservoirs (Mulholland et al. 2010). The Wind and Water Power Program of the Office of Energy Efficiency and Renewable Energy (U.S. DOE) recently expanded this evaluation to include reservoirs in the Pacific Northwest region of the United States. Pacific Northwest National Laboratory (PNNL) conducted field sampling of representative reservoirs from this region and estimated GHG emissions. The goals of PNNL's field program included 1) measurement of expected emissions pathways at sufficient temporal frequency and spatial density, 2) collection of data from hydroelectric dam complexes that are regionally representative, and 3) study of pre-impoundment proxies, such as tributaries and remaining free-flowing reaches to approximate net emissions (Mulholland et al. 2010). Ultimately, such data are needed to develop a predictive understanding of gas fluxes within man-made hydroelectric dam complexes.

The objectives of PNNL's study were to contribute to the Department of Energy's national effort by sampling Northwest reservoirs in order to 1) determine whether CO_2 and CH_4 emissions varied among different environments within representative hydroelectric dam complexes on the Columbia and Snake Rivers in Washington and 2) estimate GHG fluxes from those environments while placing them in context relative to GHG emissions from other temperate hydroelectric dam complexes.

2.0 Methods

2.1 Study Sites

Study locations were in xeric Eastern Washington, and included Priest Rapids on the mid-Columbia River and Lower Monumental on the lower Snake River. We sampled both of these hydroelectric dam complexes, with generating capacities of 955.6 MW and 810 MW, respectively (CBR 2013). Additionally, one free-flowing reach (the Hanford Reach) of the Columbia River was sampled. Field efforts at all locations occurred during March and September, 2012. The Priest Rapids complex (Priest Rapids Lake) has a residence time of 0.8 days and a surface area of 31.3 km^2 (ORNL 2013). Mean annual discharge through Priest Rapids Dam (for the time period 2002-2011) is approximately 3,115 $m^3 s^{-1}$ (USGS 2013). The Priest Rapids Dam reservoir is characterized by several embayments and agricultural (i.e., nutrient) inputs, one tributary (Crab Creek). Pre-impoundment conditions may be approximated by sampling the free flowing Hanford Reach, downstream from the dam (Figure 1). The Lower Monumental Dam complex (Lake Herbert G. West) has a residence time of 6 days and a surface area of 26.7 km^2 (ORNL 2013). Mean annual discharge through Lower Monumental Dam (for the time period 2003-2012) is approximately 1,410 $m^3 s^{-1}$ (DART 2013). The Lower Monumental Dam reservoir also has many embayments and agricultural inputs, and its tributaries include the Palouse and Tucannon Rivers. Both reservoirs are generally oxic, with winter temperatures dropping well below 5°C and summer temperatures approaching 20°C in the Priest Rapids Dam complex and often exceeding 20°C in the Lower Monumental Dam complex (DART 2013). The areas we studied were generally not nutrient limited. Summer concentrations ranged from 0 to 0.47 mg L^{-1} $PO_4^{3-}$and from 0.6 to 1.9 mg L^{-1} NO_3^- along the Hanford Reach, from 0.02 to 1.64 mg L^{-1} $PO_4^{3-}$and from 0.8 to 5.5 mg L^{-1} NO_3^- at Priest Rapids, and from 0.28 to 2.75 mg L^{-1} $PO_4^{3-}$and from 0.1 to 4.3 mg L^{-1} NO_3^- in the Lower Monumental complex. Although none of our study locations represented anoxic conditions, some reservoirs in the Pacific Northwest are known to contain seasonally anoxic environments (e.g., the Snake River's Brownlee complex; Nuernberg 2004). Both hydro projects participate in spring spill operations to aid migratory juvenile fish, a unique and important characteristic of many Pacific Northwest dam complexes, which may enhance outgassing in the tailrace. The selected hydroelectric dam complexes are fairly representative of regional hydroelectric dam complexes east of the Cascade Range, in semi-arid Washington. Within Priest Rapids and Lower Monumental reservoirs, at least one major tributary, two embayment sites, two mainstem reservoir sites, two forebay sites, and two tailrace sites were sampled (Figure 1). Additionally, two embayment sites and two mainstem reservoir sites were sampled along the free-flowing Hanford Reach (Figure 1).

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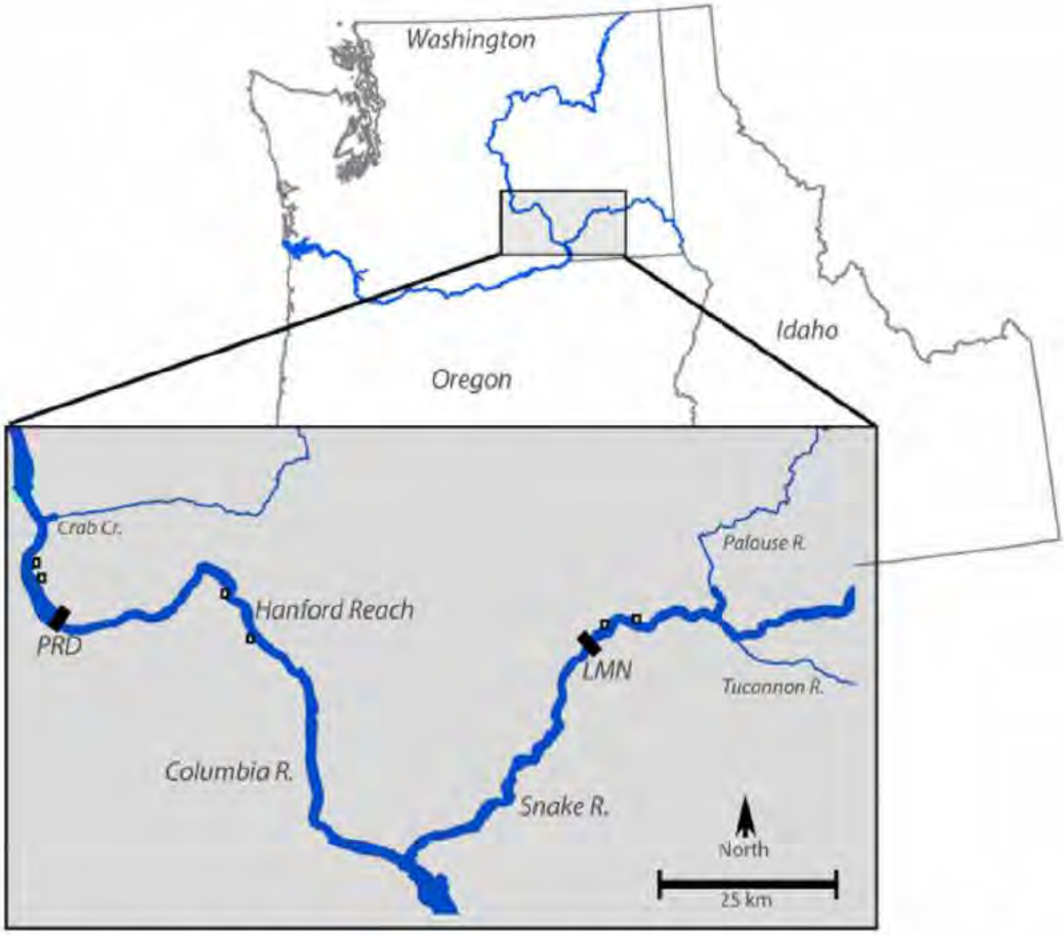

Figure 1. Greenhouse gas emissions were measured from the forebay, tailrace, mainstem reservoir, tributaries, and embayments within the Priest Rapids (PRD) and Lower Monumental Dam (LMN) complexes and from embayment and mainstem locations within the Hanford Reach, a free flowing stretch of the Columbia River. Embayments (white squares) were sampled using inverted funnel samplers to trap gas bubbles in surface water and using piezometers to sample sediment pore-water. Samples were collected from the mainstem river adjacent to each embayment.

2.2 Experimental Methods:

2.2.1 Surface flux of CO_2 and CH_4

At all sites, 7 mL of water was sampled via syringe at 0.01 m and injected into 10 mL evacuated glass vials to equilibrate with 3 mL of headspace. The same procedure was used to collect an ambient air sample. Additional samples were gathered using syringes and a gas tight Van Dorn sampler (Wildco Alpha Horizontal 3.2 L) at 1 m and other depths to show relative saturation to atmospheric concentrations of CO_2 and CH_4. All vials contained 0.4 g potassium chloride (KCl) to both inhibit further respiration and prevent partitioning of the sampled gas between headspace and water (IHA 2010). Vials were sealed with a butyl rubber stopper and an outer centrifuge tube containing DI water, and were refrigerated until analysis by gas chromatography (GC). When vials were held for extended periods, helium (He) gas was injected into the headspace vial as an additional seal. Flux at the surface of waters at all sites was calculated in September using the thin boundary layer equation, as presented by Duchemin et al. (1999), Roehm and Tremblay (2006), and Del Sontro et al. (2010):

$$F_{Surface} = K_i\left(C_w - C_{eq}\right)$$

Where $F_{Surface}$ is GHG flux, K_i is the gas exchange coefficient, C_w is the partial pressure of CO_2 and CH_4 (atm) in water (measured directly at 0.01 m depth), and C_{eq} is the atmospheric equilibrium partial pressure of CO_2 and CH_4 (atm). The gas exchange coefficient, K_i, was determined using the following relationships (Wanninkhof 1992; MacIntyre et al. 1995; Cole and Caraco 1998; Crusius and Wanninkhof 2003; Del Sontro et al. 2010; IHA 2010):

$$K_i = K_{600}(Sc/600)^{-0.66}$$

$$K_{600}\left(CO_2\right) = 2.07 + 0.215U_{10}^{1.7}$$

$$K_{600} = \left(CH_4\right) = 0.45U_{10}^{1.64}$$

$$U_{10} = U_1 1.22$$

$$Sc = a - bT + cT^2 - dT^3$$

Where U_{10} is wind speed at 10 m above the water's surface; this value was converted from wind speed measured at 2 m above the water's surface (U_1) as outlined in Wanninkhof (1992). Sc is the Schmidt number, or the ratio of momentum diffusivity and mass diffusivity as presented by Jaehne et al. (1987) and Wanninkhof (1992), T is the temperature (°C), and a, b, c, and d are constants for CO_2 and CH_4 (Wanninkhof 1992; IHA 2010). The partial pressures of CO_2 and CH_4 in water (C_w) and in the atmosphere (C_{eq}) were determined using the following relationships:

$$C_w = P_i K_H$$

$$C_{eq} = P_i K_0$$

$$P_i = \left(n_i / n_T\right) P_T$$

Where P_i is the partial pressure of CO_2 or CH_4, respectively, n_i / n_T is the mole fraction of CO_2 or CH_4 obtained via gas chromatography, and P_T is the approximate atmospheric pressure at the elevation of sampling. The relationship between pressure and concentration is determined using the ideal gas law.

Both C_w and C_{eq} were corrected for temperature dependence of gas solubility in water following Henry's Law, and C_w was further corrected for the effect of pressure due to water depth on gas solubility (Weiss 1974). These adjustments were made using the K_H and K_0 variables, which were determined as follows (Weiss 1974; Wiesenburg and Guinasso 1979; Lide 2007; IHA 2010):

$$K_H = K_0 \ln[(1-p)\bar{v}_i / RT_K]$$

$$\ln K_0(CO_2) = A + B(100/T_K) + C\ln(T_K/100) + s\left[D - E(T_K/100) + F(T_K/100)^2\right]$$

$$\ln K_0(CH_4) = G + [H/(T_K/100)] + I\ln(T_K/100) - J(T_K/100)$$

Where s is salinity (0.025 ppt), T_K is temperature in Kelvin, P is the pressure of the system, v_i is the partial molal volume of CO_2 (0.03023 mol L^{-1}) and CH_4 (0.03044 mol L^{-1}) in water as determined by Weiss (1974) and Yamamoto et al. (1976), respectively, and R is the gas constant (0.082057 L atm K^{-1} mol^{-1}). *A, B, C, D, E,* and *F* are dimensionless coefficients previously used by Weiss (1974). *G, H, I,* and *J* are dimensionless coefficients suggested by Lide (2007) and IHA (2010). K_0 was determined using an integrated form of the van't Hoff equation and the logarithmic Setchenow salinity dependence, first presented by Weiss (1974) for CO_2 and modified by Lide (2007) for CH_4.

2.2.2 Depth-discreet and continuous water quality monitoring

Depth-discreet water quality and the availability of nutrients were measured in order to help interpret GHG influx and efflux, and to provide information needed to select appropriate diffusion coefficients for the gases sampled. Oxidation-reduction potential (ORP), pH, and temperature were measured at each site by deploying a data-logging water quality sonde (Hach Environmental, Loveland, Colorado) to the riverbed and slowly raising it to the river surface while logging data every second. This resulted in data collection at approximately 0.2-m intervals, allowing for resolution of any vertical gradients present in the water column. This was investigated because pH fluctuates with dissolved CO_2, and temperature affects gas solubility, according to Henry's Law. ORP provides insight into the oxidation of CH_4, produced by anaerobic respiration in benthic interstices, to CO_2 in the oxic, overlying water column, represented by the following reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Sonde measured water quality was monitored hourly in embayment areas concurrently with the deployment of ebullition funnels to 1) capture the diurnal fluctuations in DO that can occur as a result of primary production during daylight hours and 2) measure temperature (Arntzen et al. 2009). Buoys with these sondes were deployed within each embayment location in both Priest Rapids and Lower Monumental Dam complexes, as well as the Hanford Reach. Nutrient (nitrate [NO_3^-] and phosphate [PO_4^{3-}]), dissolved oxygen (DO), and GF 45 μm-filtered dissolved organic carbon (DOC) samples were taken from 1 m and bottom depths via gastight Van Dorn sampler, and combined in a composite sample for each site. In smaller tributaries (e.g., the Tucannon River), these samples were collected from shore. Nutrients were measured in field or the laboratory using a Hach colorimeter (spectrophotometer) and associated standards (Hach Environmental, Loveland, Colorado). Upon return to the laboratory, DOC samples were refrigerated until analysis with a carbon analyzer (Model TOC-5000A, Shimadzu). All supporting data, including vertical gradients in temperature and dissolved oxygen, nutrient concentrations, and DOC were included in Appendix D.

2.2.3 Degassing of CO_2 and CH_4 through hydroelectric turbines

Degassing of CO_2 and CH_4 between the forebay and the tailrace were estimated using the same approach as IHA (2010):

$$F_D = \left[\left(C_{w,u} - C_{w,d}\right)Q_T\right] + \left[\left(C_{w,u} - C_{w,d}\right)Q_s\right]$$

Where F_D is the degassing flux, $C_{w,u}$ is the concentration of CO_2 and CH_4 entering the dam through the forebay, $C_{w,d}$ is the concentration of CO_2 and CH_4 leaving the dam in the tailrace, Q_T is the mean daily turbine discharge in $m^3\ s^{-1}$, and Q_S is the mean daily spillway discharge in $m^3\ s^{-1}$ (USACE 2012). Water samples were obtained via gas tight sampler at 1 m. Water was sampled using the same methods in the tailrace, at 1 m. Degassing flux headspace samples were preserved in a manner identical to surface flux headspace samples, and GC output concentrations were also adjusted for temperature and pressure dependence of solubility in water, or Henry's Law, as above (K_H; Soumis et al. 2004).

2.2.4 CH_4 ebullition

CH4 ebullition in each littoral embayment site was captured using two inverted funnels (Strayer and Tiedje 1978; Del Sontro et al. 2010; Mulholland et al. 2010; IHA 2010). Inverted funnels were constructed of vinyl material with minimal seams and no openings along their interior collection surface. These funnels channeled ebullated CH4 bubbles from a 0.79 m^2 opening at a depth of 2 m into a sealed syringe at their terminus. Inverted funnels were deployed for approximately 24 hours at each location, using four construction bricks as an anchor. Upon retrieval, the funnels were carefully lifted to just below the water's surface, and the captured gas withdrawn with another syringe (sometimes multiple syringes were filled from the gas reservoir of one funnel; in this case the sample from each syringe was collected as an individual sample). CH_4 headspace samples were preserved along with surface flux and degassing flux samples until GC analysis. Flux (F_E) in mg CH_4 $m^{-2}d^{-1}$ was calculated using the following equation:

$$F_E = [CH_4] \times Vol / T_d \times A_f$$

Where F_E is ebullition of CH_4, $[CH_4]$ is the CH_4 concentration (or the mean concentration if multiple samples were collected from one 24 hour funnel deployment), Vol is the volume of gas sampled, T_d is the number of days the funnel was deployed, and A_f is the cross sectional area of the funnel.

2.2.5 Hyporheic Flux of CO_2 and CH_4

A Ponar dredge was used to collect substrate samples from three random locations at each embayment site in March 2012. Each of these three samples was analyzed for sediment grainsize distribution, organic, and inorganic C content. Previous studies on the Snake River utilizing a Ponar dredge have revealed little to no significant seasonal differences among results (Arntzen et al. 2012). Substrate samples were dried inside a vented oven at 105°C for 24 hours. The dried samples were then be sieved into 1-phi size classes from 64 mm (-6 phi) to 0.062 mm (4 phi). For each sample, the weight of the substrate in each size class was taken, yielding a percent-by-weight value for each size class. All laboratory sample handling and quality assurance and quality control followed the guidelines of Guy (1969). The inorganic and organic carbon content of fine sediments less than 2 mm was determined using the loss on ignition method (LOI; Heiri et al. 2001; Arntzen et al. 2012). A 20 g sample of the less than 2 mm portion was taken from each sample. If less than 20 grams of fine sediment was available, the entirety of the less than 2 mm portion was taken for LOI. Samples were fired at 550°C for four hours in a muffle furnace. The difference between their masses prior to ignition and masses following ignition was calculated as percent organic carbon.

Concentrations of CO_2 and CH_4 present within the upper strata of benthic sediments and the hyporheic zone, where methanogenesis and gas ebullition originates, was determined by installing two mini piezometers at sites where ebullition funnels were deployed. These were installed at a subsurface depth of approximately 10 cm, where CH_4 concentrations have been shown to peak in pore water, and a surface water depth of approximately 4 m (Furrer and Wehrli 1996; Schindler and Krabbenhoft 1998). CO_2 and CH_4 headspace samples were taken from mini piezometers following the funnels' retrieval. Installation and sampling of mini piezometers, then the funnels, was timed to avoid releasing and measuring greater quantities of CO_2 and CH_4 in the ebullition funnels from a disturbed benthos. To retrieve a headspace sample, water was withdrawn from the mini piezometers' 0.64 cm diameter polyethylene tubing with a syringe while a peristaltic pump was in operation (Arntzen 2001). Before sampling, tubing was purged with up to three volumes of water (Arntzen 2001). The tubing was moored at the water's surface with a buoy for subsequent sampling. CO_2 and CH_4 headspace samples were also taken with a gas-tight Van Dorn sampler from bottom depths at each embayment site. All CO_2 and CH_4 headspace samples were then stored along with surface flux, degassing flux, and ebullition flux headspace samples until GC analysis. Flux of CO_2 and CH_4 was calculated using pore-water and bottom depth headspace sample concentrations (gathered by gas tight Van Dorn, as described previously), as well as porosity ($\varnothing$) and tortuosity (θ) estimated from sediment grainsize data (Berner 1980; Huttunen et al. 2006) using the following derivation of Fick's First Law of Diffusion:

$$F_{Porewater} = -\varnothing\left(D_0 \times \theta^{-2}\right) dC / dz$$

Where $F_{Porewater}$ is the diffusive flux of CO_2 or CH_4 at the sediment-water interface, D_0 is the diffusion coefficient for CO_2, or CH_4, dC / dz is the concentration gradient measured between the pore-water headspace sample at 10 cm and Van Dorn headspace sample at the sediment-water interface, ø is sediment porosity, and θ is sediment tortuosity. Temperature dependent diffusion coefficients were obtained from Broecker and Peng (1974). During winter sampling (Feb-March) surface water temperatures in littoral embayments ranged from approximately 4-7 °C, and diffusion coefficients for CO_2 and CH_4 were selected assuming an average water temperature of 5°C.

Table 1. Porosity values for various substrates determined using grainsize distributions found in greatest proportion at each littoral embayment, together with the relationship presented by Stephens et al. (1998).

Location	Substrate Type (D_{50})	Porosity
Han-C1	Fine Sand	0.42
Han-C2	Medium Sand	0.40
LMN-C1	Fine Silt	0.50
LMN-C2	Course Silt	0.45
PRD-C1	Medium Sand	0.40
PRD-C2	Coarse Silt	0.45

Diffusion coefficients used for CO_2 and CH_4 (in 10^{-5} cm^2/s) were 1.08 and 1.14, respectively. During summer sampling (September), surface water temperatures within embayments ranged from approximately 18°C to 21°C, and diffusion coefficients were selected assuming an average water temperature of 20°C. For summer samples, diffusion coefficients used for CO_2 and CH_4 (in 10^{-5} cm^2/s) were 1.64 and 1.75, respectively. Sediment porosity was estimated using the D_{50} sorting index from our sediment grainsize distribution (the grainsize that 50% of the sample was finer than). The D_{50} value was related to porosity using a relationship published by Stephens et al. (1998). Sediment tortuosity was then estimated directly from the resulting sediment porosity as outlined in Sweerts (1991):

$$\theta^2 = 0.73\varnothing + 2.17$$

2.2.6 Laboratory analysis

Methane and carbon dioxide concentrations were analyzed by gas chromatography (GC). The gas chromatograph was an SRI Instruments model 8610C equipped with a flame ionization detector (FID) and a methanizer accessory to enable measurement of CO_2. A 1-mL gas sample loop was used to inject samples onto the packed separation columns, which consisted of 2 m Haysep-Dand 1 m Shincarbon joined with a 30 cm length of 1/8" OD copper tubing.. The N_2 carrier gas pressure was set at 20 psi, and the column temperature was 100ºC. A set of four standards ranging in concentration from 9.93 to 245 ppm for CH_4 and 205.5 to 5018 ppm for CO_2 was used for calibration. Blanks and check standards were run regularly between samples; standard recoveries ranged from 56% to 180% for CH_4 (mean = 101%) and 96% to 101% for CO_2 (mean = 99%).

3.0 Results

3.1 Surface flux of CH_4 and CO_2

Mean surface flux of CH_4 (determined using thin boundary layer calculations) was determined for the September sampling effort only, with small and slightly positive mean (standard deviation, SD) fluxes ranging up to 0.08 mg CH_4 m^{-2} d^{-1} (0.08 mg CH_4 m^{-2} d^{-1}) in the Hanford Reach of the Columbia River (Figure 2).

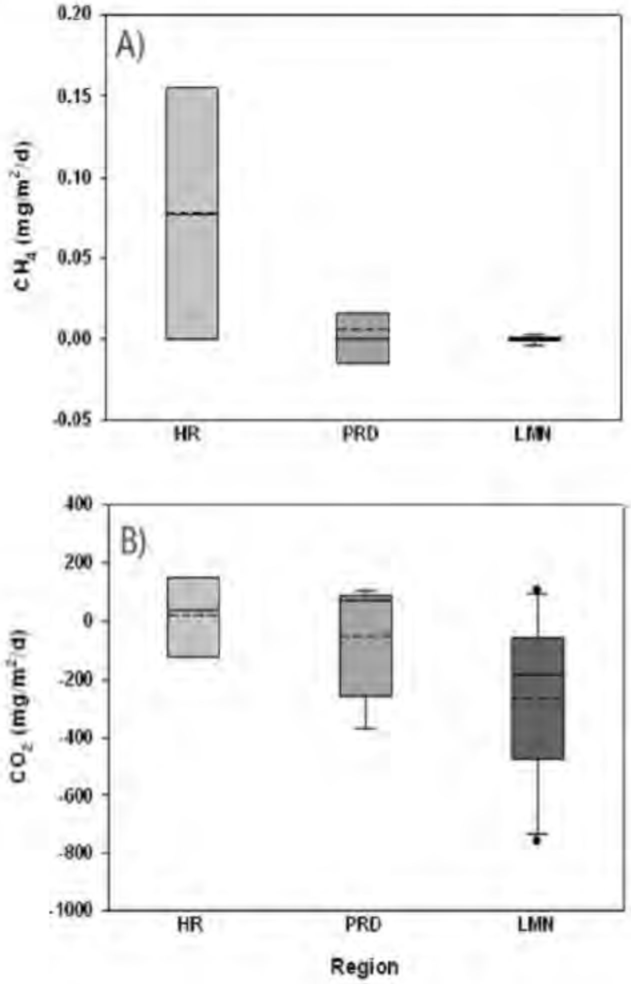

Figure 2. Surface water flux for A) CH_4 and B) CO_2 across sampling environments in the Hanford Reach (HR), Priest Rapids hydroelectric dam complex (PRD), and Lower Monumental hydroelectric dam complex (LMN). Solid horizontal lines within each box represent median flux, dashed lines within each box represent mean flux, ends of boxes represent the 25th and 75th percentiles and black dots represent outliers.

CH_4 efflux within the Priest Rapids and Lower Monumental Dam complexes occurred but was very minimal, with small positive fluxes within the Priest Rapids complex and very small negative flux within the Lower Monumental Dam complex (Figure 2). The free flowing Hanford Reach was a source of CO_2, with a mean (SD) flux of 21.7 mg $m^{-2}d^{-1}$ (146.3 mg m^{-2} d^{-1}). The Lower Monumental Dam complex was a sink for CO_2, with a mean (SD) flux –262 mg m^{-2} d^{-1} (265 mg m^{-2} d^{-1}). The Priest Rapids Dam complex was also a sink for CO2 with mean (SD) flux of –48.5 mg m^{-2} d^{-1} (190.8 mg m^{-2} d^{-1}).

3.2 Degassing of CH_4 and CO_2 at hydroelectric dam projects

Relative atmospheric contributions of CH_4 and CO_2 were evaluated by measuring gas concentrations in the forebay and the tailrace of hydroelectric dam projects as water passed through the turbines and spillway during March and September, 2012 (Figure 3). Results were highly variable within each hydroelectric dam project sampled. Overall, during March, tailrace concentrations of CH_4 were lower than forebay concentrations, meaning the system was a source for CH_4 with a mean degassing flux of 3.1×10^{-6} t CH_4 d^{-1} (Figure 3). During September, the system was a sink for CH_4 with a mean (SD) degassing flux of -5.6×10^{-4} t CH_4 d^{-1}(9.8×10^{-4} t CH_4 d^{-1}) (Figure 3). During March, the system was a sink for CO_2 with a mean (SD) degassing flux of –117 t CO_2 d^{-1}(200 t CO_2 d^{-1}). During September degassing was a source of CO_2, with a mean (SD) degassing flux of 4.5 t CO_2 d^{-1}(66 t CO_2 d^{-1}) (Figure 3).

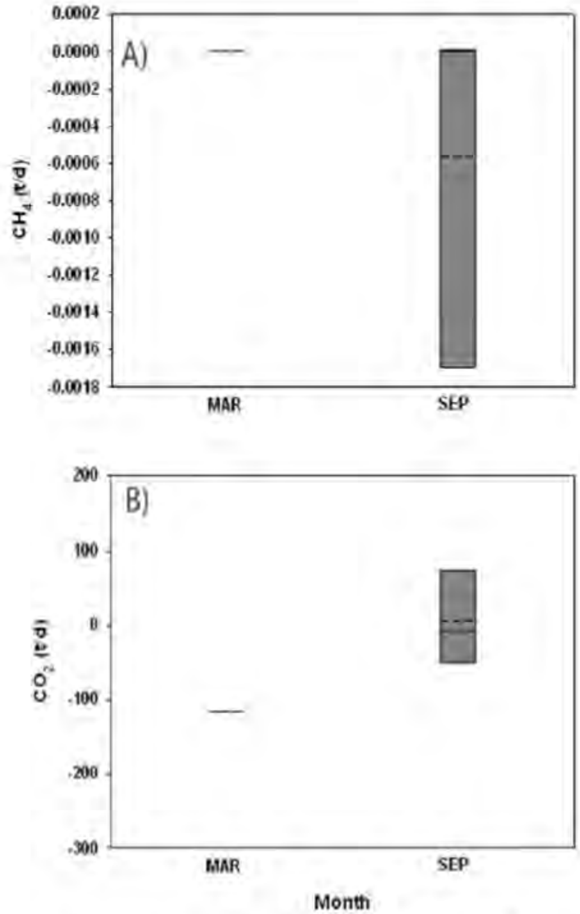

Figure 3. Degassing flux values for A) CH_4 (td^{-1}) and B) CO_2 (td^{-1}) across hydroelectric dam projects in March 2012 and September 2012. Solid horizontal lines within each box represent median flux, dashed horizontal lines represent mean flux, and ends of boxes represent the 25th and 75th percentile.

3.3 Ebullition of CH_4 and CO_2 in littoral embayments

Methane and carbon dioxide ebullition were measured from littoral embayments, or coves, by capturing bubbles ascending through the water column with inverted funnel samplers during March and September, 2012. Mean concentrations of CH_4 and CO_2 exceeded 7,000 mgL^{-1} and 4,000 mgL^{-1}, respectively, during September and were approximately an order of magnitude lower during March (Figure 4).

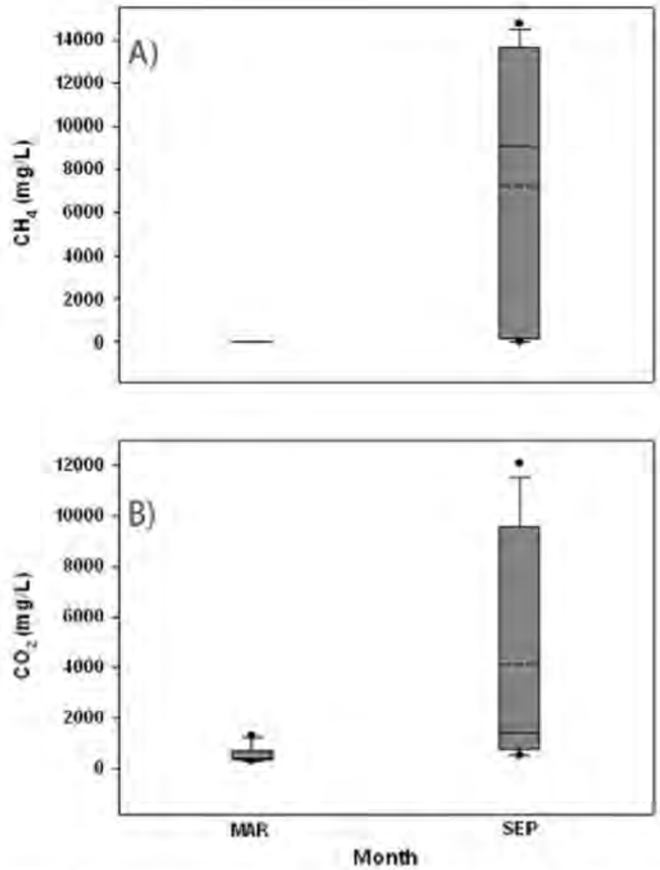

Figure 4. Gas concentration values (mgL^{-1}) for A) CH_4 and B) CO_2 gas samples collected in funnels from all littoral embayments during September 2012. Solid horizontal lines within each box represent median concentration, dashed lines within each box represent mean concentration, ends of boxes represent the 25th and 75th percentiles and black dots represent outliers.

This result is to be expected, with higher CH_4 flux expected with increased summer temperatures (Del Sontro et al. 2010). CH_4 eflux due to ebullition exceeded that of CO_2. This result may be explained by the comparatively low solubility of CH_4 in water at standard temperature and pressure (Wilhelm et al. 1977). Gas efflux due to ebullition was greater in embayments located within reservoirs than in embayments within the free flowing Hanford Reach–this was true for both CH_4 and CO_2 (Figure 5).

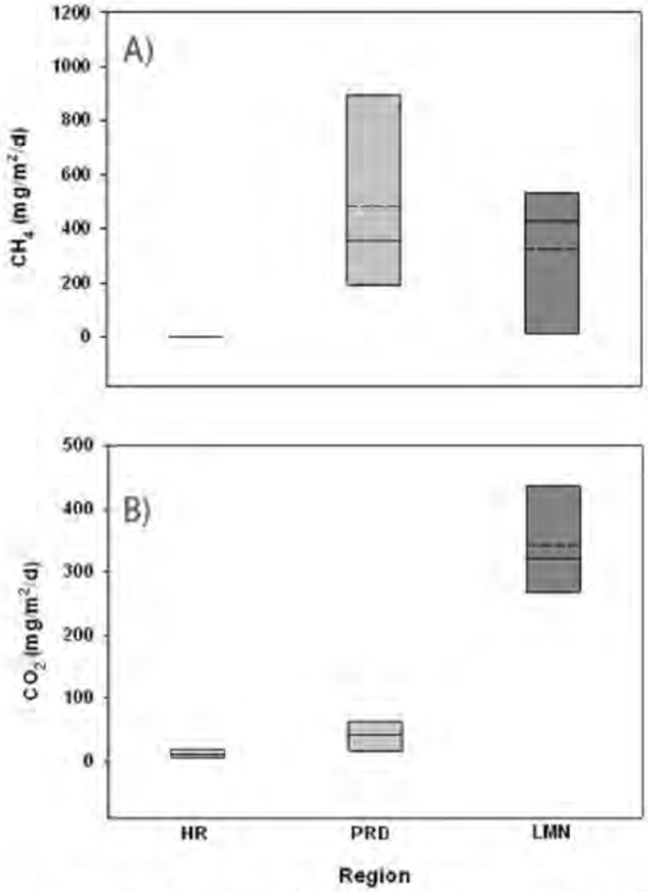

Figure 5. Flux values (mg m^{-2} d^{-1}) for A) CH_4 and B) CO_2 gas samples collected using inverted funnel samplers with littoral cove sampling environments in the Hanford Reach (HR), Priest Rapids hydroelectric dam complex (PRD), and Lower Monumental hydroelectric dam complex (LMN) during September 2012. Solid horizontal lines within each box represent median flux, dashed lines within each box represent mean flux, ends of boxes represent the 25th and 75th percentiles and black dots represent outliers.

Estimated CH_4 emissions due to ebullition varied widely across sampling locations. Within Lower Monumental Dam reservoir embayments, CH_4 flux ranged from approximately 10.5 to 533 mg CH_4 m^{-2} d^{-1}, with a mean (SD) flux of 324 mg CH_4 m^{-2} d^{-1} (276 mg CH_4 m^{-2} d^{-1}) (Figure 5). For embayments within the Priest Rapids Dam reservoir, CH_4 flux ranged from approximately 176 to 1039 mg CH_4 $m^{-2}d^{-1}$, with a mean (SD) flux of 482 mg CH_4 $m^{-2}d^{-1}$ (391 mg CH_4 $m^{-2}d^{-1}$). Maximum CH_4 flux from Hanford Reach coves was less than 4 mg CH_4 $m^{-2}d^{-1}$ Mean (SD) carbon dioxide ebullition flux ranged from approximately 10.9 mg CO_2 $m^{-2}d^{-1}$ (5.8 mg CO_2 $m^{-2}d^{-1}$) from Hanford Reach coves to approximately 342 mg CO_2 $m^{-2}d^{-1}$ (85.9 mg CO_2 $m^{-2}d^{-1}$) from Lower Monumental Dam reservoir coves (Figure 5).

3.4 Hyporheic Flux of CH_4 and CO_2

CH_4 and CO_2 flux within sediment pore-water in littoral embayments was sampled from piezometers installed within the hyporheic zone during March and September, 2012. CH_4 efflux rates were higher during September, with mean (SD) flux averaging 4.2 mg m^{-2} d^{-1}(4.4 mg m^{-2} d^{-1}) during March and 8.1 mg m^{-2} d^{-1}(10.5 mg m^{-2} d^{-1}) during September (Figure 6).

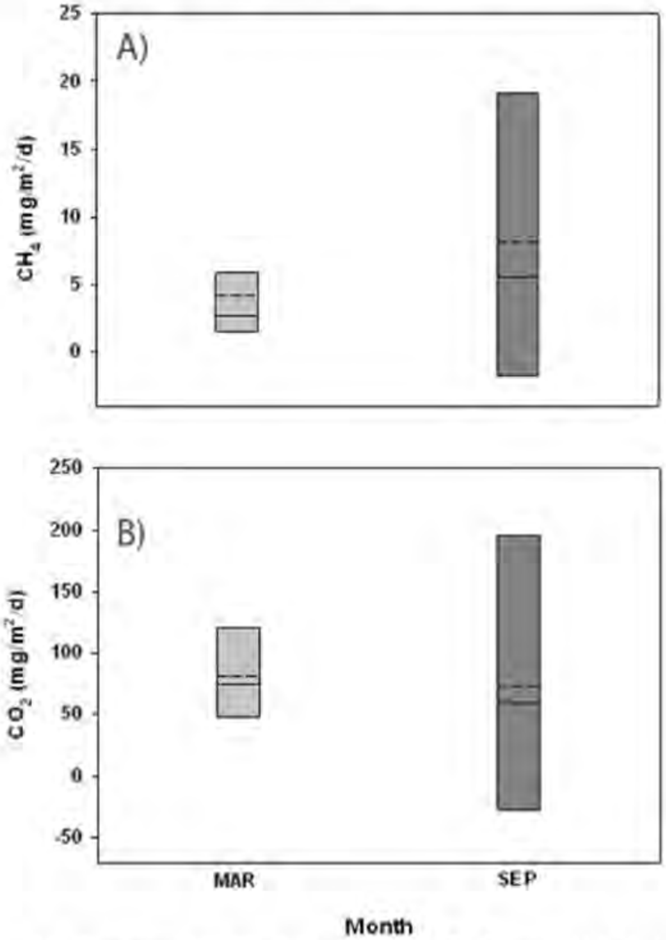

Figure 6. Porewater flux of A) CH4(mg m^{-2} d^{-1}) and B) CO_2 (mg m^{-2} d^{-1}) in littoral bays aross all study regions during March 2012 and September 2012. Solid horizontal lines within each box represent median flux, dashed horizontal lines within each box represent mean flux, and ends of boxes represent the 25th and 75th percentiles.

For CO_2 flux, there was little difference between March and September, with mean (SD) flux rates of CO_2 averaging 80.6 mg $m^{-2}d^{-1}$(35.0 mg $m^{-2}d^{-1}$) during March and 73.5 mg $m^{-2}d^{-1}$(109.7 mg $m^{-2}d^{-1}$) during September (Figure 6).

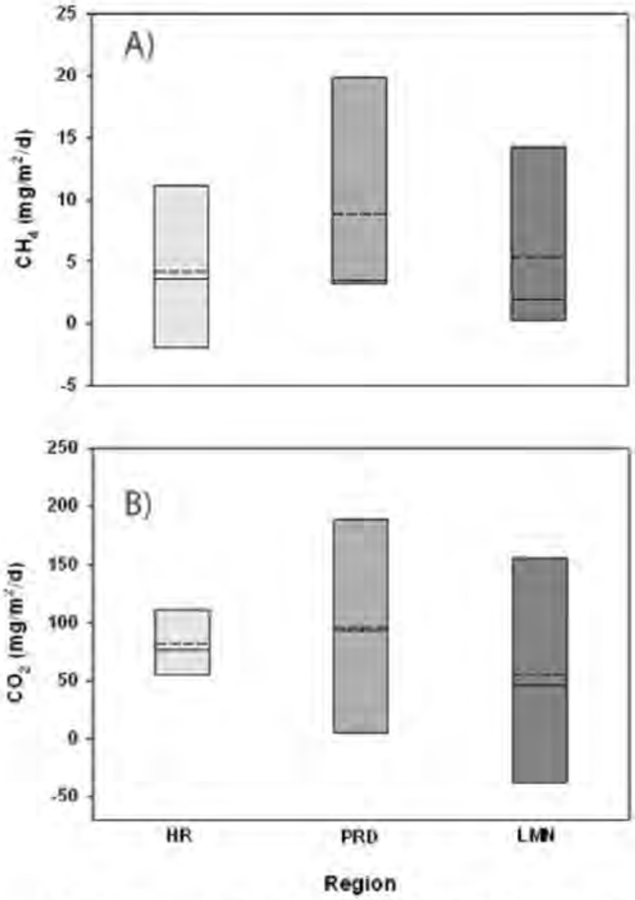

Figure 7. Porewater flux for A) CH_4 (mg $m^{-2}d^{-1}$) and B) CO_2 (mg $m^{-2}d^{-1}$) in littoral bays within the Hanford Reach (HR), Priest Rapids hydroelectric dam complex (PRD), and Lower Monumental hydroelectric dam complex (LMN) in March and September 2012. Solid horizontal lines within each box represent median flux, dashed lines represent mean flux, and ends of boxes represent the 25th and 75th percentiles.

Similar to results for CH_4 ebullition, CH_4 flux from sediment pore-water was higher in reservoirs than in the free flowing Hanford Reach, although the differences were small (Figure 7). Maximum CH_4 flux from sediment pore-water was 19.8 mg $m^{-2}d^{-1}$ from a littoral bay within the Priest Rapids Dam reservoir, where CH_4 ebullition was also the greatest (Figure 7). CO_2 from pore-water flux was greater than the CO_2 flux due to ebullition within Hanford Reach and Priest Rapids littoral bays; however this was untrue for the Lower Monumental Dam reservoir, where CO_2 flux rates due to ebullition were substantially higher than those estimated for pore-water flux (Figure 7). We found that dissolved CH_4 found in benthic sediments and from the overlying surface water were positively correlated with higher levels of DOC (Figure 8). While this relationship was significant ($P<0.001$), it was heavily reliant on only two sediment pore-water samples and the data used for the comparison were not distributed normally.

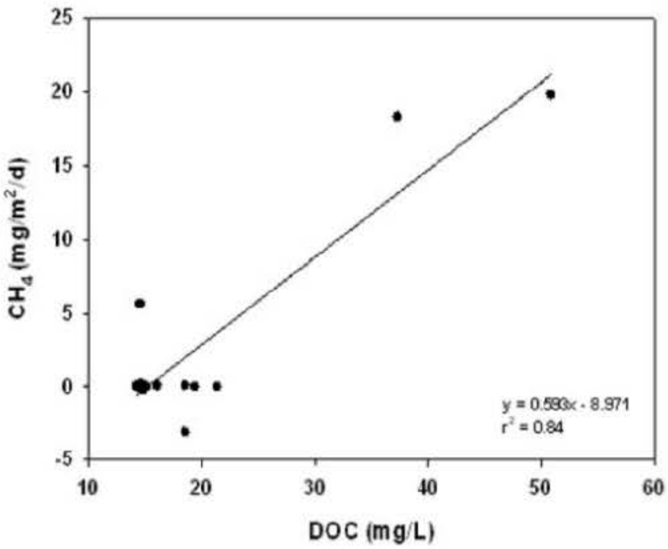

Figure 8. DOC versus CH_4 (porewater flux and surface flux combined) for all three regions during September 2012.

4.0 Discussion

The surface fluxes of methane we report here are small compared to those observed by others in similar temperate reservoirs. Delsontro et al. (2010) found that surface fluxes of methane ranged from 1.5 mg CH_4 $m^{-2}d^{-1}$ to 12.0 mg CH_4 $m^{-2}d^{-1}$ from a run-of-river reservoir on the Aare River, Switzerland. Like the run-of-river reservoirs we studied, this reservoir was characterized by oxic conditions and similar temperature regimes to those we studied, with extremes ranging from approximately 5°C in winter to approximately 17°C during summer (Delsontro et al. 2010). Soumis et al. (2004) reported a range of CH_4 surface fluxes between 3.2 and 9.0 mg CH_4 m^{-2} d^{-1} in another September study of different reservoirs—Lakes Wallula and F.D. Roosevelt—on the Columbia River, and St. Louis et al. (2000) found a range between 3.0 and 11.0 mg CH_4 m^{-2} d^{-1} in temperate Wisconsin. Concomitant with our study, Mulholland et al. (2010) measured diffusive emissions of typically less than 10 mg CH_4 m^{-2} d^{-1} in temperate Tennessee, with some higher surface effluxes in littoral embayment areas. In their review paper synthesizing results from 85 published reservoir studies worldwide, including those in the tropical and boreal zones, where flux is highest, Barros et al. (2011) estimates that reservoirs emit 5.80E+12 g CH_4 y^{-1}, accounting for 7% of annual lacustrine emissions. Of these, temperate reservoirs are assumed to emit 1.00E+11 g CH_4 y^{-1} (Barros et al. 2011). According to our mainstem results, extrapolated annual emissions of CH_4 from water surface diffusion is 350 g CH_4 y^{-1} from Priest Rapids Dam complex, and –0.5 g CH_4 y^{-1} from Lower Monumental Dam complex. Surface flux is generally measured using a floating dome sampler, and we estimated surface flux exclusively using thin boundary layer calculations, a difference that may have contributed to our comparatively low flux estimates (Duchemin et al. 1999).

The reservoirs we sampled were sinks for CO_2, with mean flux rates ranging from –48.5 mg m^{-2} d^{-1} to –262 mg m^{-2} d^{-1}. Previous research within different reservoirs in the same xeric, temperate region of the United States found varying results, with CO_2 surface flux emissions ranging up to 1,247 mg m^{-2} d^{-1} from Shasta Reservoir, and several reservoirs acting as sinks for CO_2, with fluxes ranging from –349 to – 1195 mg m^{-2} d^{-1} (Soumis et al. 2004). Given this range in values, our CO_2 surface flux results are thus comparable to previous studies in similar locations.

Previous research in temperate western reservoirs of the U.S. showed that as water passed through turbines, GHG was emitted into the atmosphere (Soumis et al. 2004). Our results differ from these findings. Overall, the tailrace environment we sampled consistently acts as a sink for CO_2. Results may differ because we directly measured gas concentrations within tailrace environments. Soumis et al. (2004) measured gas concentrations in the forebay and estimated them for tailrace environments, reporting a CO_2 degassing (efflux) of 324 $\pm$ 95, 16 $\pm$ 4, and 224 $\pm$ 56 t d^{-1} in the tailraces of Grand Coulee, Dworshak, and McNary Dams, respectively. Two of these hydroelectric dam complexes, Grand Coulee and McNary, are also located on the Columbia. Soumis et al. (2004) assumed that downstream, tailrace water concentrations were at equilibrium with mean ambient atmospheric concentrations of ~375 ppm CO2. However, as

Roehm and Tremblay (2006) highlight, this leads to "gross overestimation" because dissolved CO_2 is often supersaturated immediately downstream of hydroelectric dams. This is supportive of both our magnitude of results and our findings of CO_2 influx, due to CO_2 supersaturation in the tailrace relative to the forebay. Examining two of the Le Grande reservoirs in the boreal zone, Roehm and Tremblay (2006) reported CO_2 efflux based on turbine discharge of 5 to 45 and 5 to 25 t d^{-1}, but note the seasonal variability often observed with degassing flux. Other studies that have quantified such fluxes have generally been conducted outside of the temperate zone, in the tropics (Galy-Lacaux et al. 1997; Guerin et al. 2006; Del Sontro et al. 2011). We measured very minimal influx of CH_4 due to degassing, with an overall net flux of -4.2×10^{-4} t CH_4 d^{-1}. Soumis et al. (2004) also found low emissions of CH_4 via this pathway, with values ranging from 0.003 to 0.815 t CH_4 d^{-1}.

Based on the relatively cool, oxygenated conditions in the reservoirs that were sampled, it was expected that ebullition would represent a relatively minor input to overall CH_4 flux within the reservoirs we surveyed. However, the efflux of CH_4 from ebullition within littoral embayments was relatively high (10.5 to 533 mg CH_4 m^{-2} d^{-1}). The greatest effluxes were measured in shallow (< 10 m deep) littoral embayments where surface water temperature was approximately 20°C and dissolved oxygen levels exceeded 6 mgL^{-1}. These areas were characterized by low water velocity (near zero), surrounded by land used for agriculture and were likely not nutrient limited, with mean NO_3^- and PO_4^{3-} concentrations of 1.48 mg L^{-1} and 0.36 mg L^{-1} , respectively. Additionally, aquatic plants such as Eurasian watermilfoil (*Myriophyllum spicatum*) are known to thrive in backwater areas of the Columbia and lower Snake Rivers, which may deplete dissolved CO_2 during diurnal periods of photosynthesis, provide substrates—including DOC—to respiring microbial communities within littoral sediments, and serve as conduits for dissolved CH_4 to surface water (Kelker and Chanton 1997; Wetzel 2001; Seybold and Bennett 2010; Arntzen et al. 2012). CH_4 fluxes of a similar magnitude to those we found have recently been identified in littoral zones of other temperate reservoirs. Chen et al. (2009) found methane fluxes in littoral marshes of the Three Gorges Reservoir, China, that were approximately 360 mg CH_4 $m^{-2}d^{-1}$, a value within the range of effluxes we measured. DelSontro et al. (2010) sampled a Swiss, run-of-river reservoir (Lake Wohlen), and found methane ebullition was greatest when water quality conditions were similar to the conditions we measured during September, 2012 (i.e., dissolved oxygen concentration indicated oxic conditions, and temperatures exceeded 17°C). DelSontro et al. (2010) found CH_4 ebullition resulting in emissions of approximately 1,000 mg CH_4 $m^{-2}d^{-1}$, or approximately 2 to 3 times the efflux we measured for this study. Our investigation was considered preliminary and not designed in order to estimate reservoir wide greenhouse gas emissions via the ebullition pathway; the intent was to determine whether substantial quantities of CH_4 were escaping via ebullition from shallow, littoral embayments within the reservoirs we studied. The sites we studied are not unique, and there exists a substantial quantity of similar habitat within the reservoirs examined. In order to estimate reservoir wide emissions due to ebullition it would be necessary to use available hydrodynamic modeling and GIS tools to estimate the area of the reservoir where conditions are representative of the areas we sampled. It would also be useful to deploy inverted funnel samplers in some additional locations to determine how representative sampling results and model projections are.

Methane porewater flux was relatively low compared to mean flux from ebullition, and there was little seasonal variability in mean flux, which ranged from approximately 4 mg to 8 mg CH_4 $m^{-2}d^{-1}$, respectively. It is difficult to directly compare our pore-water flux rates to flux rates from ebullition because of the heterogeneous nature of the ebullition results. However, our results are consistent with other research in temperature reservoirs that found relatively high CH_4 flux due to ebullition compared to diffusive flux from sediment porewater. DelSontro et al (2010) found peak CH_4 diffusion from sediments to be approximately 40 mg CH_4 $m^{-2}d^{-1}$, and estimated system wide sediment flux of CH_4 to be approximately 15 mg CH_4 $m^{-2}d^{-1}$. DelSontro et al. (2010) also found CH_4 flux to be relatively constant seasonally, largely owing to the relationship between CH_4 solubility and diffusivity with respect to temperature. As temperature increases to approximately 20°C (e.g., during the summer months), CH_4 solubility decreases while CH_4 diffusivity increases by an appreciable percentage (Delsontro et al. 2010). Working in the large boreal reservoirs Lokka and Porttipahta, Huttenun et al. (2006) measured similar, even lower, CH_4 efflux from sediments, ranging from 0.44 to 25 mg CH_4 $m^{-2}d^{-1}$.

Molecular diffusion, biological mixing by organisms, respiration, and fermentation are all important benthic processes that govern concentrations of dissolved organic carbon and gases in bottom waters, including CO_2, CH_4, and O_2 (Wetzel 2001). We expect that a portion of the DOC present in the hyporheic zone sampled was labile, which means it may be respired to produce CO_2 under oxic conditions, or fermented to produce CH_4 under anoxic conditions (Morel and Herring 1993; Papadimitriou et al. 2002). In this potentially anoxic porewater environment, 10 cm below the riverbed surface, DOC may be subject to substantial amounts of fermentation and CH_4 production may be elevated as a result.

This study provides information about CH_4 and CO_2 emissions from various pathways within xeric western United States reservoirs. While our surface flux results indicated that the reservoirs sampled in our study were CO_2 sinks, and that CH_4 surface effluxes were lower compared to other studies conducted in temperate regions, we found substantive methane emissions due to ebullition and porewater flux of methane in littoral embayments, particularly during the summer. Although high, our ebullition and pore-water flux results were comparable to other recent studies conducted in temperate reservoirs. With increasing hydropower development worldwide, it is important to assess the contribution of GHG emissions from all parts of the hydropower complex, including littoral embayments, when considering the relative contribution of hydropower to global anthropogenic GHG emissions. The results presented here add to data collected on other hydropower complexes in the temperate zone that implicates this mode of power production and water management as a modest source of GHG to the atmospheric sink.

5.0 References

Arntzen, E.V. 2001. *In-situ* testing and water quality sampling in the hyporheic zone of the Columbia River, Hanford Reach, Washington. Portland State University.

Arntzen, E.V., Geist, D.R., Murray, K.J., Dawley, E.D., Vavrinec, J., and D.E. Schwartz. 2009. Influence of the Hyporheic Zone on Supersaturated Gas Exposure to Incubating Chum Salmon. North American Journal of Fisheries Management 29: 1714-1727.

Arntzen EV, KJ Klett, BL Miller, RP Mueller, RA Harnish, MA Nabelek, DD Dauble, B Ben James, AT Scholz, MC Paluch, D Sontag, and G Lester. 2012. Habitat Quality and Fish Species Composition/Abundance at Selected Shallow-Water Locations in the Lower Snake River Reservoirs, 2010-2011 -- Final Report. PNWD-4325, Battelle--Pacific Northwest Division, Richland, Washington.

Barros, N., J.J. Cole, L.J. Tranvik, Y.T. Prairie, D. Bastviken, V.L.M. Huszar, P. del Giorgio, and F. Roland. 2011. Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude. Nature Geoscience 4(9): 593-596.

Bastviken, D., J.J. Cole, M. Pace, and L. Tranvik. 2004. Methane emissions from lakes: Dependence on lake characteristics, two regional assessments, and a global estimate. Global Biogeochemical Cycles 18: GB4009.

Bednarek, A.T. 2001. Undamming rivers: A review of the ecological impacts of dam removal. Environmental Management 27(6): 803-814.

Bergstrom, I., S. Makela, P. Kankaala, and P. Kortelainen. 2007. Methane efflux from littoral vegetation stands of southern boreal lakes: An upscaled regional estimate. Atmospheric Environment 41: 339-351.

Berner, R.A. 1980. Early diagenesis: A theoretical approach. Princeton University Press, Princeton, N.J.

Broecker, W.S. and T.H. Peng. 1974. Gas exchange rates between air and sea. Tellus 26: 21-35.

Butman, D., P.A. Raymond, K. Butler, Aiken, G. 2012. Relationships between ^{14}C and the molecular quality of dissolved organic carbon in rivers draining to the coast from the conterminous United States. Global Biogeochemical Cycles 26(4): 0886-6236.

Chen, H., Y. Wu, X. Yuan, Y. Gao, N. Wu, and D. Zhu. 2009. Methane emissions from newly created marshes in the drawdown area of the Three Gorges Reservoir. Journal of Geophysical Research 114: D18301.

Cole, J.J. and N.F. Caraco. 1998. Atmospheric exchange of carbon dioxide in a low-wind oligotrophic lake measured by the addition of SF_6. Limnology and Oceanography 43(4):

647-656.

Cole, J.J., N.F. Caracao, G.W. Kling, and T.K. Kratz. 1994. Carbon dioxide supersaturation in the surface waters of lakes. Science 265: 1568-1570.

Columbia Basin Research (CBR). 2013. Lower Monumental Dam: Hydroelectric Project Information. Available at http://www.cbr.washington.edu/hydro/priestrapids and http://www.cbr.washington.edu/hydro/lowermonumental. Accessed on March 13, 2013.

Columbia River Data Access in Real Time (DART). 2013. DART River Environment. Available at: http://www.cbr.washington.edu/dart/river.html. Accessed on January 25, 2013.

Crusius, J. and R. Wanninkhof. 2003. Gas transfer velocities measured at low windspeed over a lake. Limnology and Oceanography 48(3): 1010-1017.

Del Sontro, T., D.F. McGinnis, S. Sobek, I. Ostrovsky, B. Wehrli. 2010. Extreme methane emissions from a Swiss hydropower reservoir: Contribution from bubbling sediments. Environmental Science and Technology 44: 2419-2425.

Duchemin, E., Lucotte, M., and Caneul, R. 1999. Comparison of static chamber and thin boundary layer equation methods for measuring greenhouse gas emissions from large water bodies. Environmental Science and Technology 33: 350-357.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.). Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate. Cambridge University Press, Cambridge, United Kingdom and New York, NY.

Furrer, G. and B. Wehrli. 1996. Microbial reactions, chemical speciation, and multicomponent diffusion in porewaters of a eutrophic lake. *Geochimica et Cosmochimica Acta* 60(13): 2333-2346.

Galy-Lacaux, C., R. Delmas, C. Jambert, J. Dumestre, L. Labroue, S. Richard, and P. Gosse. 1997. Gaseous emissions and oxygen consumption in hydroelectric dams: A case study in French Guiana. *Global Biogeochemical Cycles* 11: 47-483.

Guerin, F., G. Abril, S. Richard, B. Burban, C. Reynouard, P. Seyler, and R. Delmas. 2006. Methane and carbon dioxide emissions from tropical reservoirs: Significance of downstream reservoirs. Geophysical Research Letters 33: doi:10.1029/2006GL027929.

Guy, H.P. 1969. Laboratory theory and methods for sediment analysis. In: U.S. Geological Survey (ed.), Techniques of water resources investigations of the United States Geological Survey. U. S. Government Printing Office, Washington, D.C.

Heiri O., A.F. Lotter, and G. Lemcke. 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: Reproducibility and comparability of results. Journal of Paleolimnology 25: 101-110.

Huttunen, J.T., T.S. Vaisanen, S.K. Hellsten, and P.J. Martikainen. 2006. Methane fluxes at the sediment-water interface in some boreal lakes and reservoirs. Boreal Environmental Research 11: 27-34.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: The scientific basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. S. Solomon et al., Cambridge University Press, New York.

International Hydropower Association, United Nations Education, Scientific, and Cultural Organzation. 2010. GHG Measurement guidelines for freshwater reservoirs. IHA London.

Jaehne, B., G. Heinz, and W. Dietrich. 1987. Measurement of the diffusion coefficients of sparingly soluble gases in water. Journal of Geophysical Research 92: 10767-10776.

Juutinen, S., J. Alm, T. Larmola, J.T. Huttunen, K. Moreo, P.J. Martikainen, and J. Silvola. 2003. Major implication of the boreal zone for methane release from boreal lakes. Global Biogeochemical Cycles 17: doi:10.1029/2003GB002105.

Kankaala, P., T. Kaki, S. Makela, A. Ojala, H. Pajunen, and L. Arvola. 2005. Methane efflux in stands of three common emergent macrophytes in boreal mesoeutrophic lakes. Global Change Biology 11: 145-153.

Kelker, D. and J. Chanton. 1997. The effect of clipping on methane emissions from *Carex*. Biogeochemistry 39: 37-44.

Lide, D.R. 2007. CRC Handbook of Chemistry and Physics, 88th Ed. CRC Press, New York.

MacIntyre, S., R. Wanninkhof, and J.P. Chanton. 1995. Trace gas exchange across the air-water interface in freshwater and coastal marine environments. In Freshwater and coastal marine environments, P.A. Matson and Harris (eds.). Blackwell Science, Hoboken, New Jersey.

Morel, F.M.M. and J.G. Hering. 1993. Principles and Applications of Aquatic Chemistry. John Wiley and Sons, Inc., New York, NY.

Mulholland, P., J. Mosher, A. Fortner, J. Phillips, and M. Bevelhimer. 2010. Greenhouse gas emissions from U.S. hydropower reservoirs. Submitted to the Wind and Water Power Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

Nuernberg, G. 2004. Quantified hypoxia and anoxia in lakes and reservoirs. Freshwater Research 4: 42-54.

ORNL (Oak Ridge National Laboratory). 2013. National Hydropower Asset Assessment Project (NHAAP) Database.

Papadimitriou, S., H. Kennedy, I. Bentalen, and D.N. Thomas. 2002. Dissolved organic carbon in sediments from the eastern North Atlantic. Marine Chemistry 79: 37-47.

Roehm, C. and A. Tremblay. 2006. Role of turbines in the carbon dioxide emissions from two reservoirs. Journal of Geophysical Research Atmospheres 111(D24): DOI: 10.1029/2006JD007292

Santos, M., B. Matvienko, L. Rosa, L. Sikar, and E. Santos. 2005. Gross greenhouse gas emissions from Brazilian hydro reservoirs. In: Tremblay, A., L. Varfalvy, C. Roehm, and M. Garneau (eds.). Greenhouse gas emissions: Fluxes and processes, hydroelectric reservoirs and natural environments. *Environmental Science Series*, Springer, New York, NY.

Schindler, J.E. and D.P. Krabbenhoft. 1998. The hyporheic zone as a source of dissolved organic carbon and carbon gases to a temperate forested stream. Biogeochemistry 43: 157-174.

Seybold WF and DH Bennett. 2010. Inventory and Impact/Benefit Analyses of Sediment Disposal for Salmonid Fishes at Selected Sites in the Lower Snake River Reservoirs, Washington. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Soumis, N., E. Duchemin, R. Canuel, and M. Lucotte. 2004. Greenhouse gas emissions from reservoirs of the western United States. Global Biogeochemical Cycles 18: GB3022

St. Louis, V.L., Kelly, C.A., Duchemin, E., Rudd, J.W.M. and Rosenberg, D.M. 2000. Reservoirs surfaces as sources of greenhouse gases to the atmosphere: A global estimate. BioScience 50: 766-775.

Stephens, D.B., K.C. Hsu, M.A. Prieksat, M.D. Ankeny, N. Blandford, T.L. Roth, J.A. Kelsey, J.R. Whitworth. 1998. A comparison of estimated and calculated effective porosity. Hydrogeology Journal 6: 156-165.

Strayer, R.F. and J.M. Tiedje. 1978. In situ methane production in a small, hypereutrophic, hard-water lake: Loss of methane from sediments by vertical diffusion and ebullition. Limnology and Oceanography 23(6): 1201-1206.

Sweerts, J.R.A., M. Bar-Gilissen, A.A. Cornelese, and T.E. Cappenberg. 1991. Oxygen-consuming processes at the profundal and littoral sediment-water interface of a small meso-eutrophic lake (Lake Vecten, The Netherlands). Limnology and Oceanography 36(6): 1124-1133.

Taub, D. 2010. Effects of rising atmospheric concentrations of carbon dioxide on plants. Nature Education Knowledge 3(10): 21.

Therrien, J., Tremblay, A. and Jacques, R. 2005. CO_2 emissions from semi-arid reservoirs and natural aquatic ecosystems. In Tremblay, A., L. Varfalvy, C. Roehm et M. Garneau (eds.). Greenhouse gas emissions: Fluxes and processes, hydroelectric reservoirs and natural environments. Environmental Science Series, Springer, Berlin, Germany, Heidelberg, Germany, and New York, NY.

Tremblay, A., L. Varfalvy, C. Roehm, M. Garneau. 2005. Greenhouse gas emissions: Fluxes and processes, hydroelectric reservoirs and natural environments. Springer, Berlin, Germany, Heidelberg, Germany, and New York, NY.

USACE (U.S. Army Corps of Engineers). 2012. Watermanagement anonymous FTP site. USACE, Northwestern Division Civil Works and Management Directorate, Columbia Basin Water Management Division. Available: www.nwd-wc.usace.army.mil/ftppub/water_quality/12data/. (January 2013).

U.S. Geological Survey (USGS). 2013. National Water Information System. Available at: http://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00060=on&cb_00065=on&format=gif_stats&period=&begin_date=2012-01-01&end_date=2013-01-01&site_no=12472800. Accessed January 1, 2013.

Wanninkhof, R. 1992. Relationship between wind speed and gas exchange over the ocean. Journal of Geophysical Research 97: 7373-7382.

Weiss, R.F. 1974. Carbon dioxide in water and seawater: The solubility of a non-ideal gas. Marine Chemistry 2: 203-215.

Wiesenburg, D.A. and N.L. Guinasso. 1979. Equilibrium solubilities of methane, carbon monoxide, and hydrogen in water and sea water. Journal of Chemical and Engineering Data 24(4): 356-360.

Wilhelm, E., R. Battino, and R.J. Wilcox. 1977. Low-pressure solubility of gases in liquid water. Chemical Reviews 77(2): 219-262.

Wetzel, R.G. 2001. Limnology: Lake and river ecosystems. Academic Press, San Diego, CA and London, United Kingdom.

Yamamoto, S., J.B. Alcauskas, and T.E. Crozier. 1976. Solubility of methane in distilled water and seawater. Journal of Chemical and Engineering Data 21(1): 78-80.

Appendix A

Study Site Locations
(electronic file submitted to DOE)

Appendix B

Gas Concentrations and Flux Data
(electronic file submitted to DOE)

Appendix C

Gas Concentrations and Flux Summary Tables
(electronic file submitted to DOE)

Appendix D

Water Quality Data
(electronic file submitted to DOE)

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From: Aaron Bush <abush@ppcpdx.org>
Sent: Tuesday, November 19, 2019 3:53 PM
To: Kaseweter,Alisa D (BPA) - DI-7
Subject: RE: carbon conversation
Attachments: 2017 Methane in Temperature Hydropower Reservoirs.pdf

Hi Alisa,

I was wondering if you've seen the attached study? It is from 2017 and includes methane emissions measurements at Lower Monumental and Priest Rapids. Has the USACE put out a response to this? (it was completed after the document you sent me)

Aaron Bush
Energy Analyst
Public Power Council
503-595-9778

From: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Sent: Tuesday, November 19, 2019 9:42 AM
To: Aaron Bush <abush@ppcpdx.org>
Subject: RE: carbon conversation

Hi Aaron,

I was just pulling together information for you. I feel like the question about methane emissions from reservoirs comes up every few years. The Corps and Council have concluded that methane emissions are not a major issue for the reservoirs on the Columbia and Snake Rivers. The level of methane emissions from a reservoir is pretty site specific and depends on the amount of decaying material. It's typically a more significant issue in tropical areas or where there is large amounts of agricultural runoff.

I've attached a 2016 Corps memo on this subject and the Council's findings are here. The Council also links you to some more information if you really want to dive into it.

I hope this is helpful and happy to discuss further.

Best,
Alisa

From: Aaron Bush [mailto:abush@ppcpdx.org]
Sent: Tuesday, November 19, 2019 9:24 AM
To: Kaseweter,Alisa D (BPA) - DI-7
Subject: RE: carbon conversation

A couple more questions:

Do you have any resources on hand that you could forward over about this issue? Has BPA taken a stance on this before?

Thanks!

Aaron Bush
Energy Analyst
Public Power Council
503-595-9778

From: Aaron Bush
Sent: Monday, November 18, 2019 4:27 PM
To: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Subject: RE: carbon conversation

Sorry, I must be getting cross-eyed because I hit the wrong button and sent it without the attachment as I was about to attach the document. Here's the bill.

Aaron Bush
Energy Analyst
Public Power Council
503-595-9778

From: Aaron Bush
Sent: Monday, November 18, 2019 4:24 PM
To: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Subject: RE: carbon conversation

Hi Alisa,

Scott asked me to investigate recent House bill language regarding hydro's carbon emissions related to reservoirs and I was hoping we could tack it on to our conversation next Monday. Attached, Section 203 (b)(4) and 203 (g). I think the goal would be to form a response about the types of reservoirs in the BPA system. Let me know if you have any questions.

Thanks,

Aaron Bush
Energy Analyst
Public Power Council
503-595-9778

From: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Sent: Friday, November 15, 2019 1:48 PM
To: Aaron Bush <abush@ppcpdx.org>; Michael Deen <mdeen@ppcpdx.org>; Lauren Tenney Denison <tenney@ppcpdx.org>; Megan Stratman <mstratman@nru-nw.com>
Subject: RE: carbon conversation

That works for me. Thanks!

Alisa

From: Aaron Bush [mailto:abush@ppcpdx.org]
Sent: Friday, November 15, 2019 11:49 AM
To: Kaseweter,Alisa D (BPA) - DI-7; Michael Deen; Lauren Tenney Denison; Megan Stratman
Subject: RE: carbon conversation

Hi again,

It looks like the morning of the 25th works for everyone. How about 10 a.m. at the PPC offices?

Thanks

Aaron Bush
Energy Analyst
Public Power Council
503-595-9778

From: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Sent: Friday, November 15, 2019 9:58 AM
To: Aaron Bush <abush@ppcpdx.org>; Michael Deen <mdeen@ppcpdx.org>; Lauren Tenney Denison <tenney@ppcpdx.org>
Subject: RE: carbon conversation

Hi Aaron,

The 25th is open for me other than 1:30-3:30. I'm happy to have Megan join us as well.

Thanks!
Alisa

From: Aaron Bush [mailto:abush@ppcpdx.org]
Sent: Friday, November 15, 2019 9:32 AM
To: Kaseweter,Alisa D (BPA) - DI-7; Michael Deen; Lauren Tenney Denison
Subject: RE: carbon conversation

Hi Alisa,

It looks like the 25th or 26th would work best for us so that everyone can come (we were also thinking of including Megan Stratman from NRU). If that doesn't work, we could do sometime after Thanksgiving, maybe the morning of the 3rd?

Thanks,
Aaron

Aaron Bush
Energy Analyst
Public Power Council
503-595-9778

From: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Sent: Thursday, November 14, 2019 2:24 PM
To: Aaron Bush <abush@ppcpdx.org>; Michael Deen <mdeen@ppcpdx.org>; Lauren Tenney Denison <tenney@ppcpdx.org>
Subject: carbon conversation

Hi Aaron, Lauren, and Mike,

Do you guys have some time in the next few weeks to talk about an informal public power forum on carbon? I'd appreciate your input as I try to pull something together to get started early in the new year.

Thanks!
Alisa

Alisa Kaseweter
Acting Oregon Liaison | Intergovernmental Affairs
Climate Change Specialist
BONNEVILLE POWER ADMINISTRATION
alkaseweter@bpa.gov
503-230-4358 (office) | [redacted] (cell)

From:	Kaseweter,Alisa D (BPA) - DI-7
Sent:	Friday, November 20, 2020 11:48 AM
To:	Lut,Agnes (BPA) - E-4
Cc:	Zelinsky,Benjamin D (BPA) - E-4; Leary,Jill C (BPA) - LN-7; Guiao,Rebecca C (BPA) - LN-7; Olive,J Courtney (BPA) - LP-7
Subject:	RE: GHGs and Hydropower: NHA prep for 2021
Attachments:	DRAFT NHA Whitepaper - Hydropower and GHGs (002)_BPA edits.docx

Hi Agnes,

I took a light approach to edits, but do have a few suggestions you could share with NHA. Overall, I found it a little difficult to follow the trail from the technical information to the points I think they are trying to make. They may want to connect those dots a little better for the audience.

Again, in addition to these suggestions, I'd send the reservoir emission section from the CRSO EIS Air Quality appendix (chapter 5 of appendix G) + Jill's suggestion of responses to comments (Appendix T of the final EIS and can be found by searching for "methane.").

Thanks, and happy Friday!
Alisa

From: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>
Sent: Monday, November 16, 2020 1:02 PM
To: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Cc: Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Guiao,Rebecca C (BPA) - LN-7 <rcguiao@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: GHGs and Hydropower: NHA prep for 2021

Alisa,
It would be great if you could get your edits to me in track changes before Dec. 16th.

Same, I have heard of the same proposals considering reservoir emissions from hydropower in determining how "clean" hydro is.

I'll pull the methane section from the EIS and send it over to Dennis as a start. I'll let him know BPA will provide him with edits by Dec. 22. I'll add my edits to your edit's to NHAs doc once I get it from you. And yes, we already have TMDL talking points that speak to the methane and interconnection benefit that I can use in my email to Dennis:

"These federal dams have a legacy of providing carbon-free energy to the Pacific Northwest and are not a contributor to increasing global greenhouse gas (GHG) emissions levels and air temperatures. The dams also provide valuable integration services for other renewable resources like wind and solar and are positioned to help states like Oregon and Washington reach their GHG emission reduction goals. Additionally, the federal reservoirs emit significantly less methane than dams in other regions."

Thank you
Agnes

From: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Sent: Monday, November 16, 2020 12:01 PM
To: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>
Cc: Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Guiao,Rebecca C (BPA) - LN-7 <rcguiao@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: GHGs and Hydropower: NHA prep for 2021

Hi Agnes,

Thanks. I can take a look at this more closely over the next couple weeks. This is about methane emissions from reservoirs – I'm assuming the NHA reached out to the Corps as well? We (BPA) actually did a fairly complete overview of methane emissions – and why they aren't likely a significant source of emissions for the CRS – in the CRSO EIS. We may just forward them that section as an FYI. My other thought on a quick initial read through is the "conclusion" could do a better job of articulating the role carbon-free hydropower plays in integrating intermittent renewable resources thus playing an important role in the shift to clean energy. We might make some suggestions there.

Cc'ing Courtney to bring him into the email chain. Erik Pytlak wouldn't have much to add here as he doesn't work on GHG emissions. Jen Boyer is very knowledgeable on methane emissions from reservoirs due to work in her old position, but this document is pretty light on conclusions from that.

Dennis Cakert mentions preparing for what might come up with the new administration. Some of the clean energy legislation that I've seen floating around at a national level proposes considering reservoir emissions from hydropower in determining how "clean" hydro is.

Alisa

From: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>
Sent: Monday, November 16, 2020 11:35 AM
To: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Cc: Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Guiao,Rebecca C (BPA) - LN-7 <rcguiao@bpa.gov>
Subject: GHGs and Hydropower: NHA prep for 2021

Alisa
NHA has asked if we can provide them with feedback on the attached GHG paper by end of year. Are you good with that? If yes, I suggest we get our comments to NHA before Dec. 22nd. I can manage the process.

I think it would be helpful for you, Eric and I to take a look at the attached paper and provide NHA feedback. Since climate change plays a pivotal part in the temperature TMDL, and both us and NHA provided EPA public comments (TMDL and NPDES public comments) on how climate change is impacting the Columbia and Snake river temps – I think it would be a good idea for us to provide NHA comments on the attached.

Thumbs up?

Thank you
Agnes

From: Dennis Cakert (NHA) <dennis@hydro.org>
Sent: Monday, November 16, 2020 10:40 AM

To: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>
Subject: [EXTERNAL] NHA prep for 2021

Hi Agnes,

I am hoping for your feedback on two unrelated items before the year is over:

First, attached is a survey regarding expected investment in hydropower assets the next few years. We're hopeful the survey results will demonstrate that hydropower is a robust and active marketplace, not merely cement in the ground. This information will help us move the ball on a number of issues.

Second, attached is a first draft of NHA's whitepaper on hydropower and greenhouse gases. Given the change in administration, NHA needs to be prepared to address the methane question in 2021. Any feedback is greatly appreciated.

Both are items of importance to the NHA Board heading into 2021. If you have any questions I'd be happy talk anytime.

Sincerely,

Dennis Cakert
Manager of Regulatory Affairs and Market Policy
National Hydropower Association
601 New Jersey Ave. NW Suite 660
Washington, D.C. 20001
202.697.2404

Understanding Greenhouse Gases and Hydropower

Opening paragraph?

According to the United Nations Intergovernmental Panel on Climate Change (U.N. IPCC), hydropower is one of the cleanest energy resources in the United States.[1] Along with wind, solar, and nuclear, hydropower produces no direct emissions.

However, a few recent studies suggest hydropower lifecycle emissions can act as either a carbon source or sink. Taken out of context, both of these claims are misleading. The lifecycle emissions associated with hydropower in these reports, whether as a source or sink, is attributable to dams. While dams and hydropower are related, there are important distinctions: Of the 87,000 dams in the U.S., only 3% produce hydropower. To the extent emissions from dams are a concern, it is an issue for all 87,000 dams in the U.S., not only those that produce hydropower.

Source (2018)	MMT CO2 equivalent
Total	6,667
Fossil Fuels	5,423
Agriculture	618
Industry	376
Landfills	111
Cropland	39
Wastewater Treatment	19
Forest Fires	11
Composting	5
Coastal Wetlands	4
*Hydropower (NHA)	2
Other	59

Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO2 Eq.) **(EPA 2018)**
*NHA Estimate Based on U.N. IPCC Data

To accurately estimate net lifecycle emissions from hydropower requires two steps: First, estimating the net emissions impact of the dam. Second, attributing those emissions among the different purposes of the dam. Both are difficult measurements with no widely accepted methodologies, but using U.N. IPCC data and this two-step process shows that lifecycle emissions from hydropower are negligible as compared to….

Comment [KD(-D1]: Perhaps more clearly state that the estimates are fairly dam specific

Comment [KD(-D2]: For all dams collectively, or generally, or as compared to global emissions? Because some dams do have significant emissions in and of themselves.

Step 1: Calculate emissions specific to Dams

Dams are multi-purpose water infrastructure projects that store water for irrigation, drinking water, flood control, navigation, and recreation. Of the 87,000 dams in the U.S., less than 3% produce hydropower.[2] For example, New York City supplies daily water to tens of millions of residents by using a series of large dams to store water outside the city, none of which produce hydropower.[3] Another example is the Bureau of Reclamation, which manages water in the west using 500 dams, of which only 78 produce hydropower.[4]

Dam construction and removal create potential emissions sources or sinks by altering natural processes in aquatic ecosystems. All aquatic ecosystems act as emissions sources or sinks through the production and consumption of organic carbon.[5] For example: The EPA estimates coastal wetlands produce methane at a rate of 3.6 MMT of CO2 equivalent per year.[6]

> *"All freshwater systems, whether they are natural or manmade, emit GHGs due to decomposing organic material. This means that lakes, rivers, estuaries, wetlands, seasonal flooded zones and reservoirs emit GHGs."* – U.N. IPCC, Renewable Energy Sources and Climate Change Mitigation (2012)

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[1] Renewable Energy Sources and Climate Change Mitigation (Special Report of the Intergovernmental Panel on Climate Change 2012)
[2] A Handbook of Hydropower Basics (FERC 2017)
[3] New York City's Water Supply System (New York Department of Environmental Protection)
[4] Projects and Facilities (Bureau of Reclamation 2020)
[5] Understanding the Uncertainty Regarding Methane Emissions from Waterbodies (Department of Energy)
[6] U.S. Greenhouse Gas Emissions and Removals from Land Use, LandUse Change, and Forestry (EPA 2018)

Understanding Greenhouse Gases and Hydropower

Estimates of emissions from aquatic ecosystems are complex and difficult to replicate because of the many variables to consider, such as depth, temperature, duration, location, latitude, land uses, sunshine, and more.[7] Given the highly site-specific nature of dams and aquatic ecosystems, transferring methodologies or results from one dam to the next does not guarantee accurate results. At times dams also act as a sink for GHG emissions, which would also need to be considered.

Step 2: Allocate emissions specific to Hydropower

Hydropower is the force of gravity pulling water through a turbine, which spins a generator to create electricity. While hydropower is most often located at a dam, 24% of U.S. hydropower facilities are located on canals and conduits, such as those used for irrigation.[8] Simply passing water through a turbine does not produce or consume greenhouse gases. Rather, the emissions associated with hydropower are those that result from the dam.

The 3% of dams in the U.S. that produce hydropower are multi-purpose projects, of which hydropower is one of many different uses. The Federal Energy Regulatory Commission, which oversees the 2,000 non-federal hydropower dams in the U.S., requires projects to be "best adapted to a comprehensive plan for improving or developing a waterway or waterways for the benefit of multiple public uses," such as irrigation, flood control, conservation, navigation, and recreation. For example: many hydropower dams elevate reservoir levels above the intakes of irrigation systems. They also create whitewater rafting opportunities by releasing water at certain times.

> *"An important issue for hydropower is the multipurpose nature of most reservoir projects, and allocation of total impacts to the several purposes that is then required. Many LCAs to date allocate all impacts to the electricity generation function, which in some cases may overstate the emissions for which they are 'responsible"* – U.N. IPCC, Renewable Energy Sources and Climate Change Mitigation (2012)

The same is true for the 175 federal hydropower dams: The Bureau of Reclamation, Army Corps of Engineers, and Tennessee Valley Authority operate dams for the purpose of water management, of which hydropower is one of many different uses. There is no formula for allocating the overall purpose of a dam to individual uses; this is generally project-specific.

Step 1 + Step 2 = Hydropower is Clean:

The U.N. IPCC finds most estimates of lifecycle emissions from hydropower are between 4 – 14 grams of CO2 equivalent per kwh, less than solar (30-80g CO2/kwh) and similar to wind (8-20g CO2/kwh).[9] Hydropower produced 292.52 billion kwh of electricity in the U.S. in 2018, the most of any renewable resource.[10] Multiplying 292.52 billion kwh by 14 grams of CO2 equals 4 million metric tons (MMT) of CO2 equivalent emissions. Factoring in a conservative estimate that hydropower is 50% of the purpose of these dams results in a maximum of 2 MMT of CO2 equivalent attributable to hydropower in the U.S. in 2018. Compared to other sources of emissions in the electricity sector (?), hydropower lifecycle emissions are negligible.[11]

---

[7] Greenhouse Gas Emissions from Freshwater Reservoirs: What Does the Atmosphere See? (Prairie et al 2017)
[8] Hydropower Vision Report (Department of Energy 2016)
[9] AR5 Synthesis Report: Climate Change (United Nations Intergovernmental Panel on Climate Change 2014)
[10] Short Term Energy Outlook (Energy Information Administration 2020)
[11] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 (EPA 2018)

Understanding Greenhouse Gases and Hydropower

In addition, of the more than 2,000 MWs of hydropower growth in the U.S. since 2000, only five small projects required a new dam.[12] Instead, hydropower growth in the U.S. takes advantage of existing water infrastructure by upgrading conduits, canals, and non-powered dams to produce electricity. These projects do not have emissions impacts since they do not require a new dam. The Department of Energy estimates there is 5 GWs of new hydropower potential at 671 existing non-powered dams in the U.S.[13]

Conclusion:
Hydropower is ~~arguably~~ one of the cleanest energy resources available in the U.S.~~,~~ As a baseload resource, it provides valuable integration services for other renewable resources like wind and solar, making hydropower well-positioned to help decarbonize the electricity sector and economy. ~~especially considering the low impact nature of new hydropower developments.~~ Lifecycle emissions from hydropower are negligible when considering lifecycle emissions of other resources, and are not a factor of hydropower generation itself but rather the original construction of the dam itself. To the extent that lifecycle emissions of hydropower are a concern, it is an issue for all dams in the U.S., since only 3% of the Nation's 87,000 dams produce hydropower.

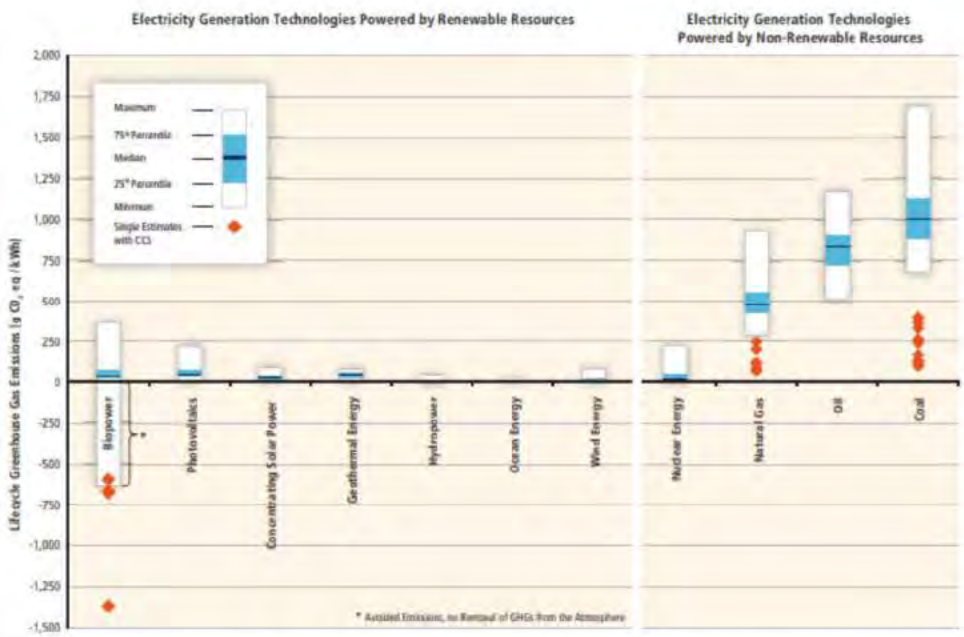
To reduce emissions economy wide, the United States needs a renewable, reliable, and affordable electric grid. Today, electricity production is responsible for 27% of total emissions in the United States, of which 99% is from fossil fuels, such as coal and natural gas.[14] Expanding renewable energy, including hydropower, reduces emissions from the electric sector, which can help reduce emissions economy wide through electrification.[15]

Comment [KD(-D3]: I started this above, but would elaborate on the importance of hydropower as a baseload resource bringing the ability to provide integration services, etc.

[12] 2017 Hydropower Market Report (Department of Energy 2018)
[13] Hydropower Vision Report (Department of Energy 2016)
[14] Overview of Greenhouse Gases (EPA 2018)
[15] EIA projects that renewables will provide nearly half of world electricity by 2050 (EIA 2019)

Field Code Changed

Understanding Greenhouse Gases and Hydropower



Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

Figure SPM.8 | Estimates of lifecycle GHG emissions (g CO_2eq/kWh) for broad categories of electricity generation technologies, plus some technologies integrated with CCS. Land use-related net changes in carbon stocks (mainly applicable to biopower and hydropower from reservoirs) and land management impacts are excluded; negative estimates[10] for biopower are based on assumptions about avoided emissions from residues and wastes in landfill disposals and co-products. References and methods for the review are reported in Annex II. The number of estimates is greater than the number of references because many studies considered multiple scenarios. Numbers reported in parentheses pertain to additional references and estimates that evaluated technologies with CCS. Distributional information relates to estimates currently available in LCA literature, not necessarily to underlying theoretical or practical extrema, or the true central tendency when considering all deployment conditions. [Figure 9.8, 9.3.4.1]

From: Koehler,Birgit G (BPA) - PG-5
Sent: Wednesday, November 3, 2021 1:27 PM
To: Webster-Wharton,Stacy T (BPA) - PGA-6; Johnson,Kimberly O (BPA) - PGAF-6; Calvert,Paula P (BPA) - E-4
Subject: FW: [EXTERNAL] AM DOE Reservoir Emissions Presentation
Attachments: LIHI_GHG Presentation_Final.pdf

You might be interested in seeing this. It looks like it is being passed around the agency, and I didn't see your names in the distributions below.

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Tuesday, November 2, 2021 1:28 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Cc: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: [EXTERNAL] AM DOE Reservoir Emissions Presentation

I think that the future work is interesting and could be informative, but it's years in the making. The key takeaways to me are that the science is immature, and emissions are reservoir specific and can vary temporally. This is consistent with what we included in the CRSO (AQ appendix), so for now that is still a good reference document if questions come up. I like that they are looking at what emissions might be attributable to hydropower versus other purposes of the dam.

From: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>
Sent: Tuesday, November 2, 2021 12:57 PM
To: Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: FW: [EXTERNAL] AM DOE Reservoir Emissions Presentation

Thanks Courtney for passing this along…it would be interesting to hear if you or Alisa have any thoughts on this issue since it may come up in future discussions.

From: Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Sent: Friday, October 29, 2021 2:37 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Subject: FW: [EXTERNAL] AM DOE Reservoir Emissions Presentation

Passing along DOE document "Understanding Greenhouse Gas Emissions from U.S. Hydropower Reservoirs." I haven't looked at it.

From: Malin,Debra J (BPA) - PTL-5 <djmalin@bpa.gov>
Sent: Friday, October 29, 2021 11:25 AM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Spain,Alex J (BPA) - PTF-5 <ajspain@bpa.gov>; Germer,Matthew J (BPA) - PTM-5 <mjgermer@bpa.gov>; Federovitch,Eric C (BPA) - PTL-5 <ecfederovitch@bpa.gov>; Rohe,Kristina E (BPA) - PTC-5 <kerohe@bpa.gov>; Johnson,Anders L (BPA) - TPLE-TPP-2 <aljohnson@bpa.gov>; Aggarwal,Ravi K (TFE)(BPA) - TPL-TPP-2 <rkaggarwal@bpa.gov>; Marker,Douglas R (BPA) - AIR-7 <drmarker@bpa.gov>; Farleigh,Kevin S (BPA) - PSW-6

<ksfarleigh@bpa.gov>; Baskerville,Sonya L (BPA) - AIN-WASH <slbaskerville@bpa.gov>; Cogswell,Peter (BPA) - AI-7 <ptcogswell@bpa.gov>; Klumpp,Elizabeth C (BPA) - AIR-WSGL <ecklumpp@bpa.gov>; Meyers,Andrew P (BPA) - PTF-5 <apmeyers@bpa.gov>; Stalnaker Jr,John David (BPA) - PSRF-6 <jdstalnaker@bpa.gov>; Cornejo,Paulina (BPA) - PSRF-6 <ypcornejo@bpa.gov>; Burczak,Sarah E (BPA) - BD-3 <seburczak@bpa.gov>; Fahy,Benjamin J L (BPA) - PGST-5 <bjfahy@bpa.gov>; Patton,Kathryn B (BPA) - PSS-SEATTLE <kbpatton@bpa.gov>; Peacock,Julie (BPA) - AIR-7 <jxpeacockwilliamson@bpa.gov>; Green,Laura E (TFE)(BPA) - TSE-TPP-2 <legreen@bpa.gov>; Sheckells,Katie (BPA) - TSB-TPP-2 <kksheckells@bpa.gov>; Maslow,Jeffrey J (BPA) - ECP-4 <jjmaslow@bpa.gov>; Doumbia,Julie A (BPA) - PEH-6 <jadoumbia@bpa.gov>; Palmer,Michele L (BPA) - ECP-4 <mlpalmer@bpa.gov>; Dickenson-Scrivner,Brianna N (BPA) - TPLE-TPP-2 <bndickenson@bpa.gov>; Perry,Marcus I (BPA) - PSW-SEATTLE <miperry@bpa.gov>; Traetow,Emily G (BPA) - PSR-6 <egtraetow@bpa.gov>; Dernovsek,David K (MFE)(BPA) - PTF-5 <dkdernovsek@bpa.gov>; Stiffler,Peter B (BPA) - PSRF-6 <pbstiffler@bpa.gov>
Subject: FW: [EXTERNAL] AM DOE Reservoir Emissions Presentation

FYI

From: Shannon Ames <sames@lowimpacthydro.org>
Sent: Friday, October 29, 2021 11:16 AM
To: Julie Gantenbein <jgantenbein@waterpowerlaw.com>; Rick Glick <richardglick@dwt.com>; T.J. Heibel <tj.heibel@pnnl.gov>; Julie McNamara <jmcnamara@ucsusa.org>; Jack Palmer <jacob.palmeriii@gmail.com>; Brenda Pracheil <pracheilbm@ornl.gov>; Shawn Seaman <sseaman@lowimpacthydro.org>; Mark Zakutansky <mzakutansky@outdoors.org>; Lisa Zarek <leezarek@comcast.net>; Sam Krasnow <skrasnow@nrdc.org>; Elizabeth Ablow <Elizabeth.Ablow@seattle.gov>; Sean Faulds <sean.faulds@brookfieldrenewable.com>; Sarah Hill Nelson <shn@bowersockpower.com>; Andrew Locke <alocke@essexhydro.com>; Malin,Debra J (BPA) - PTL-5 <djmalin@bpa.gov>; Dan Parker <Dan.parker@eaglecreekre.com>; Jon Petrillo <jon@gravityrenewables.com>; John Ragonese <jragonese@greatriverhydro.com>; Sania <sania.radcliffe@pgn.com>; Todd Wynn <twynn@hullstreetenergy.com>; Tim Welch <timothy.welch@ee.doe.gov>; Jonathan Burnston <jonathan.burnston@karbone.com>; Philip Raphals <philip@centrehelios.org>; Maya Kelty <mkelty@3degreesinc.com>; Jennifer Martin <jmartin@resource-solutions.org>; Robert Deibel <rhdeibel56@gmail.com>; Shannon Ames <sames@lowimpacthydro.org>; Whitman Constantineau <wconstantineau@lowimpacthydro.org>; mfischer@lowimpacthydro.org
Subject: [EXTERNAL] AM DOE Reservoir Emissions Presentation

Dear board,

Attached please find the slides from DOE's presentation on the state of the science of reservoir emissions.

Best,
Shannon

Shannon Ames, Executive Director (she/her)
sames@lowimpacthydro.org
(b)(6) [redacted] cell
http://lowimpacthydro.org
1167 Massachusetts Ave, Office 407, Arlington, MA 02476
The Low Impact Hydropower Institute (LIHI) is a non-profit 501(c)(3) organization dedicated to reducing the impacts of hydropower generation through the certification of hydroelectric projects that avoid or significantly reduce environmental impacts and invest in rivers.

Sent via Superhuman

OAK RIDGE National Laboratory

Understanding Greenhouse Gas Emissions from U.S. Hydropower Reservoirs

Natalie Griffiths, the ORNL Team, & Hoyt Battey

Oak Ridge National Laboratory; Water Power Technologies Office, Department of Energy

October 26, 2021

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Summary of state of the science

- Greenhouse gases (GHGs) are emitted from all inland waters.
- Three main GHGs (CO_2, CH_4, N_2O); CH_4 is of greatest uncertainty and concern for reservoirs (both with and without hydropower).
- High uncertainty in GHG emission estimates:
  - GHG measurements are often spatially and temporally "spotty", especially with respect to CH_4 emissions.
  - Not all emission pathways are measured, and methodology is not consistent.
  - Lack of emission measurements especially from temperate latitudes when compared to tropical and boreal areas.
- Ability to evaluate and attribute emissions to reservoirs compared to the pre-reservoir state is immature.

Summary of state of the science

- Extrapolated / modeled estimates for global GHG emissions are also highly uncertain.
  - Global emission estimates for reservoirs range from 71 to 3,380 Tg CO_2 eq./y; translates to 0.14 to 6.6% of global GHG emissions.
- Coarse screening tools for estimating reservoir emissions (IHA's G-res), but uncertainty in the underlying models, including in the drivers of GHG emissions.
- Ability to evaluate extent to which hydropower operations within a reservoir influence GHGs is the most immature. Difficult to disentangle and attribute which portion of emissions may be attributed to hydropower vs. other reservoir uses/purposes.

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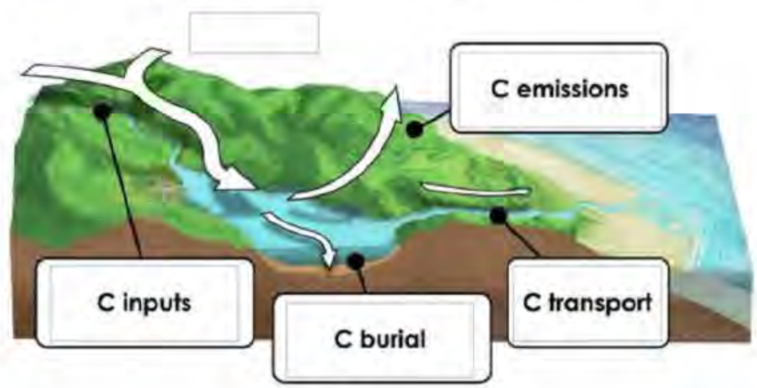
GHGs are emitted from all water bodies

- Carbon enters freshwaters from land. There are multiple fates of C in freshwaters (emission, burial, transport downstream).
- Of these fates, estimates of emissions are the most uncertain.
- Greenhouse gases (GHGs) emitted from water bodies:
  - Carbon dioxide (CO_2): formed from respiration of organic matter, source is often terrestrial.
  - Methane (CH_4): high global warming potential (28), formed under anoxic conditions.
  - Nitrous oxide (N_2O): not well studied, may be important given its high global warming potential (265).



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Multiple sources and emission pathways for GHGs

- Sources of GHGs emitted from freshwaters:
  - Emission of terrestrially derived CO_2 (from soil respiration)
  - Mineralization of organic C to CO_2
  - In-situ primary production and decomposition to CO_2
  - **Methanogenesis (anaerobic respiration) converting organic C to CH_4**
  - Methane oxidation (conversion of CH_4 to CO_2)
- Pathways for GHG emission:
  - Diffusion
  - **Ebullition (bubble formation)**
  - Plant-mediated transport (emergent vegetation)
  - **Degassing (spillways, turbines)**

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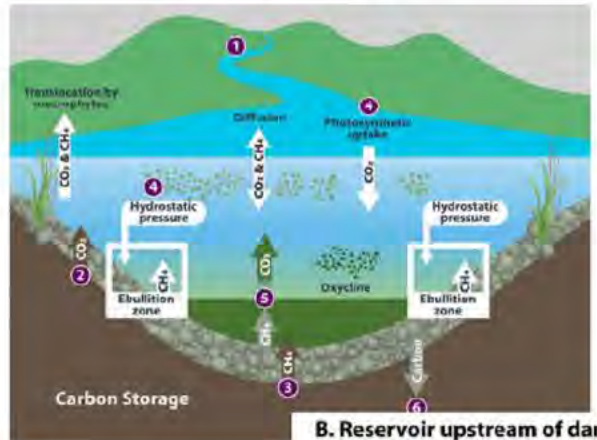
Understudied CH_4 emission pathways in reservoirs

- Ebullition (bubbling):
  - Large contribution to GHG emissions from reservoirs.
  - Very hard to accurately measure due to spatiotemporal variation.
  - Predominantly from littoral zone.
- Degassing (spillways, turbines):
  - Large contribution to emissions.
  - Dependent on intake depth(s): high emissions if removing deep, anoxic water with high CH_4.
- Emissions from dried areas due to water level drawdown (diurnal, seasonal).

A. Watershed to reservoir
(cross-section view)



B. Reservoir upstream of dam to tailwater
(river) (side view)

Figure from Jager et al. in prep

Attributing GHG emissions to reservoirs

- Only GHGs not emitted from a pre-reservoir freshwater network should be attributed to the reservoir (net emissions).
- For carbon dioxide:
  - Most CO_2 emissions are not attributed to reservoirs because processing would have occurred in the absence of a reservoir.
  - Exception: respired flooded plant biomass & soil C = reservoir emissions.
- For methane:
  - Pre-reservoir ecosystem likely had minimal CH_4 emissions. Therefore, all CH_4 emissions are counted as reservoir emissions.
- Attribution to hydropower:
  - Important to identify GHG emission pathways attributable to hydropower vs. to the reservoir, but very difficult to do in practice.

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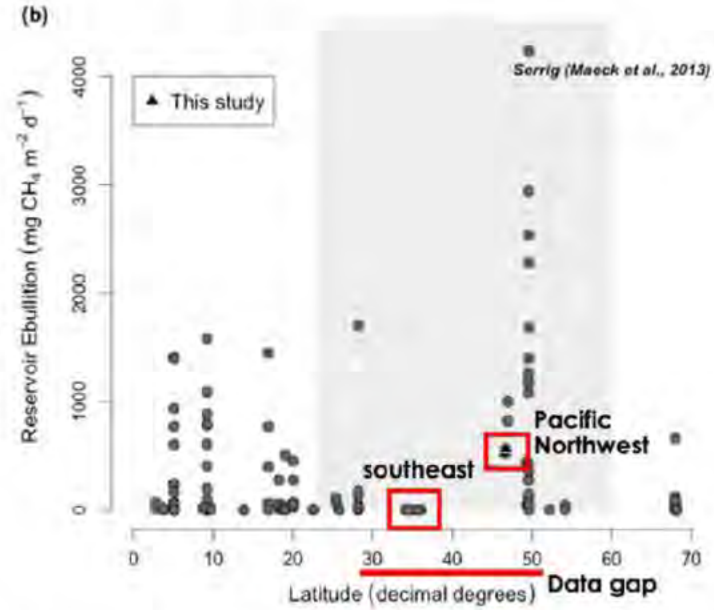
Summarized from Prairie et al. 2018

WPTO-funded GHG emission studies

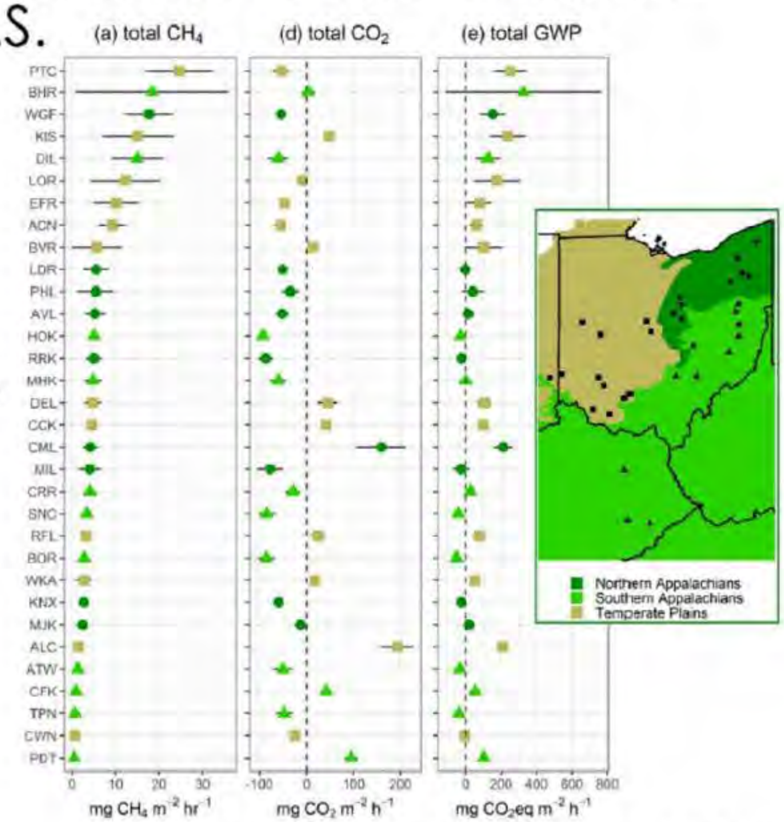
- ~10 years ago, DOE funded some of the first work to measure GHG emissions from U.S. hydropower reservoirs.
- ORNL measured emissions (diffusive, ebullitive, degassing) at 6 southeast hydropower reservoirs.
  - Degassing emissions were high relative to other pathways (but varied by reservoir). Ebullition was low.
- PNNL measured GHG emissions in two Columbia River reservoirs in the Pacific Northwest.
  - CH_4 ebullition was high; 97% of total flux.
- Data gap at 30-50 degrees latitude.



Findings from Mosher et al. 2015, Bevelhimer et al. 2016, Figure from Miller et al. 2017

Current, national-scale effort led by U.S. EPA

- SuRGE: collaborative survey to measure diffusive and ebullitive emissions from reservoirs across the U.S.
- Four-year field project (2020-2023).
- 108 reservoirs across all ecoregions, by depth and productivity.
- Initial study measured GHG emissions from 32 midwestern reservoirs.



Map from EPA SuRGE project, Figure from Beaulieu et al. 2020

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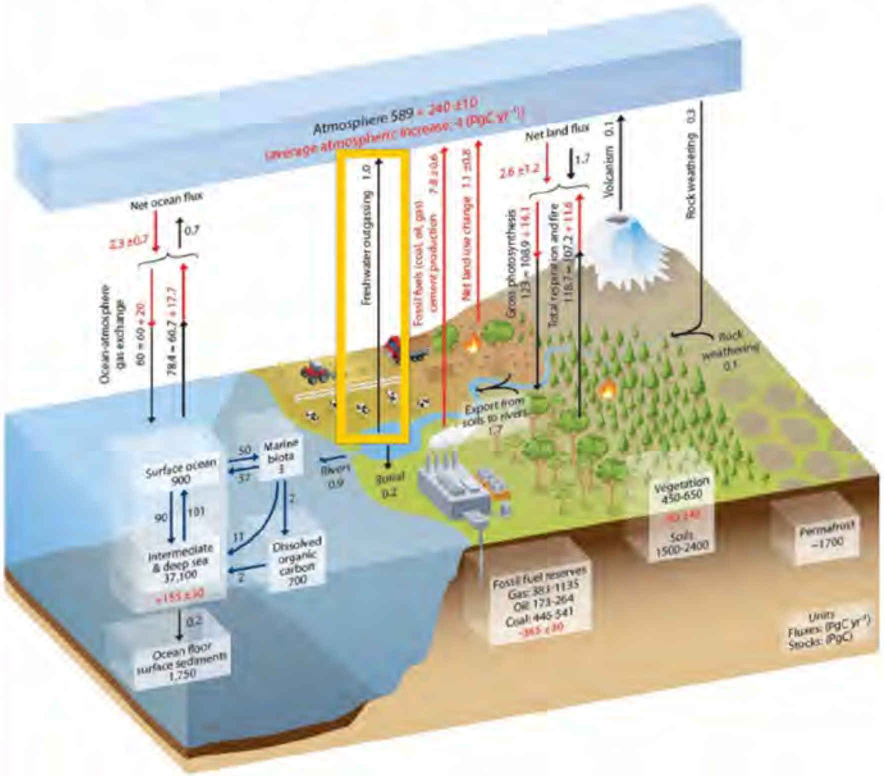
Role of reservoirs in the global GHG budget

- Carbon fluxes (including GHG emissions) from inland waters have only recently been included in global budgets.



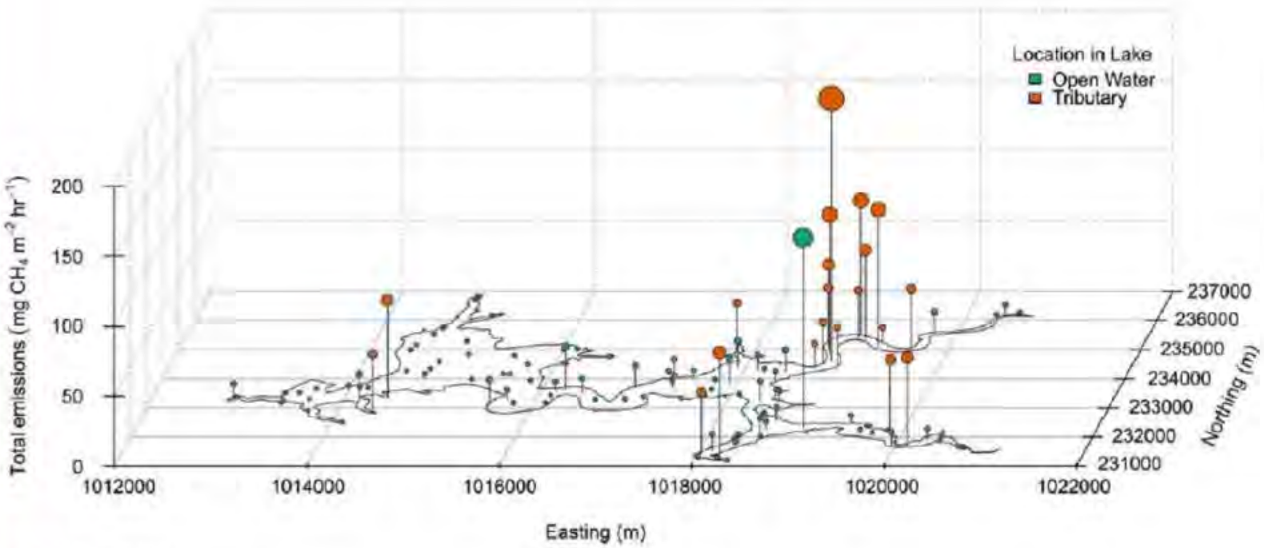
- Global reservoir GHG emission estimates range from 71 to 3,380 Tg CO_2 eq./y. (summarized in Harrison et al. 2021).

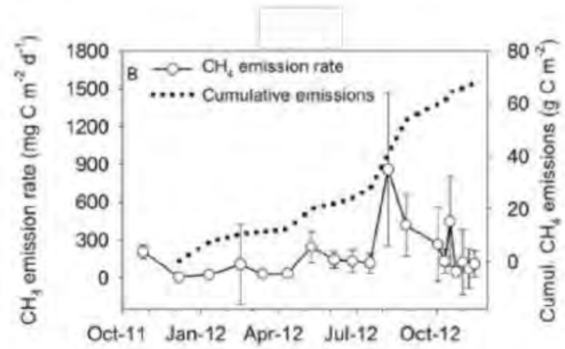
- Reservoirs might contribute 0.14-6.6% of global GHG emissions (calculation based on global GHG estimate of 50 billion tons as CO_2 eq.).

Figure from IPCC AR5

High uncertainty in measured and extrapolated GHG emissions from reservoirs

- GHG emissions within and across reservoirs are highly variable, both spatially and temporally, leading to high uncertainty in upscaled emission estimates.





Figures from Beaulieu et al. 2014, 2016

Summary of state of the science

- Greenhouse gases (GHGs) are emitted from all inland waters.
- Three main GHGs (CO_2, CH_4, N_2O); CH_4 is of greatest uncertainty and concern for reservoirs (both with and without hydropower).
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Where do we go from here?

- Reducing uncertainty in GHG emission estimates from reservoirs and understanding the role of hydropower is a large challenge that requires a long-term, coordinated research program.
- Next 3 years:
  - Comprehensive measurements of GHG emissions at more U.S. reservoirs to improve existing data. Measurements of understudied but potentially important pathways (degassing, ebullition), locations (drawdown areas), and periods of time (water withdrawals).
  - Develop and validate novel measurement techniques.
  - Contextualize emission rates from hydropower reservoirs with non-powered systems, natural lakes, rivers. Begin to assess operation-specific effects on GHG emissions.
  - Assessment and application of current models for upscaling and exploration of process-based models.

Where do we go from here?

- Next 5 years:
  - CONUS-scale assessment of GHG emissions from reservoirs to understand temporal patterns (daily, seasonal, interannual) within a regional context.
    - Hybrid measurement approach with intensive spatiotemporal monitoring in a subset of reservoirs and coarser-scale measurements at a higher number of reservoirs across the U.S.
  - Combine literature data with CONUS-scale assessment to evaluate drivers of GHG emissions as a first step to providing a screening tool for reservoirs.
  - Development of process-based models for examining mechanistic drivers of CO_2 and CH_4 production, GHG emissions, and related C cycle processes (e.g., C burial).

Where do we go from here?

- Next 10 years:
  - Move toward watershed-scale assessments of GHG emissions from reservoirs.
    - To date, scaled-up GHG emission estimates to CONUS are based on point-measurements in single reservoirs.
    - Need to assess GHGs in the context of the larger watershed, including activities/properties/management decisions that impact processes in the reservoir.
  - Couple observations and model outputs with experiments.
    - Informed by observations & models, conduct targeted experiments to resolve pathways and processes driving GHG emissions.
  - Evaluate how GHG emissions may change under future scenarios using process-based models.

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Where do we go from here?

- Next 10 years:
  - Provide tools for assessing GHG emissions relative to reservoir operations.
    - Provide information on when and where should GHG emissions be measured.
    - Advance monitoring technology to allow for cost-effective and easy-to-use sensors.
    - Develop monitoring systems where measurements feed back into operations in real time.
    - Model development to screen reservoirs and identify hot spots and hot moments of GHG emissions.

Thank you! Questions?

References

Beaulieu, J.J., R.L. Smolenski, C.T. Nietch, A. Townsend-Small, and M.S. Elovitz. 2014. High methane emissions from a midlatitude reservoir draining an agricultural watershed. Environmental Science & Technology 48:11100-11108.

Beaulieu, J.J., M.G. McManus, and C.T. Nietch. Estimates of reservoir methane emissions based on a spatially balanced probabilistic-survey. Limnology and Oceanography 61:S27-S40.

Beaulieu, J.J., S. Waldo, D.A. Balz, W. Barnett, A. Hall, M.C. Platz, and K.M. White. 2020. Methane and carbon dioxide emissions from reservoirs: controls and upscaling. JGR Biogeosciences 125:e2019JG005474.

Bevelhimer, M.S., A.J. Stewart, A.M. Fortner, J.R. Phillips, and J.J. Mosher. 2016. CO_2 is dominant greenhouse gas emitted from six hydropower reservoirs in southeastern United States during peak summer emissions. Water 8:15.

Harrison, J.A., Y.T. Prairie, S. Mercier-Blais, and C. Soued. 2021. Year-2020 global distribution and pathways of reservoir methane and carbon dioxide emissions according to the greenhouse gas from reservoirs (G-res) model. Global Biogeochemical Cycles 35:e2020GB006888.

Mosher, J.J., A.M. Fortner, J.R. Phillips, M.S. Bevelhimer, A.J. Stewart, and M.J. Troia. 2015. Spatial and temporal correlates of greenhouse gas diffusion from a hydropower reservoir in the southern United States. Water 7:5910-5927.

Miller, B.L., E.V. Arntzen, A.E. Goldman, and M.C. Richmond. 2017. Methane ebullition in temperate hydropower reservoirs and implications for US policy on greenhouse gas emissions. Environmental Management 60:615-629.

Prairie, Y.T., J. Alm, J. Beaulieu, N. Barros, T. Battin, J. Cole, P. del Giorgio, T. DelSontro, F. Guérin, A. Harby, J. Harrison, S. Mercier-Blais, D. Serça, S. Sobek, and D. Vachon. 2018. Greenhouse gas emissions from freshwater reservoirs: what does the atmosphere see? Ecosystems 21:1058-1071.

Prairie, Y.T., S. Mercier-Blais, J.A. Harrison, C. Soued, P. del Giorgio, A. Harby, J. Alm, V. Chanudet, and R. Nahas. 2021. A new modelling framework to assess biogenic GHG emissions from reservoirs: the G-res tool. Environmental Modelling and Software 143:105117.

From: Kaseweter,Alisa D (BPA) - AI-7
Sent: Wednesday, March 23, 2022 10:55 AM
To: Klumpp,Elizabeth C (BPA) - AIR-WSGL; Pytlak,Erik S (BPA) - PGPW-5
Subject: RE: Wash. Ecology request: Dams and GHG emissions
Attachments: LIHI_GHG Presentation_Final.pdf

The generators themselves are non-emitting. The methane emissions are from the operation of the reservoir - which is not just related to hydropower production and can be equated to the various purposes that those reservoirs support. It is reservoir specific, can vary by time of year (in fact, at times the reservoirs can be sinks for CO_2) and influenced by many other factors. While we don't have quantifiable data on the methane emissions from the reservoirs in the basin, we believe the methane emissions are relatively minor.

Appendix G of the CRSO EIS is a good reference. It has a several page overview that is specific to the Columbia River basin and includes cites to other literature on this topic. Final EIS (army.mil)

And DOE has contracted PNNL and ORNL to look at this more closely (on a national scale). I've attached a presentation from last fall that does a nice job summarizing the science and is consistent with the CRSO EIS analysis. The next steps for work are several years out though.

I've also heard Reclamation is looking at this for the reservoirs they operate, but I haven't seen anything on it. I could reach out to inquire if useful.

From: Klumpp,Elizabeth C (BPA) - AIR-WSGL <ecklumpp@bpa.gov>
Sent: Wednesday, March 23, 2022 10:30 AM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Subject: Wash. Ecology request: Dams and GHG emissions

Do we have a response and references I can send to this person (and friend) at Wash. Dept. of Ecology?

Thanks,
Liz

From: Waterman-Hoey, Stacey (ECY) <swat461@ECY.WA.GOV>
Sent: Wednesday, March 23, 2022 10:28 AM
To: Klumpp,Elizabeth C (BPA) - AIR-WSGL <ecklumpp@bpa.gov>
Subject: Dams and GHG emissions

Hi Liz,
There has been a flurry of conversation here about GHG emissions from dams in response to some recent action at EPA on this issue. Do you know of any studies that have quantified this for any of the PNW dams? It feels so counterintuitive, I have a hard time believing it. I think a fair amount of these emissions would biogenic, from the sediments, algae and oxygen build up, though this article references emissions from the generators. I didn't think there would be any...am I wrong? I am not sure it is a fair comparison to incorporate all emissions associated with up and downstream impacts of a dam to just the stacks of a coal plant. The article claims some of those emissions are from synthetic fertilizers...I wonder if that is as big a problem on the Columbia as it is in Lake Mead or the Ohio River? Some data on this would be useful, if you have any.
https://insideepa.com/climate-blog/environmentalists-ask-epa-require-dams-report-ghgs?s=em

The petitions flags estimated GHG emissions from several major hydropower dams, including Hoover Dam and the connected Lake Mead, which emit roughly 12.3 million tons of carbon dioxide equivalent annually. This includes 3.1 million tons attributable to hydropower infrastructure and generation.

It adds that such emissions "exceed the annual GHG emissions from coal- and gas-fired power plants with similar generation capacity," and that an EPA researcher co-authored a 2020 study estimating that reservoirs in Ohio are the fourth-largest anthropogenic source of methane.

Thanks!
-Stacey

Stacey Waterman-Hoey | she/her
Greenhouse Gas Emissions Analyst
Climate Policy Section | Air Quality Program
stacey.waterman-hoey@ecy.wa.gov | [redacted]

DEPARTMENT OF
ECOLOGY
State of Washington

From:	Warner,Joshua P (BPA) - AIR-7
Sent:	Wednesday, April 20, 2022 5:32 PM
To:	ADL_AIR_ALL; Baskerville,Sonya L (BPA) - AIN-WASH; Kaseweter,Alisa D (BPA) - AI-7
Subject:	FW: Modernizing hydropower on the Snake River
Attachments:	Patagonia et al - Petition to Add Dams and Reservoirs to the GHGRP.pdf

FYI. Nothing to do, just information.

Josh

From: steven hawley <sjhawley@me.com>
Sent: Wednesday, April 20, 2022 2:59 PM
To: Scott Levy <redfishbluefishfilm@icloud.com>
Cc: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>; Simpson.concept@mail.house.gov; info@lsrdoptions.org; salmon@ceq.eop.gov
Subject: Re: Modernizing hydropower on the Snake River

Hi Scott, Hello Josh,
I'm attaching a petition that was just filed in March of this year with the EPA. Signed by 130 conservation organizations and businesses, it requests that the EPA add dams and reservoirs to its greenhouse gas inventory program. There is no doubt that the Snake River Dams, and the FCRPS more generally are significant contributors to greenhouse gas emissions in the Pacific Northwest, and I would venture to guess that within a few years' time, we will know exactly how much methane these dams are polluting the atmosphere with each year. Recent research has established that dams and reservoirs worldwide have a carbon dioxide equivalent footprint equal to that of Germany, the world's fourth largest GHG polluter. In the meantime, the federal agencies that manage the FCRPS should stop making the spurious claim that energy from any Columbia Basin dams is "carbon free." An excerpt from the petition:

These scientific studies show that individual dams and reservoirs emit large amounts of GHGs every year. For example, Hoover Dam and Lake Mead (which is a reservoir and not a natural lake) emit approximately 12.3 million metric tons of carbon dioxide equivalent (CO_2e) annually. These emissions include 3.1 million metric tons of CO_2e attributable to hydropower infrastructure and generation. Kentucky Lake (which is also a reservoir and not a natural lake) emits over 1.8 million metric tons per year of CO_2e, including 407,000 metric tons attributed to hydropower infrastructure and generation. These emissions exceed the annual GHG emissions from coal- and gas-fired power plants with similar generation capacity, and these emissions are equivalent to the GHG emissions of hundreds of thousands, even millions, of gas-powered vehicles. In addition, the collective GHG emissions of all dams and reservoirs across the United States are significant. Notably, a 2020 scientific study co-authored by an EPA researcher estimated that reservoirs in Ohio are the state's fourth largest anthropogenic source of methane emissions.

Steve

> On Apr 20, 2022, at 2:01 PM, Scott Levy <redfishbluefishfilm@icloud.com> wrote:
>
> Josh,
>
> I see that Bonneville is continuing to promote Lower Snake River hydropower as "carbon-free energy".

> "Ice Harbor and the other three other dams on the lower Snake River provide low-cost, carbon-free energy to the Pacific Northwest…"
> — Modernizing hydropower on the Snake River USACE Press Release

This statement runs opposite to what the Pacific Northwest National Laboratories tells us regarding methane emissions being emitted by the Lower Snake Reservoirs.

> "Gas efflux due to ebullition was greater in comes located within reservoirs than in coves within the free flowing Hanford Reach, and CH4 efflux exceeded that of CO2. CH4 ebullition varied widely across sampling locations, ranging from 10.5 to 1039 mg CH4/(m^2 day) in Lower Monumental Dam reservoir and 482 mg CH4/(m^2 day) in Priest Rapids Dam reservoir. The magnitude of CH4 efflux due to ebullition was relatively high, falling with the range recently reported for other temperate reservoirs around the world, **further suggesting that this CH4 source should be considered in estimates of global greenhouse gas emissions.**"
> — Evaluating greenhouse gas emissions from hydropower complexes on large rivers in Eastern Washington

These two statements should coincide and the government really should provide the truth with a unified voice. When I buy a peanut-free or a gluten-free product, I expect it to be as the label states it to be.

Contradicting oneself is often difficult to justify, and continuing to remain silent on this discussion is becoming more and more unacceptable.

Sincerely,

Scott Levy
bluefish.org
promoting an open and **honest dialogue** concerning the plight of Idaho's wild Salmon and Steelhead.

cc: Council on Environmental Quality, Congressman Mike Simpson, Senator Patty Murray and Governor Jay Inslee.

EARTHJUSTICE
BECAUSE THE EARTH NEEDS A GOOD LAWYER

patagonia

SAVE THE COLORADO

March 21, 2022

Michael Regan
Administrator
United States Environmental Protection Agency
Office of the Administrator, Mail Code 1101A
1200 Pennsylvania Ave. NW
Washington DC 20460
Regan.Michael@epa.gov

Submitted via Email and Certified Mail, Return Receipt Requested

Re: Petition for rulemaking to add dams and reservoirs as a source category under the Greenhouse Gas Reporting Program

Dear Administrator Regan:

Earthjustice respectfully submits this Petition for Rulemaking on behalf of Patagonia and Save the Colorado. Over 130 other organizations and businesses that are listed on the final pages of the Petition have joined the Petition as well. The Petitioners request that the U.S. Environmental Protection Agency (EPA) exercise its authorities under Clean Air Act section 114(a)(1) and the Administrative Procedure Act and promptly initiate a rulemaking to add dams and reservoirs as a source category under the Greenhouse Gas Reporting Program (GHGRP).

Numerous scientific studies over the past two decades have established that dams and reservoirs produce and emit substantial amounts of carbon dioxide, methane, and nitrous oxide. These greenhouse gas (GHG) emissions include reservoir surface emissions, which occur when dams trap organic material and leached synthetic fertilizers that decompose beneath a reservoir's water. Dam and reservoir operations also emit GHGs from several other emission points, including hydropower turbines, spillways, and downstream water discharges.

29010014 BPA-2024-00643-F 0093

These scientific studies show that individual dams and reservoirs emit large amounts of GHGs every year. For example, Hoover Dam and Lake Mead (which is a reservoir and not a natural lake) emit approximately 12.3 million metric tons of carbon dioxide equivalent (CO_2e) annually. These emissions include 3.1 million metric tons of CO_2e attributable to hydropower infrastructure and generation. Kentucky Lake (which is also a reservoir and not a natural lake) emits over 1.8 million metric tons per year of CO_2e, including 407,000 metric tons attributed to hydropower infrastructure and generation. These emissions exceed the annual GHG emissions from coal- and gas-fired power plants with similar generation capacity, and these emissions are equivalent to the GHG emissions of hundreds of thousands, even millions, of gas-powered vehicles. In addition, the collective GHG emissions of all dams and reservoirs across the United States are significant. Notably, a 2020 scientific study co-authored by an EPA researcher estimated that reservoirs in Ohio are the state's fourth largest anthropogenic source of methane emissions.

Although dams and reservoirs emit large amounts of GHGs, these facilities are currently not required to measure or report their GHG emissions. As a result, federal agencies, states, utilities, and other stakeholders frequently overlook and ignore these GHG emissions. For example, dams and reservoirs are interconnected and necessary components of most hydropower generation. Regulators and policymakers often incorrectly assume and state that hydropower is a clean energy resource that emits zero carbon, when in fact some hydropower facilities emit massive amounts of GHGs. As a result, the federal government, states, and utilities frequently make decisions regarding climate policies and advancing toward a cleaner electric sector based on incomplete information and mistaken assumptions regarding dams and reservoirs' GHG emissions. In addition, federal agencies typically fail to assess dams and reservoirs' substantial GHG emissions when they analyze and approve new water supply projects and make other management decisions regarding water projects.

Because of the lack of awareness and mistaken assumptions regarding dams and reservoirs' GHG emissions, this Petition requests that EPA promptly initiate a rulemaking to add dams and reservoirs as a source category under the GHGRP. Granting this Petition would be an important step toward raising awareness of dams and reservoirs' GHG emissions and ensuring that regulators, policymakers, and the public have access to accurate and timely GHG data for this source category. Adding dams and reservoirs to the GHGRP would also result in better-informed climate policies at the federal, state, and local levels. Requiring dams and reservoirs to report their GHG emissions will ensure that agencies and utilities have access to the best available information regarding hydropower's GHG emissions as they make decisions on the future of the electric sector, and not risk inadvertently pursuing a clean energy future that is not actually clean. Moreover, obtaining accurate and timely data on dams and reservoirs' substantial methane emissions will help the United States achieve the Global Methane Pledge, which commits the United States to reducing its methane emissions 30% by 2030.

Granting this petition would also align with recent statements from the Biden Administration and EPA that highlight the need for better data and inventories of methane emissions. For example, a recent White House statement regarding the Global Methane Pledge noted that participating nations should commit to "moving towards using best available inventory methodologies to quantify methane emissions."[1] But this is currently not the case for dams and reservoirs. In addition, a news article regarding EPA's new methane regulations for the oil and gas sector quoted Administrator Regan as stating: "Methane is such a potent pollutant, it's important that we understand what the contribution is from this industry."[2] This statement applies equally to methane emissions from dams and reservoirs, and this Petition seeks to advance the understanding and awareness of this substantial source of methane emissions.

When EPA implemented the GHGRP in 2009, it recognized that the program should expand and evolve over time to include additional source categories. Yet EPA has not added any new source categories to the GHGRP since 2010. Because dams and reservoirs emit large amounts of GHGs and because these emissions are often overlooked, EPA should seize this opportunity to expand and evolve the GHGRP so that policymakers and the public have accurate and timely information regarding these significant sources of GHG emissions.

BACKGROUND

I. Petitioners

Founded by Yvon Chouinard in 1973, Patagonia is an outdoor apparel company based in Ventura, California. As a Certified B Corporation, the company is in business to save our home planet. Patagonia's grant making, advocacy, communications, and activism have long prioritized the health of America's freshwater ecosystems. Patagonia has advocated for the removal of dams to support the protection of wild, native fish populations and the communities that depend on them. This has included more than $4 million in grants to nonprofit groups since 2000, as well as numerous films and campaigns, including three award-winning documentaries: *DamNation*, *Blue Heart*, and *Artifishal*.

Save the Colorado is a grassroots, non-profit 501(c)(3) environmental organization dedicated to the protection and restoration of the Colorado River and its tributaries. Save the Colorado has approximately 25,000 members, supporters, and followers throughout the Colorado River Basin who live, work, and recreate on the Colorado River and other rivers that are impacted by dams and reservoirs. Save the Colorado's mission is to promote the conservation of the Colorado River and its tributaries through science, public education, advocacy, and litigation.

The additional undersigned Petitioners listed on the final pages of this Petition include international, national, regional, and local nonprofit organizations that represent

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1 Press Release, White House, Joint US-EU Press Release on the Global Methane Pledge (Sept. 18, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/18/joint-us-eu-press-release-on-the-global-methane-pledge/.

2 Dino Grandoni & Tony Romm, *White House doubles down on executive action as Democrats weigh trimming Hill climate plan*, Wash. Post, Oct. 19, 2021, https://www.washingtonpost.com/climate-environment/2021/10/19/climate-reconciliation-biden-white-house/.

members and supporters who have an interest in mitigating the climate crisis and ensuring that EPA accurately accounts for the GHG emissions from dams and reservoirs. These Petitioners include organizations that have thousands of members who live, work, and enjoy outdoor activities and recreation throughout the United States, including on rivers that are impacted by dams and reservoirs.

II. Statutory and Regulatory Background

A. The Greenhouse Gas Reporting Program

The GHGRP requires sources to report their GHG emissions to EPA. 40 C.F.R. Part 98. A source must generally report its GHG emissions to EPA annually if the source is in a listed source category and it emits more than 25,000 metric tons or more per year of CO_2e. *Id.* §§ 98.1, 98.2. A source must report its GHG emissions at the facility level, except certain suppliers and vehicle and engine manufacturers report GHG emissions at the corporate level. Mandatory Reporting of Greenhouse Gases, 74 Fed. Reg. 56,260, 56,264 (Oct. 30, 2009) [hereinafter "Final 2009 GHGRP Rule"]. EPA currently requires over forty source categories to report their GHG emissions through the GHGRP. *See* 40 C.F.R. Part 98, Subparts B–UU. Since 2011, EPA has collected and reported GHG emissions from approximately 8,000 facilities and other sources through the GHGRP.[3]

When EPA implemented the GHGRP in 2009, it recognized that obtaining accurate and detailed GHG emissions data is a critical first step for addressing climate change. EPA articulated the following principles that underlie the GHGRP:

- <u>The GHGRP should provide GHG emissions data that informs climate change policies at the federal, state, and local levels.</u>

  EPA stated that "[a]ccurate and timely information on GHG emissions is essential for informing many future climate change policy decisions," and "the data collected in this rule will provide useful information for a variety of policies." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,265. The agency noted that "[t]he data collected by this rule will also improve the U.S. government's ability to formulate climate policies." *Id.* EPA further explained that it "is promulgating this rule to gather GHG information to assist EPA in assessing how to address GHG emissions and climate change under the Clean Air Act." *Id.* The agency also stated that it "expect[s] that the information will prove useful for other purposes as well [because] [f]or example, using the rich data set provided by this rulemaking, EPA, States and the public will be able to track emission trends from industries and facilities within industries over time, particularly in response to policies and potential regulations." *Id.*

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[3] Angela Jones, Cong. Rsch. Serv., IF11754, *In Focus: EPA's Greenhouse Gas Reporting Program* 1 (Nov. 16, 2021), https://crsreports.congress.gov/product/pdf/IF/IF11754.

- The GHGRP should document the relative GHG emissions of various industries and source categories.

  EPA explained that "[t]hrough data collected under [the GHGRP], EPA, States and the public will gain a better understanding of the relative emissions of specific industries across the nation." *Id.* The agency stated that "[t]he data collected by this rule will also improve the U.S. government's ability to . . . assess which industries might be affected, and how these industries might be affected by potential [climate] policies." *Id.*

- The GHGRP should document the GHG emissions of specific facilities within an industry or source category.

  EPA noted that the GHGRP will provide "EPA, States and the public [with] a better understanding of . . . the distribution of emissions from individual facilities within [specific] industries." *Id.* The agency further explained that "[t]he facility-specific data will also improve our understanding of the factors that influence GHG emission rates and actions that facilities could in the future or already take to reduce emissions, including under traditional and more flexible programs." *Id.*

- The GHGRP data should raise awareness of sources' GHG emissions.

  EPA stated that its "experience with other reporting programs is that such programs raise awareness of emissions among reporters and other stakeholders, and thus contribute to efforts to identify and implement emission reduction opportunities." *Id.* The agency explained that "[t]hese data can also be coupled with efforts at the local, State and Federal levels to assist corporations and facilities in determining their GHG footprints and identifying opportunities to reduce emissions." *Id.*

- The GHGRP should expand and evolve over time.

  EPA recognized that while the initial scope of the GHGRP would provide useful information, "additional data collection (e.g., for other source categories or to support additional policy or program needs) will no doubt be required as the development of climate policies evolves." *Id.*

The Congressional Research Service also recently recognized that the GHGRP will likely need to expand and evolve. Its November 2021 report on the GHGRP raised several issues for Congress, including whether "the application and scope of GHGRP regulations align with EPA's stated goal of enhanced understanding of GHG emissions now and in the future."[4] The report also stated that "policymakers could consider expanding the scope of sources required to report and/or adjust the emissions reporting threshold for particular sources."[5]

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4 Jones, Cong. Rsch. Serv., *supra* note 3, at 2.
5 *Id.*

After EPA implemented the GHGRP in 2009, it promptly added several additional source categories to the program that were not covered by its initial rulemaking.[6] However, EPA has not added any new source categories to the GHGRP since 2010.[7]

B. Clean Air Act Section 114 and the Administrative Procedure Act

EPA has the authority to grant this Petition and require dams and reservoirs to report their GHG emissions through the GHGRP under the Administrative Procedure Act and Clean Air Act section 114(a)(1). The Administrative Procedure Act requires federal agencies to provide "an interested person the right to petition for the issuance, amendment, or repeal of a rule." 5 U.S.C. § 553(e).

Clean Air Act section 114 authorizes EPA to require sources to monitor and report their emissions, and it authorizes the agency to request information from sources that will assist EPA in carrying out any Clean Air Act provision. 42 U.S.C. § 7414. As EPA previously explained, the agency implemented the GHGRP pursuant to its existing authority under Clean Air Act sections 114(a)(1) and 208, as these sections "provide EPA broad authority to require the information mandated by [the GHGRP] because such data will inform and are relevant to EPA's carrying out a wide variety of [Clean Air Act] provisions." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,264. EPA has added additional source categories to the GHGRP pursuant to its authority under Clean Air Act section 114(a)(1), and it also recognized that the program informs its implementation of sector-based non-regulatory strategies to reduce air pollutants under Clean Air Act section 103(g). *See, e.g.*, Mandatory Reporting of Greenhouse Gases: Petroleum and Natural Gas Systems, 75 Fed. Reg. 74,458, 74,460–61 (Nov. 30, 2010); Mandatory Reporting of Greenhouse Gases From Magnesium Production, Underground Coal Mines, Industrial Wastewater Treatment, and Industrial Waste Landfills, 75 Fed. Reg. 39,736, 39,738–39 (July 12, 2010).

FACTUAL BACKGROUND REGARDING GREENHOUSE GAS EMISSIONS FROM DAMS AND RESERVOIRS

I. Dams, reservoirs, and hydropower facilities in the United States.

Dams and reservoirs are located throughout the United States. These facilities have been built for numerous purposes, including water supply, hydroelectric power generation, flood control, recreation, irrigation, and navigation.

According to the U.S. Army Corps of Engineers, approximately 3% of the dams and reservoirs in the United include hydropower generation.[8] In 2020, hydropower accounted

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6 EPA, Greenhouse Gas Reporting Program (GHGRP), Historical Rulemakings, https://www.epa.gov/ghgreporting/historical-rulemakings (last visited Mar. 18, 2022).

7 *Id.*

8 U.S. Army Corps of Eng'rs, National Inventory of Dams, https://nid.usace.army.mil (last visited Mar. 18, 2022).

for approximately 7% of the total utility-scale electricity generation in the United States.[9] Although some hydropower generation occurs at run-of-the-river dams that may not have a reservoir (or a small reservoir), the U.S. Energy Information Administration has explained that "[m]ost U.S. hydroelectricity is produced at large dams on major rivers, and most of these hydroelectric dams were built before the mid-1970s by federal government agencies."[10] The largest hydropower facility in the United States is the Grand Coulee Dam facility in Washington, which has 6,765 megawatts of total generation capacity.[11]

This Petition to list dams and reservoirs as a source category under the GHGRP encompasses dams and reservoirs that generate hydropower, as well as dams and reservoirs without hydropower components. Moreover, when this Petition discusses hydropower facilities, it is referring to hydropower facilities that include dams and reservoirs that divert, manipulate, or impound water, which account for most of the hydropower generation in the United States.

II. Methane, carbon dioxide, and nitrous oxide are key drivers of the climate change crisis, yet greenhouse gas emissions from dams and reservoirs are often overlooked.

In August 2021, the Intergovernmental Panel on Climate Change (IPCC) issued several reports that vividly highlight the climate emergency the planet is facing.[12] Heat-trapping climate pollution—especially methane, carbon dioxide, and nitrous oxide—are singled out by climate scientists as GHGs for having the intense short- and long-term effects of increasing the "greenhouse effect" that causes climate change.

In the United States, scientists have linked climate change to the ever-increasing environmental calamities battering our landscape, such as wildfires, hurricanes, and drought. The 2021 IPCC reports have been described as a "code red for humanity."[13] In 2021 alone, wildfires in California and the Pacific Northwest, drought in the Southwest, and hurricanes in the East have been particularly intense and financially damaging.

Climate scientists, including those affiliated with the IPCC and EPA, have identified many of the primary GHG emission sources in numerous reports. Chief among those sources is the production and consumption of fossil fuels and GHG emissions from land use, including high-intensity industrial agriculture, forestry, and land use changes.[14] The EPA,

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[9] U.S. Energy Info. Admin., Hydropower explained, https://www.eia.gov/energyexplained/hydropower/ (last visited Mar. 18, 2022).

[10] *Id.*

[11] *Id.*

[12] IPCC, *Sixth Assessment Report, Climate Change 2021: The Physical Science Basis* (2021), https://www.ipcc.ch/report/ar6/wg1/.

[13] Matt McGrath, *Climate change: IPCC report is 'code red for humanity,'* BBC News, Aug. 9, 2021, https://www.bbc.com/news/science-environment-58130705.

[14] *See, e.g.*, EPA, Sources of Greenhouse Gas Emissions, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (last visited Mar. 18, 2022).

other federal agencies, and governments across the world have conducted considerable research regarding the GHG emissions from these sources, and regulatory efforts in the United States have primarily focused on reducing emissions from fossil fuel production and consumption.

Some sources of GHG emissions have historically received less scientific and regulatory attention. Yet these overlooked GHG sources are gaining increasing attention as scientific evidence of their impacts accumulates. As an example, in a 2006 report the IPCC provided a framework for calculating methane emissions from flooded landscapes, including reservoirs.[15] The IPCC further refined these GHG estimates for flooded lands in 2019.[16] This 2019 refinement focuses on "Flooded Land" and includes a discussion of GHG emissions from reservoirs.[17] Although the IPCC has developed these frameworks for emissions inventories, GHG emissions from flooded lands and reservoirs have largely been overlooked. For example, the EPA currently does not recognize GHG emissions from dams and reservoirs as a source category with emissions that must be measured, reported, or regulated, despite the growing evidence regarding GHG emissions from reservoirs.

III. Multiple peer-reviewed scientific studies show that dams and reservoirs directly emit substantial amounts of methane and carbon dioxide annually.

A. Scientists have repeatedly documented substantial greenhouse gas emissions from dams and reservoirs in the United States and across the world.

Twenty-five years ago, a team of scientists in Brazil began measuring the methane produced at hydropower dams and reservoirs. Led by Dr. Philip Fearnside, a research scientist at Brazil's National Institute for Amazonian Research, these scientists discovered something new at the time: hydropower dams and reservoirs in tropical countries such as Brazil emit high levels of GHGs, especially methane. Some of the hydropower facilities they studied produced several times more GHG emissions than coal-fired power plants, when the emissions were attributed to the energy produced. Dr. Fearnside first reported the discovery of GHG emissions from these facilities in 1995, and after years of research, he published a 2008 article in *Oecologia Australis* detailing these findings.[18]

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15 *See* IPCC, *App. 3, CH_4 Emissions from Flooded Land: Basis for Future Methodological Development, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry and Other Land Use* (2006), https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

16 IPCC, *Chapter 7: Wetlands, in 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry and Other Land Use* (2019), https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html.

17 *Id.* § 7.3.

18 Philip Fearnside, *Hydroelectric Dams as "Methane Factories": The Role of Reservoirs in Tropical Forest Areas as Sources of Greenhouse Gases*, 12 Oecologia Australis (2008), https://www.semanticscholar.org/paper/HYDROELECTRIC-DAMS-AS-%E2%80%9CMETHANE-FACTORIES%E2%80%9D%3A-THE-ROLE-Fearnside/a4454cf836d9543cc3f087e47457749207d943d0.

Around the same time, other scientists around the world launched new studies that confirmed the Brazilian results in subtropical and temperate regions. International studies of dams and their reservoirs multiplied over the last two decades. For the first time in 2006, the IPCC included calculations for measuring methane emissions from flooded lands in national greenhouse gas inventories.[19] Since 2006, study after study has confirmed high levels of methane emissions from many dams and reservoirs. One 2016 study co-authored by an EPA researcher found methane emissions from a reservoir in the midwestern United States to be as high as those measured at hydropower facilities in Brazil.[20] EPA published a blog highlighting the study, which noted that "improved estimates of methane emissions from reservoirs will result in better information that can aid in the global effort to reduce greenhouse gas emissions."[21]

While the initial dam and reservoir GHG studies were conducted in tropical locations, more recent studies have also found significant emissions at dams and reservoirs in northern latitudes, including northern regions of the United States. In 2016, this science came to a head when an international team of scientists synthesized dozens of studies from around the world, which indicated that methane emissions from dams and reservoirs have been widely ignored and dramatically underestimated.[22] The EPA, the U.S. Army Corps of Engineers, and the National Science Foundation funded this *Bioscience* study.[23] The study made international news and stated that the IPCC should revise its calculations for GHG inventories for flooded lands and include dams and reservoirs' significant GHG emissions.[24] Additional data published in 2020 associated with this analysis further supports the earlier findings that reservoirs are a large source of GHG emissions across the world.[25]

Attachment 1 to this Petition lists many of the scientific studies conducted over the past twenty-five years that analyze and document the GHG emissions of dams and reservoirs. These forty-four scientific studies are among the most significant studies on this issue, and this body of science makes clear that dams and reservoirs are substantial sources of GHG emissions in tropical, temperate, and other regions around the world.

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19 IPCC, *Chapter 7: Wetlands, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol. 4: Agriculture, Forestry and Other Land Use* § 7.3 (2006), https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

20 Jake Beaulieu et al., *Estimates of reservoir methane emissions based on a spatially balanced probabilistic-survey*, 61 Limnology and Oceanography S27 (2016), https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lno.10284.

21 EPA, Bubbling Up: Methane from Reservoirs Presents Climate Change Challenge, The EPA Blog (Sept. 8, 2016).

22 Bridget Deemer et al., *Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis*, 66 BioSci. 949, 949–50, 954–61 (Nov. 2016), https://academic.oup.com/bioscience/article/66/11/949/2754271.

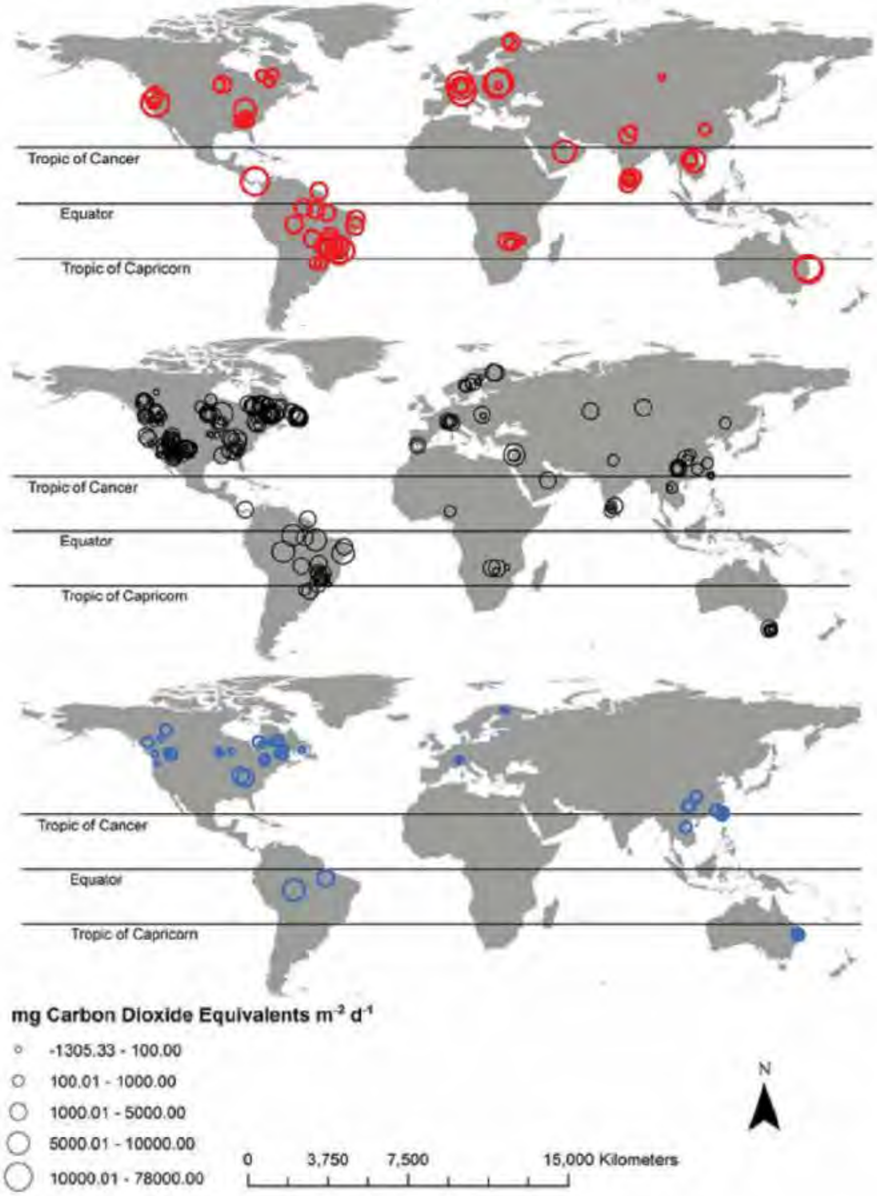
23 *Id.* at 961.

24 *Id.* at 960–61.

25 Bridget Deemer et al., *Data from: Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis,* Dryad Dataset (Jan. 6, 2020), https://datadryad.org/stash/dataset/doi:10.5061/dryad.d2kv0.

Figure 1 below—which is a map from the 2016 *Bioscience* study—provides one example that illustrates the scope of GHG emissions from dams and reservoirs in the United States and across the world.

Figure 1. GHG Flux Estimates from Reservoirs: Diffusive + Ebullitive Methane (top), Carbon Dioxide (middle), and Nitrous Oxide (bottom) on a CO_2-Equivalent Basis (100-year horizon)[26]



[26] Deemer et al., *Greenhouse Gas Emissions from Reservoir Water Surfaces*, *supra* note 22, at 953.

B. The peer-reviewed scientific studies show that U.S. dams and reservoirs directly emit large amounts of methane and carbon dioxide annually, both individually and collectively.

A study published in September 2016 by a team of Swiss scientists used previous measurements at dams and reservoirs around the world to create a model that estimates the equivalent carbon emissions from nearly 1,500 hydropower facilities, including 350 hydropower facilities in the United States.[27] The study findings illustrate that individual dams and reservoirs across the United States emit massive amounts of GHGs each year. These emissions include the following prominent examples:

- Lake Mead (Reservoir): Lake Mead and Hoover Dam emit CO_2e equal to that of a coal-fired power plant producing the same amount of electricity. The total reservoir emissions are approximately 9.2 million metric tons of CO_2e per year. This is equivalent to the emissions from approximately 2 million gas-powered automobiles per year.[28] In addition to these reservoir emissions, the total emissions attributed solely to the hydropower turbines equal about 3.1 million metric tons of CO_2e per year. The hydropower turbine emissions are equivalent to the annual emissions from approximately 674,000 vehicles.[29]

- Lake Whitney (Reservoir): In Texas, Whitney Dam and Lake Whitney (which is a reservoir and not a natural lake) emit six times more CO_2e than a coal-fired power plant producing the same amount of electricity. The total reservoir emissions equal about 884,000 metric tons of CO_2e per year, or the equivalent emissions from about 192,000 gas-powered vehicles per year.[30] In addition to these reservoir emissions, the total emissions attributed to hydropower equal about 250,000 metric tons of CO_2e per year. The hydropower turbine emissions are equivalent to the annual emissions from approximately 54,370 vehicles.[31]

- Kentucky Lake (Reservoir): Kentucky Lake is the largest reservoir in the eastern United States, and it emits approximately 80% as much CO_2e as a natural gas-fired power plant producing the same amount of electricity. The total reservoir emissions equal about 1.4 million metric tons of CO_2e per year, or the equivalent emissions from about 304,000 gas-powered vehicles per year.[32] In addition to these reservoir emissions, the total emissions attributed to hydropower equal about 407,000 metric

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[27] Laura Scherer & Stephan Pfister, *Hydropower's Biogenic Carbon Footprint*, PLoS ONE (Sept. 14, 2016), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0161947.

[28] EPA, Greenhouse Gas Equivalencies Calculator, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (last visited Mar. 18, 2022).

[29] *Id.*

[30] *Id.*

[31] *Id.*

[32] *Id.*

tons of CO_2e per year. The hydropower turbine emissions are equivalent to the annual emissions from approximately 88,000 vehicles.[33]

In addition, a 2020 study co-authored by an EPA researcher highlights the substantial scope of dams and reservoirs' collective GHG emissions. The study abstract explained that estimating the carbon dioxide and methane emissions from reservoirs "is important for regional and national greenhouse gas inventories."[34] The study analyzed the carbon dioxide and methane emissions from thirty-two reservoirs, and it found that all the reservoirs are a source of methane.[35] Notably, the study estimated that dams and reservoirs in Ohio are the state's fourth largest anthropogenic methane source.[36]

IV. The current scientific studies underestimate the full scope of dams and reservoirs' greenhouse gas emissions.

The current peer-reviewed science has largely focused on direct GHG emissions from reservoir surfaces. At least two major sources of organic material in reservoirs cause these surface emissions. One source is organic materials that are washed into reservoirs and unnaturally trapped by the dams from upstream watersheds (e.g., soils, suspended organic matter, organic matter in sediments, and algae). Another source is synthetic fertilizer and livestock manure leaching, and runoff from agricultural fields and pastures in the upstream watershed. This runoff effectively fertilizes reservoirs and leads to higher algae growth in reservoirs. These organic materials and leached synthetic fertilizers become trapped behind dams because of their operations and are decomposed or mineralized by microbes and other organisms beneath the reservoir surface. Anaerobic decomposition in the oxygen-depleted reservoir depths creates methane as a byproduct, and aerobic decomposition in other parts of the reservoir creates carbon dioxide and nitrous oxide. It is concerning that warming temperatures and eutrophication of water bodies significantly increase both the surface carbon dioxide and nitrous oxide, as well as subsurface methane in the anoxic zones from which hydropower facilities draw water into turbines. The more eutrophication and warming that occur, the greater the GHG emissions. Moreover, a warming climate can produce a positive feedback loop that exacerbates the problem. Eutrophication is a major problem in the United States, and it affects the great majority of waterways and reservoirs.[37] Yet the increase in GHG emissions caused by eutrophication has only been partially quantified, and the impact of warmer air and water temperatures on reservoir emissions has also not been adequately assessed.

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[33] *Id.*

[34] Jake Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs: Controls and Upscaling*, 125 J. Geophysical Rsch. Biogeosciences 1 (2020), https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019JG005474.

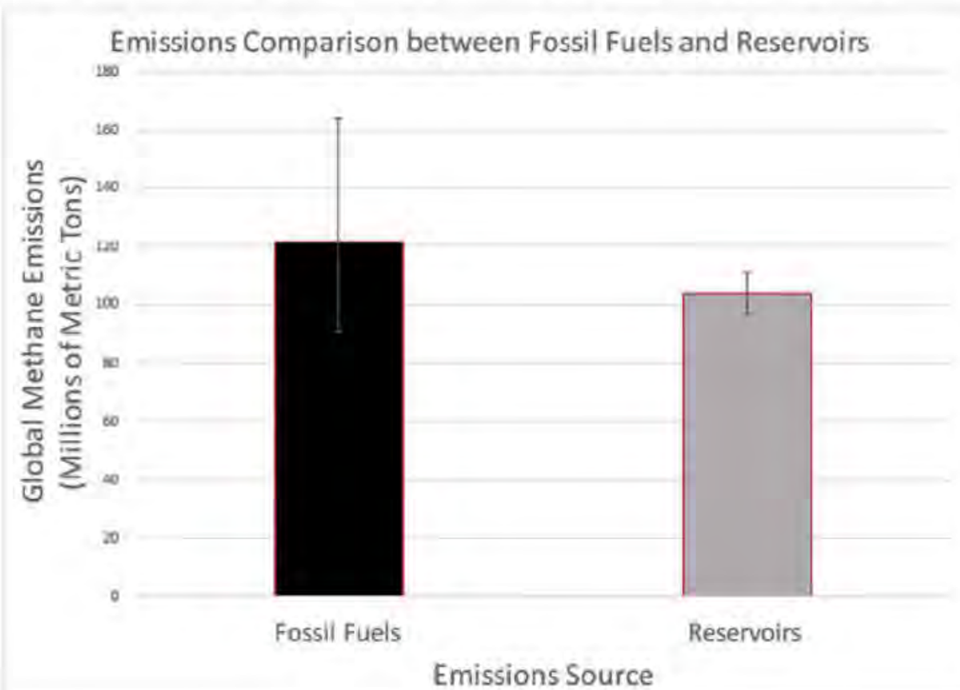
[35] *Id.* at 1, 9–10, 15.

[36] *Id.* at 1–2, 19.

[37] Walter Dodds et al., *Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages*, 43 Envtl. Sci. & Tech. 12, 15–16 (2009), https://pubs.acs.org/doi/10.1021/es801217q.

Looking solely at the methane emissions from reservoir surfaces, dams and reservoirs are a significant and consequential contributor to climate change. The most recent comprehensive review of global methane emissions estimates that methane emissions from the production and distribution of fossil fuels was between 91 and 164 teragrams in 2017, averaging 122 teragrams.[38] In comparison, a 2008 study stated that reservoirs could emit 104 +/- 7.2 teragrams annually.[39] Figure 2 below highlights the comparative global methane emissions from fossil fuels and reservoirs.

Figure 2. Comparison of Methane Emissions from Fossil Fuels and Reservoirs



To further illustrate the overall magnitude of GHG emissions from dam and reservoir operations in the United States, Mark Easter has authored a white paper in support of this Petition, which estimates the surface emissions from U.S. reservoirs using a combination of publicly available, peer-reviewed sources.[40] Mr. Easter is an ecologist and research affiliate at Colorado State University, and his white paper is included as Attachment 2 to the Petition. Mr. Easter concludes that reservoir surface emissions alone

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[38] Marielle Saunois et al., *The Global Methane Budget 2000–2017*, 12 Earth Sys. Sci. Data 1561, 1580 (2020), https://essd.copernicus.org/articles/12/1561/2020/.

[39] Ivan Lima et al., *Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective*, 13 Mitigation & Adaptation Strategies for Glob. Change 193, 201 (2008), https://link.springer.com/article/10.1007/s11027-007-9086-5.

[40] Mark Easter, *Greenhouse Gas Emissions from Dams and Reservoirs in the United States* 3–5 (2022) (Attach. 2).

account for at least 459 teragrams (millions of metric tons) CO_2e per year.[41] GHG emissions from reservoir surfaces are thus comparable to the overall GHG emissions of the U.S. agricultural sector (669 teragrams of CO_2e in 2019) and home energy use in the United States (380 teragrams of CO_2e in 2019).[42] Mr. Easter's GHG calculations for reservoir surfaces are consistent on a per-area basis with emissions calculated in other peer-reviewed inventories in North America and other temperate regions.[43]

Some industry-affiliated studies have used or endorsed methodologies that result in less GHG emissions from dams and reservoirs.[44] However, these studies do not calculate reservoir surface emissions correctly. In addition, these studies often have at least one of the following three flaws: (1) they use faulty methods that underestimate the emissions from hydropower turbines;[45] (2) the measurements result in undercounting because they do not reflect seasonal variation, particularly during critical periods, such as when reservoirs "turn" in the spring and fall;[46] and (3) they omit crucial components of life cycle emissions, such as dam construction and decommissioning.[47] Ultimately, none of these studies dispute the central point that dams and reservoirs emit large amounts of GHGs.

In addition, while the GHG emissions from reservoir surfaces are substantial, these emissions are just one component of the overall GHG emissions from dams and reservoirs. Dams and reservoirs emit GHGs from many different emissions points that are spread across numerous processes and sources. In fact, scientists have identified at least seventeen distinct individual sources and sub-sources of GHG emissions from dams and reservoirs. These GHG emissions result from multiple GHG inventory sectors, including industrial processes, energy, and land use and forestry. Mr. Easter's white paper describes these seventeen distinct GHG emission points in greater detail.[48]

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[41] *Id.* at 3–4.

[42] EPA, Greenhouse Gas Inventory Data Explorer, https://cfpub.epa.gov/ghgdata/inventoryexplorer/ (last visited Mar. 18, 2022).

[43] *See, e.g.*, Deemer et al., *Greenhouse Gas Emissions from Reservoir Water Surfaces*, *supra* note 22; Deemer et al., *Data from: Greenhouse Gas Emissions from Reservoir Water Surfaces*, *supra* note 25; Scherer & Pfister, *supra* note 27.

[44] *See, e.g.*, A. Levasseur et al., *Improving the accuracy of electricity carbon footprint: Estimation of hydroelectric reservoirs greenhouse gas emissions*, 136 Renewable & Sustainable Energy Revs. (2021), https://www.sciencedirect.com/science/article/pii/S1364032120307206.

[45] *See generally* Int'l Hydropower Ass'n, GHG Measurement Guidelines for Freshwater Reservoirs, https://www.hydropower.org/publications/ghg-measurement-guidelines-for-freshwater-reservoirs (last visited Mar. 18, 2022).

[46] Deemer et al., *Greenhouse Gas Emissions from Reservoir Water Surfaces*, *supra* note 22, at 959.

[47] Cuihong Song et al., *Cradle-to-grave greenhouse gas emissions from dams in the United States of America*, 90 Renewable & Sustainable Energy Revs. 7, 13–15 (2018), https://www.sciencedirect.com/science/article/abs/pii/S1364032118302235.

[48] Easter, *supra* note 40, at 1–3 (Attach. 2).

Although most of the current science focuses on GHG emissions from reservoir surfaces, some of the peer-reviewed science also illustrates the size and scope of these other GHG emission points. These are just a few examples of the unquantified, or only partially quantified, GHG emissions from dams and reservoirs.

- GHG emissions from fluctuating reservoir levels: Dam operations often cause reservoir levels to rise and fall. When reservoir levels fall, revegetation occurs on reservoir banks. And when reservoirs levels subsequently rise, this vegetation is resubmerged and results in additional GHG emissions. Scientific studies have found that reservoir drawdowns increase overall GHG emissions from dams and reservoirs.[49]

- GHG emissions from degraded wetlands and riparian forests: The Colorado River delta historically contained two million acres of wetlands, riparian forests, and mangrove forests. After more than a century of dam construction, river diversions, and evaporation from reservoir surfaces, less than 5% of that area now contains wetlands and riparian forests, nearly all which are now degraded. No mangrove wetland forests remain. Based on a conservative estimate of 60 million metric tons of biomass carbon per hectare and 100 metric tons of soil carbon per hectare in these systems, the total ecosystem carbon loss exceeds 450 million metric tons CO_2e of ecosystem carbon, or approximately 4 million metric tons per year averaged over the period since dam construction began.[50] This does not include potential nitrous oxide losses from decaying vegetation or degraded riparian forests and riparian-associated wetlands in the watershed upstream of the delta.

- Loss of ecosystem function and the potential for carbon sequestration after dam decommissioning and restoration: Carbon sequestration occurs at restored dam sites in the United States. For example, it is estimated that the Elwha River watershed in the Olympic Peninsula and the White Salmon River watershed in the Columbia River Gorge sequester 6,023 and 286 metric tons CO_2e per year, respectively, as forests and vegetation reclaim formerly inundated sites.[51] The dam footprints of the formerly dammed Elwha and White Salmon rivers likely held biomass carbon stocks equal to or greater than 1.2 million metric tons CO_2e before they were inundated. This does not include the carbon in the soils of these forests, which would likely double the total ecosystem carbon stocks.

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49 *See, e.g.*, Philipp Keller et al., *Global Carbon Budget of Reservoirs is Overturned by the Quantification of Drawdown Areas*, 14 Nature Geoscience 402 (2021), https://www.nature.com/articles/s41561-021-00734-z.

50 *See generally* IPCC, *Chapter 11: Agriculture, Forestry and Other Land Use (AFOLU), in Climate Change 2014: Mitigation of Climate Change* (2014), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter11.pdf.

51 Carbon sequestration values calculated with the U.S. Department of Agriculture's COMET-Farm GHG accounting system. U.S. Dep't of Agric., COMET-Farm, https://comet-farm.com (last visited Mar. 18, 2022).

Beyond these additional GHG emission points, the full carbon footprint and climate impact of dams and reservoirs is expected to be far greater due to the millions of acres of destroyed and submerged forests, grasslands, soil, and farmlands caused by the construction and ongoing operations at dams and reservoirs across the country. GHG emissions from land use change are well understood and documented by the EPA in its existing national inventory, however most of the initial land use change from constructing dams and filling reservoirs occurred prior to the EPA inventory baseline year of 1990.[52] These reservoirs submerged lands that historically sequestered carbon, and thus inundating these lands by constructing a dam and reservoir has eliminated these expansive carbon sinks. Accordingly, the cumulative carbon footprint (and carbon equivalent) of dams and reservoirs is expected to be much higher than the direct GHG emissions alone.

Relatedly, recent dam removal projects around the country have restored thousands of acres of carbon-capturing habitats. These dam removal projects can significantly increase carbon capture objectives in the United States, without reducing or reforesting existing farmlands or other terrestrial habitats. In fact, removing dams and restoring former habitats and farmlands provides an unparalleled opportunity for the United States to simultaneously eliminate GHG emissions; create new carbon sinks; and increase biologically rich riparian and wetlands habitats, as well as productive alluvial soils and farmlands. Other climate-related opportunities exist with the elimination of dam and reservoir GHG emissions. For example, the recent federally-supported removal of two dams on the Elwha River in Washington State has created nearly 100 acres of new coastal habitat at its delta, by accumulating the beneficial sediment flushed from reservoirs behind the decommissioned dams. These projects also help sediment-deprived coastal communities build up their shorelines to combat sea level rise. The elimination of reservoirs paired with groundwater recharge and storage can also eliminate massive reservoir evaporation and promote more climate resilient water storage solutions without most of the dam and reservoir-related GHG emissions (and siltation/reduced storage problems).

In sum, as these studies and findings demonstrate, the GHG emissions from dams and reservoirs are even greater than the emissions identified in the peer-reviewed scientific studies summarized above. While some of these GHG emissions may be beyond the scope of what owners and operators would be required to report under the GHGRP, they illustrate the broad scope of GHG emissions from dams and reservoirs and the need for EPA to begin accounting for dams and reservoirs' direct GHG emissions.

V. Federal agencies, states, utilities, and other stakeholders often incorrectly assume and state that dams and reservoirs have no greenhouse gas emissions.

While the science has clearly and consistently shown that dams and reservoirs cause substantial annual GHG emissions, the federal agencies operating dams and reservoirs in the United States do not count or report these emissions. Moreover, federal agencies,

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52 *See* EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks (last visited Mar. 18, 2022).

states, utilities, and other stakeholders often mistakenly claim that dams and reservoirs have no GHG emissions, and that hydropower is a low- or zero-carbon electricity source.

Numerous federal agencies incorrectly characterize hydropower as a clean energy resource. The Bureau of Reclamation's hydropower website claims that "[h]ydropower is a renewable and reliable resource providing clean energy to the western United States."[53] Similarly, the Tennessee Valley Authority states that "[h]ydroelectric power is the most clean, reliable, efficient and economical of all renewable energy sources."[54] The Bonneville Power Administration also claims that its hydropower facilities "fuel[] the cleanest power system in the nation."[55] However, Reclamation's statement disregards the fact that it operates Lake Mead and Hoover Dam, which emit approximately 12.3 million metric tons of CO_2e annually, including 3.1 million metric tons attributable to hydropower generation. *See supra* p. 11. The Tennessee Valley Authority's statement similarly ignores the fact that it operates Kentucky Lake, which emits over 1.8 million metric tons of CO_2e annually, including 407,000 metric tons attributed to hydropower generation. *Id.*

Beyond hydropower, federal agencies also commonly overlook and disregard the GHG emissions from dams and reservoirs when they conduct National Environmental Policy Act reviews of water supply and dam management projects. As one example, the U.S. Army Corps of Engineers issued a final environmental impact statement in 2018 for the Northern Integrated Supply Project in Colorado.[56] This water supply project will result in the construction of two new reservoirs, with capacities of 170,000 and 45,624 acre-feet.[57] However, the Army Corps of Engineers' environmental impact statement does not acknowledge or attempt to quantify the surface GHG emissions from these new dams and reservoirs, or most of the other emission points from dams and reservoirs.

States with ambitious climate goals also frequently overlook dams and reservoirs' GHG emissions, and mistakenly claim that hydropower is a clean energy resource. For example, California states that it "uses a wide range of renewable energy resources to meet its clean energy goals, combat climate change, and promote sustainable energy use."[58] Yet California characterizes hydropower as one of those clean energy resources, and small

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53 Bureau of Reclamation, Hydropower Program, https://www.usbr.gov/power/ (last visited Mar. 18, 2022).
54 Tenn. Valley Auth., Hydroelectric, https://www.tva.com/energy/our-power-system/hydroelectric (last visited Mar. 18, 2022).
55 Bonneville Power Admin., Clean Energy: The Northwest way of life, https://www.bpa.gov/learn-and-participate/community-education/hydropower-101/clean-energy (last visited Mar. 18, 2022).
56 U.S. Army Corps of Eng'rs, *Environmental Impact Statement – Northern Integrated Supply Project* (July 2018), https://www.nwo.usace.army.mil/Missions/Regulatory-Program/Colorado/EIS-NISP/.
57 *Id.*
58 Cal. Energy Comm'n, Renewable Energy Resources, https://www.energy.ca.gov/programs-and-topics/topics/renewable-energy/renewable-energy-resources (last visited Mar. 18, 2022).

hydropower plants count toward the state's Renewables Portfolio Standard.[59] Similarly, New York counts hydropower generation in its Clean Energy Standard, which it claims is the "most comprehensive and ambitious clean energy goal in the State's history."[60] But hydropower currently accounts for the vast majority of New York's "clean energy" under this standard.[61] New York also plans to increase its hydropower generation, as it recently announced plans during "Climate Week" to power New York City with "wind, solar and hydropower projects from upstate New York and Canada."[62]

In addition, utilities across the United States often incorrectly presume that hydropower has a necessary role in a low- or zero-carbon future. For example, Xcel Energy— which is a utility with operations in Colorado, Michigan, Minnesota, New Mexico, North Dakota, South Dakota, Texas, and Wisconsin—touts its existing hydropower facilities as providing its customers with "clean, reliable power."[63] In a recent Colorado Public Utilities Commission filing, Xcel claimed that "resource technologies such as pumped storage hydropower . . . will be required to achieve 100 percent carbon reductions by 2050."[64] Additionally, a Deloitte article analyzing U.S. utilities' decarbonization strategies stated that "[h]ydroelectric power is expected to continue as an important cost-effective source of low-carbon baseload power."[65]

The hydropower industry also regularly repeats the false claim that hydropower is a clean energy resource. The National Hydropower Association states that hydropower is "clean, renewable energy," and that hydropower "provides clean, carbon-free energy."[66] The International Hydropower Association claims that pumped storage hydropower is an "ideal

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[59] *Id.*; Cal. Energy Comm'n, Hydroelectric Power, https://www.energy.ca.gov/data-reports/california-power-generation-and-power-sources/hydroelectric-power (last visited Mar. 18, 2022).

[60] N.Y. State Energy Rsch. & Dev. Auth., Clean Energy Standard, https://www.nyserda.ny.gov/all-programs/programs/clean-energy-standard (last visited Mar. 18, 2022).

[61] *Id.*

[62] Press Release, N.Y. State Energy Rsch. & Dev. Auth., During Climate Week, Governor Hochul Announces Major Green Energy Infrastructure Projects to Power New York City With Wind, Solar and Hydropower From Upstate New York and Canada (Sept. 20, 2021), https://www.nyserda.ny.gov/About/Newsroom/2021-Announcements/2021-09-20-Governor-Hochul-Announces-Major-Green-Energy-Infrastructure-Projects-to-Power-New-York-City-With-Wind.

[63] Xcel Energy, Hydro Energy, https://co.my.xcelenergy.com/s/energy-portfolio/hydro (last visited Mar. 18, 2022).

[64] Colo. Pub. Utils. Comm'n, Proceeding No. 21A-0141E, Brooke Trammell Direct Test. 8:14–15 (Mar. 31, 2021), https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Resource%20Plans/Clean%20Energy%20Plan/HE_103_-Direct_Testimony-Brooke_A_Trammell.pdf.

[65] Stanley Porter et al., *Utility Decarbonization Strategies*, Deloitte Insights (Sept. 21, 2020), https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/utility-decarbonization-strategies.html.

[66] Nat'l Hydropower Ass'n, https://www.hydro.org/ (last visited Mar. 18, 2022).

complement to modern clean energy systems."[67] Multiple news articles have also repeated industry claims that pumped storage hydropower is critical to the clean energy future.[68]

Various other entities and stakeholders also frequently overlook GHG emissions from dams and reservoirs. For example, media coverage of the August 2021 IPCC report highlighting methane emissions often discussed the significant methane emissions from oil and gas production and agriculture, while failing to mention the large amounts of methane emissions from dams and reservoirs.[69] Similarly, a recent McKinsey research report regarding methane claimed that five industries are responsible for 98% of anthropogenic methane emissions: agriculture, oil and gas, coal mining, solid-waste management, and wastewater management.[70] This claim is likely incorrect, as the 2020 Beaulieu et al. study estimated that dams and reservoirs are the fourth largest source of anthropogenic methane emissions in Ohio.[71] Yet the McKinsey research made no mention of methane emissions from dams and reservoirs.

Perhaps the most telling example of how stakeholders overlook dams and reservoirs' methane emissions is The Climate Registry's Water-Energy Nexus Registry. The Climate Registry is a non-profit organization that various states and Canadian provinces advise, and it offers programs for businesses and other organizations to voluntarily measure and report their GHG emissions.[72] In 2019, The Climate Registry launched a Water-Energy Nexus Registry, which focuses on California water providers.[73] The Water-Energy Nexus Registry correctly recognizes that water supply systems cause substantial GHG emissions, and it provides a voluntary registry for water providers to measure and report their

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67 Int'l Hydropower Ass'n, Clean Energy Systems, https://www.hydropower.org/what-we-do/clean-energy (last visited Mar. 18, 2022).

68 *See, e.g.*, Theresa Smith, *Pumped Storage Hydropower Critical for Future Clean Energy Systems*, Power Eng'g Int'l (Sept. 20, 2021), https://www.powerengineeringint.com/smart-grid-td/energy-storage/pumped-storage-hydropower-critical-for-future-clean-energy-systems/; Sammy Roth, *Environmental Disaster or Key to a Clean Energy Future? A New Twist on Hydropower*, L.A. Times, Mar. 5, 2020, https://www.latimes.com/environment/story/2020-03-05/is-hydropower-key-to-a-clean-energy-future.

69 *See, e.g.*, Rebecca Leber, *It's Time to Freak Out About Methane Emissions*, Vox (Nov. 3, 2021, 4:14 PM), https://www.vox.com/22613532/climate-change-methane-emissions.

70 Sam DeFabrizio et al., *Curbing Methane Emissions: How Five Industries Can Counter a Major Climate Threat*, McKinsey Sustainability (Sept. 23, 2021), https://www.mckinsey.com/business-functions/sustainability/our-insights/curbing-methane-emissions-how-five-industries-can-counter-a-major-climate-threat.

71 Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs*, *supra* note 34.

72 The Climate Registry, About Us, https://www.theclimateregistry.org/who-we-are/about-us/ (last visited Mar. 18, 2022).

73 The Climate Registry, Water-Energy Nexus Registry, History, https://www.theclimateregistry.org/waterenergynexusregistry/about/history/ (last visited Mar. 18, 2022).

systems' GHG emissions.[74] The registry claims its program allows water providers to calculate and track their carbon footprint. But the registry only measures and reports the GHG emissions resulting from the energy used to pump and transport water. The registry does not measure or account for reservoir surface emissions, or most of the other emission points from dams and reservoirs discussed above. *See supra* pp. 11–16. Consequently, this registry that purports to quantify the carbon footprint of water supply systems overlooks a significant portion of water providers' actual GHG emissions.

ARGUMENT

The Petitioners request that EPA grant this Petition and promptly initiate a rulemaking to list dams and reservoirs as a source category that must report GHG emissions under the GHGRP. 40 C.F.R. Part 98. EPA should grant this Petition and expand the scope of the GHGRP because dams and reservoirs emit substantial amounts of GHGs each year that are currently underreported and ignored. Accordingly, expanding the GHGRP to include dams and reservoirs will result in more accurate GHG emissions data from a long-overlooked source category of substantial GHG emissions. This additional data should result in increased awareness of GHG emissions from dams and reservoirs and better-informed climate policies at the federal, state, and local levels.

When EPA implemented the GHGRP in 2009, it recognized it would likely need to expand the program in the future by adding new source categories. Yet EPA has not added any source categories since 2010. This Petition provides EPA with a timely opportunity to expand the GHGRP so that regulators, policymakers, and the public will have access to important new data regarding this significant source category of GHG emissions.

I. Adding dams and reservoirs to the GHGRP will result in better informed U.S. climate policies by ensuring that dams and reservoirs' GHG emissions are no longer underreported and ignored.

Dams and reservoirs emit large amounts of GHGs each year, yet these emissions are often underreported and disregarded. As detailed above, some dams and reservoirs in the United States emit massive amounts of GHGs annually, at levels greater than the GHG emissions of coal- and gas-fired power plants and millions of gas-powered vehicles. For example, Lake Mead and its hydropower operations emit approximately 12.3 million metric tons of CO_2e annually, Kentucky Lake and its hydropower operations emit over 1.8 million metric tons of CO_2e annually, and Lake Whitney and its hydropower operations emit over 1.1 million metric tons of CO_2e per year. *See supra* p. 11. For comparison, Lake Mead's GHG emissions are equivalent to the emissions of over 2.6 million gas-powered vehicles, and Lake Whitney's GHG emissions are six times greater than a coal-fired power plant that produces a similar amount of energy. Yet these facilities are currently not required to measure or report their GHG emissions.

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[74] The Climate Registry, Programs and Services, Water-Energy Nexus Registry, https://www.theclimateregistry.org/programs-services/california-water-energy-nexus-registry/ (last visited Mar. 18, 2022); The Climate Registry, Water-Energy Nexus Registry, https://www.theclimateregistry.org/waterenergynexusregistry/ (last visited Mar. 18, 2022).

The collective GHG emissions of all dams and reservoirs across the nation are similarly underreported and disregarded. The 2020 Beaulieu et al. study estimated that Ohio's dams and reservoirs are the fourth largest source of anthropogenic methane emissions in the state.[75] And nationally, methane emissions from dam and reservoir surfaces are comparable to the methane emissions from the production and distribution of fossil fuels. *See supra* p. 13. Moreover, the overall CO_2e emissions from reservoir surfaces are comparable to the CO_2e emissions from the entire U.S. agricultural sector and home energy use in the United States. *See supra* pp. 13–14. Yet again, this source category's consequential GHG emissions are not measured or reported.

Because dam and reservoir facilities are not required to measure or report their annual GHG emissions, ignoring these emissions is the current status quo. Federal agencies, states, utilities, and other stakeholders too often assume that hydropower is a low- or zero-carbon resource, when that assumption is unfounded and incorrect. *See supra* pp. 16–20. Leaving the GHG emissions from dams and reservoirs "off the books" in this manner has given federal agencies, states, utilities, and private energy developers license to expand hydropower development, despite the substantial body of scientific research showing that dams and reservoirs are major contributors to the climate crisis.

This Petition seeks to rectify the omission of dam and reservoir GHG emissions from national inventories, so that EPA and other agencies and stakeholders can utilize accurate science and emissions data when they make decisions concerning the construction, operation, regulation, and decommissioning of dams in the United States. Adding dams and reservoirs to the GHGRP will ensure that policymakers and the public have access to greater and more accurate information regarding this significant source category of GHG emissions. This additional and improved emissions data will be a critical first step toward developing more well-informed policies on climate change, hydropower, and river management. GHG emissions data will also help ensure that the federal government does not provide funding for dam and reservoir facilities with GHG emissions that will frustrate the United States' climate goals. Similarly, water storage investments that utilize dams and reservoirs, rather than groundwater storage, may result in significantly higher GHG emissions and lost carbon capture opportunities. As EPA acknowledged when it implemented the GHGRP, "[a]ccurate and timely information on GHG emissions is essential for informing many future climate change policy decisions." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,265. But this essential information is lacking for dams and reservoirs. EPA should therefore grant this Petition and promptly initiate a rulemaking to list dams and reservoirs as a source category under the GHGRP.

II. Adding dams and reservoirs to the GHGRP will help prevent the ill-informed expansion of hydropower based on the mistaken assumption that hydropower is a carbon-free electricity source.

The August 2021 IPCC reports and the recent wildfires, hurricanes, and drought that have battered the United States have vividly highlighted the climate crisis and the

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75 Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs*, *supra* note 34.

need to take prompt actions to further reduce GHG emissions. The Biden Administration has set a goal of a 100% carbon-free electric sector by 2035.[76] President Biden also recently signed Executive Order 14057, which instructs the federal government to power its buildings and operations with 100% carbon pollution-free electricity by 2030. Exec. Order No. 14,057, 86 Fed. Reg. 70,935, 70,936 (Dec. 13, 2021). The Biden administration expects this order will "catalyze the development of at least 10 gigawatts of new American clean electricity production by 2030."[77] In addition, over the past year Congress has extensively debated legislation that would shape the future of our electricity system and accelerate the transition to clean energy.[78] Many states and utilities are similarly charting paths toward a zero-carbon future. *See supra* pp. 17–18.

As the federal government, states, and utilities determine how they will decarbonize the electric sector, it is imperative that they accurately account for the GHG emissions of various generation resources. The GHG emissions from coal- and gas-fired power plants, wind, and solar are well understood. In contrast, the GHG emissions from hydropower facilities are typically not recognized and not quantified. Even more problematically, the federal government, states, and utilities almost uniformly assume that hydropower is a clean and zero-carbon generation resource. *See supra* pp. 16–20. But that is not true for many hydropower facilities. The federal government, states, and utilities should not continue to make important and long-lasting decisions regarding the future of the electric sector based on incomplete and incorrect information that ignores hydropower's GHG emissions.

Granting this Petition and adding dams and reservoirs to the GHGRP will help ensure that the federal government, states, and utilities no longer mistakenly presume that hydropower is a clean energy resource. The core problem is the lack of awareness of dams and reservoirs' GHG emissions, and increasing this awareness and understanding is precisely the point of the GHGRP. When EPA implemented the GHGRP, it recognized that reporting programs "raise awareness of emissions among reporters and other stakeholders, and thus contribute to efforts to identify and implement emission reduction opportunities." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,265. This is a pivotal time to ensure the federal government, states, and utilities have access to accurate and timely information

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76 Fact Sheet, The White House, President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies (Apr. 22, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

77 Fact Sheet, The White House, President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability (Dec. 8, 2021); https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/.

78 *See, e.g.*, Brad Plumer & Winston Choi-Schagrin, *Major Climate Action at Stake in Fight Over Twin Bills Pending in Congress*, N.Y. Times, Oct. 10, 2021, https://www.nytimes.com/2021/10/10/climate/climate-action-congress.html.

regarding hydropower's GHG emissions. If regulators and policymakers continue to disregard or undercount the GHG emissions from the dams and reservoirs used for hydropower generation, the United States runs the risk of inadvertently pursuing a "clean" electric sector that is not actually clean.

Given the imperative to promptly reduce GHG emissions, the United States cannot afford to make ill-informed and mistaken decisions regarding hydropower's role in a zero-carbon future, particularly when data on hydropower's GHG emissions can be calculated but these facilities are not required to measure and report their emissions. The EPA should therefore grant this Petition and ensure that the federal government, states, utilities, and other stakeholders have access to the best available information on dams and reservoirs' GHG emissions as they make crucial decisions regarding the electric sector's future.

III. Adding dams and reservoirs to the GHGRP will assist the United States in achieving its Global Methane Pledge.

In August 2021, the IPCC issued a report highlighting methane's contribution to climate change and the need to promptly reduce methane emissions.[79] In October 2021, the United States announced that it will join the Global Methane Pledge to reduce methane emissions 30% by 2030, and more than one-hundred governments have now joined the pledge.[80]

Dams and reservoirs emit large amounts of methane. Individual dams and reservoirs can emit substantial amounts of methane annually, and the collective methane emissions of all dams and reservoirs across the United States are exceedingly large. As previously noted, the 2020 Beaulieu et al. study estimated that Ohio's dams and reservoirs are the fourth largest source of anthropogenic methane emissions in the state.[81] Yet again, these methane emissions from dams and reservoirs are mostly overlooked and ignored.

The Biden Administration and EPA have recently acknowledged the need for better data regarding methane emissions. For example, a White House statement regarding the Global Methane Pledge noted that participating countries commit to "moving towards using

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[79] *See supra* pp. 7–8; Matt McGrath, *Climate Change: Curbing Methane Emissions Will 'Buy Us Time,'* BBC News, Aug. 11, 2021, https://www.bbc.com/news/science-environment-58174111.

[80] Lisa Friedman, *More Than 30 Countries Join U.S. Pledge to Slash Methane Emissions*, N.Y. Times, Oct. 11, 2021, https://www.nytimes.com/2021/10/11/climate/methane-global-climate.html; Fact Sheet, The White House, President Biden Tackles Methane Emissions, Spurs Innovations, and Supports Sustainable Agriculture to Build a Clean Energy Economy and Create Jobs (Nov. 2, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/02/fact-sheet-president-biden-tackles-methane-emissions-spurs-innovations-and-supports-sustainable-agriculture-to-build-a-clean-energy-economy-and-create-jobs/.

[81] Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs*, *supra* note 34.

best available inventory methodologies to quantify methane emissions."[82] In addition, a news article regarding EPA's new methane regulations for the oil and gas sector quoted Administrator Regan as stating that "[m]ethane is such a potent pollutant, it's important that we understand what the contribution is from this industry."[83] Moreover, a recent Washington Post investigation found that countries around the world collectively underreport their methane emissions by 57 million to 76 million tons, and that this underreporting of methane emissions (and other GHGs) presents a significant hurdle to achieving climate goals.[84]

To effectively reduce the United States' methane emissions, it is imperative that EPA and other federal agencies understand the contribution of methane emissions from dams and reservoirs. Granting this Petition and adding dams and reservoirs to the GHGRP would further that goal and help ensure that the federal government possesses accurate and timely information on dams and reservoirs' methane emissions as it determines how it will meet the Global Methane Pledge. The federal government will be better positioned to achieve this goal if it understands the relative contribution of methane emissions from dams and reservoirs compared to other source categories, and this is one of the GHGRP's primary purposes. As EPA stated when it implemented the program, "[t]hrough data collected under [the GHGRP], EPA, States and the public will gain a better understanding of the relative emissions of specific industries across the nation." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,265. Moreover, the data regarding methane emissions from individual dams and reservoirs may illustrate additional ways the United States can achieve its methane goal, such as decommissioning certain high-emitting facilities. Granting this petition will thus help ensure that the federal government has access to the best available information on methane emissions from dams and reservoirs as it determines how it will reduce the nation's methane emissions 30% by 2030.

IV. Adding dams and reservoirs to the GHGRP will further the program's underlying principles.

EPA should grant this Petition because adding dams and reservoirs to the GHGRP will further the underlying purposes of the program. When EPA implemented the GHGRP in 2009 it articulated five principles for the program, and expanding the program to include dams and reservoirs will advance each principle.

First, EPA stated that the program should provide GHG emissions data that informs climate change policies at all levels of government. For example, EPA stated that "[a]ccurate and timely information on GHG emissions is essential for informing many future climate change policy decisions," and the data will "improve the U.S. government's ability to formulate climate policies." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,265. As detailed throughout this Petition, GHG emissions from dams and reservoirs are

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[82] Press Release, The White House, *supra* note 1.

[83] Grandoni & Romm, *supra* note 2.

[84] Chris Mooney et al., *Countries' Climate Pledges Built on Flawed Data, Post Investigation Finds*, Wash. Post, Nov. 7, 2021, https://www.washingtonpost.com/climate-environment/interactive/2021/greenhouse-gas-emissions-pledges-data/.

substantial, yet federal agencies, states, utilities, and other stakeholders frequently overlook and ignore these emissions. As a result, regulators and policymakers in the United States have developed climate polices that are based on fundamentally flawed and incorrect assumptions that hydropower is a clean energy resource, and that dams and reservoirs are not significant contributors to climate change. Granting this Petition will be an important step toward better-informed climate policies for federal, state, and local governments.

Second, EPA explained that the GHGRP should document the relative GHG emissions of different industries and source categories. EPA stated that "[t]hrough data collected under [the GHGRP], EPA, States and the public will gain a better understanding of the relative emissions of specific industries across the nation." *Id.* Adding dams and reservoirs to the GHGRP will advance this goal in several ways. Some individual dams and reservoirs have annual GHG emissions greater than coal- and gas-fired power plants, yet federal agencies, states, utilities, and other stakeholders often presume that all hydropower is a clean energy resource. In addition, water storage projects that utilize dams and reservoirs have greater GHG emissions than groundwater storage or other water storage options that do not involve dams and reservoirs. Requiring dams and reservoirs to report their GHG emissions will therefore allow regulators and utilities to compare an individual dam and reservoir facility's GHG emissions to the emissions of other generation resources and other water storage systems.

In addition, requiring dams and reservoirs to report their GHG emissions will allow agencies, states, and stakeholders to compare the collective GHG emissions from dams and reservoirs to the GHG emissions from other source categories. For example, many stakeholders overlook dams and reservoirs as a substantial source of methane emissions, and instead focus only on methane emissions from oil and gas production, agriculture, and landfills. *See supra* p. 19. Yet the 2020 Beaulieu et al. study estimated that Ohio's dams and reservoirs are the fourth largest source of anthropogenic methane emissions in that state.[85] Granting this petition will provide important insights into how the GHG emissions from dams and reservoirs compare to the GHG emissions from other industries and source categories.

Third, EPA stated that the GHGRP should document the GHG emissions of specific facilities within an industry or source category. EPA explained that the GHGRP will provide "EPA, States and the public [with] a better understanding of . . . the distribution of emissions from individual facilities within [an] industr[y]," and that "the facility-specific data will also improve our understanding of the factors that influence GHG emission rates and actions that facilities could in the future or already take to reduce emissions." Final 2009 GHGRP Rule, 74 Fed. Reg. at 56,265. Requiring dams and reservoirs to report their GHG emissions will advance this goal. Some dam and reservoir facilities emit massive amounts of GHGs, while other dams and reservoirs emit less GHGs. Consequently, requiring dams and reservoirs to report their emissions will provide valuable data regarding the relative GHG emissions between different facilities, and this will help

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[85] Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs*, *supra* note 34.

policymakers develop more effective climate policies to reduce GHG emissions from dams and reservoirs.

Fourth, EPA explained that the GHGRP data should raise awareness of sources' GHG emissions. EPA stated that its "experience with other reporting programs is that such programs raise awareness of emissions among reporters and other stakeholders, and thus contribute to efforts to identify and implement emission reduction opportunities." *Id.* As detailed throughout this Petition, the lack of awareness of dams and reservoirs' GHG emissions—even among federal agencies and states—is a fundamental problem. In short, there is a pressing need to raise awareness of the GHG emissions from dams and reservoirs, and requiring facilities to measure and report their emissions through the GHGRP will increase public awareness of these emissions.

Finally, EPA acknowledged that the GHGRP should expand and evolve over time to include additional source categories. EPA stated that "additional data collection (e.g., for other source categories or to support additional policy or program needs) will no doubt be required as the development of climate policies evolves." *Id.* The Congressional Research Service also recently reiterated this principle and stated that "policymakers could consider expanding the scope of sources required to report."[86] However, EPA has not added any new source categories to the GHGRP since 2010.[87] For all the reasons discussed above, dams and reservoirs are a source category that warrant expanding the GHGRP. EPA should therefore seize this opportunity to expand and evolve the GHGRP to cover dams and reservoirs, so that policymakers and the public have access to accurate and timely information regarding this significant source of GHG emissions.

V. Dams and reservoirs meet the definition of a "facility" under the GHGRP, and EPA may consider subcategories and determine the GHG calculation methodology in a future rulemaking.

If EPA grants this Petition and begins a rulemaking to list dams and reservoirs as a source category under the GHGRP, the Petitioners look forward to working with EPA and other stakeholders regarding the details of the reporting requirements for dams and reservoirs. The Petitioners offer the following preliminary comments regarding some of the technical matters that would be the subject of the future rulemaking.

The GHGRP requires owners and operators of covered facilities to report their GHG emissions. 40 C.F.R. § 98.1. The GHGRP regulations define a "facility" as "any physical property, plant, building, structure, source, or stationary equipment located on one or more contiguous or adjacent properties . . . that emits or may emit any greenhouse gas." *Id.* § 98.6. A dam and its artificially produced and maintained reservoir meet this definition of a "facility." A dam is a "structure," and its reservoir is a connected, interdependent, and essential part of the physical property, plant, and source. Moreover, a dam and its reservoir often include buildings, structures, stationary equipment, and plants that emit GHGs, such as turbines and spillways. Accordingly, the "facility" that must report GHG

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86 Cong. Research Serv., *supra* note 3, at 2.
87 EPA, GHGRP Historical Rulemakings, *supra* note 6.

emissions for the dam and reservoir source category should include the dam, the reservoir, and all other buildings, structures, stationary equipment, and plants located at the property that emit GHGs.

Relatedly, when EPA defines the source category in the subsequent rulemaking, it should define the dam and reservoir source category to include, at a minimum, each dam; the reservoir it creates, including the maximum fill line and area of the reservoir; and related infrastructure (e.g., hydropower turbines, spillways, desilting operations, and fish passage operations). EPA may also consider creating subcategories of dams and reservoirs that would be required to report their GHG emissions. For example, dams and reservoirs with hydropower generation could be a separate subcategory from non-hydro dams and reservoirs, if different reporting thresholds or reporting requirements are reasonable for these hydropower facilities.

In addition, there are several methodologies currently used for calculating GHG emissions from dams and reservoirs. As noted above, some of these methodologies more accurately calculate dams and reservoirs' GHG emissions than others. *See supra* p. 14. As a result, it will be important in future rulemakings for EPA to ensure that the equations and methodologies it requires owners and operators to use for this source category represent the best available science and accurately reflect the actual and complete GHG emissions from dams and reservoirs.

CONCLUSION

The time to take prompt and decisive action on climate change is now. Every day that dams and reservoirs continue to emit large amounts of GHGs that go uncounted and unreported is a missed opportunity to better understand and address this significant source of GHG emissions. Moreover, every day that federal agencies, states, and utilities incorrectly assume and state that all hydropower is a low- or zero-carbon resource—or that reservoir water storage has no GHG emissions—the United States goes further down the path of making pivotal and long-lasting decisions regarding electricity and water based on mistaken assumptions. Continuing these erroneous assumptions and ill-informed decisions will have dire consequences. For these reasons, the Petitioners strongly urge the EPA to grant this Petition and promptly initiate a rulemaking to add dams and reservoirs as a source category under the GHGRP.

We look forward to your prompt reply to this Petition, no later than 180 days from today. If you have any questions about this Petition, please contact Michael Hiatt at Earthjustice (303-996-9617).

Sincerely,

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350 Central Mass
350 Brattleboro
350 Maine
350 Seattle
Addison County River Watch Collaborative (VT)
Alabama Rivers Alliance
Alliance for the Wild Rockies
Alvraddarnas Waterkeeper

American Alpine Club
American Rivers
American Whitewater
Association "Resource Aarhus center in BiH"
Atchafalaya Basinkeeper
Atlantic Salmon Federation
Back Country Excursions of Maine, LLC
Backbone Campaign
Balkanka Association Sofia, Bulgaria
Beyond Searsville Dam
Black Warrior Riverkeeper
Boulder Waterkeeper
Bozeman Birders
Cahaba Riverkeeper
California Trout
California Wilderness Coalition (CalWild)
Centar za životnu sredinu/Center for Environment
Center for Biological Diversity
Coastal Watershed Institute
Collier County Waterkeeper
Columbia Riverkeeper
Commons BC
Connecticut River Conservancy
Creative Chi
Dam Sense
Dam Watch International
Deschutes Estuary Restoration Team
Downeast Salmon Federation
Earth Law Center
Earth Matters/350VT
EcoAlbania
Elliotsville Foundation
Endangered Species Coalition
Energy and Climate Upper Valley
Energy Balance, Inc.
Environmental Defense Center
Environmental Stewardship
EuroNatur
Foothill Conservancy

Forest Ecology Network
Friends of Butte Creek
Friends of Merrymeeting Bay
Friends of Sebago Lake
Friends of the Eel River
Friends of the River
Gallatin Wildlife Association
Glen Canyon Institute
Global Justice Ecology Project
Grand Riverkeeper Labrador, Inc.
Great Basin Waterkeeper and Great Basin Water Network
Idaho Rivers United
International Rivers
Lake Pend Oreille Waterkeeper
Last Tree Laws
LEAD Agency, Inc.
Living Rivers and Colorado Riverkeeper
Long Island Soundkeeper
Los Padres ForestWatch
LRB Hydrology & Analytics
Maine Youth for Climate Justice
Matilija Coalition
Mediterranean Institute for Nature and Anthropos
MHG Solar LLC
Milwaukee Riverkeeper
Missouri Confluence Waterkeeper
National Lawyers Guild - NYC Environmental Justice Committee
Native Fish Society
Nevada Conservation League
New York Environmental Law and Justice Project
NGO Green Home
Nimiipuu Protecting the Environment
North American Megadam Resistance Alliance
North Fork Studios
Northern California Council, Fly Fishers International
o2 Utah
Orange County Coastkeeper
Outdoor Alliance
Peace Valley Environment Association

Peace Valley Landowner Association
Peconic Baykeeper
Pippin Ventures
Port Phillip EcoCentre / Port Phillip Baykeeper
Raincoast Conservation Foundation
RAVEN (Respecting Aboriginal Values and Environmental Needs)
Restore Hetch Hetchy
RESTORE: The North Woods
Rio Grande Waterkeeper
Ríos to Rivers
Riverkeeper
Rivers for Change
Riverwatch
Rogue Riverkeeper
Sacramento River Council
San Francisco Baykeeper
San Luis Obispo Coastkeeper
San Marcos High School
Satilla Riverkeeper
Save Our Wild Salmon Coalition
Save The Poudre
Sierra Club
Slovenian Native Fish Society
Snake River Waterkeeper
Solutionary Rail
South Yuba River Citizens League
Stoecker Ecological
SunCommon
Surfrider Foundation
Tennessee Riverkeeper
The Conservation Alliance
The Rewilding Institute
The Sierra Fund
Three Rivers Waterkeeper
Tualatin Riverkeepers
Two Rivers Action Coalition
University of Montana, Flathead Lake Biological Station
Upper Colorado River Watershed Group
Upper Valley Affinity Group (Vermont)

Vermont Chapter of the Sierra Club
Washington Wild
Water Climate Trust
Waterkeeper Alliance, Inc.
Waterkeepers Chesapeake
Wild Fish Conservancy
Wild Orca
WildEarth Guardians
William S. Boyd School of Law's Environmental Law Society

Attachments

Attachment 1: Bibliography of Scientific Studies
Attachment 2: Mark Easter, *Greenhouse Gas Emissions from Dams and Reservoirs in the United States* (2022)
Attachment 3: List of Cited Documents and Sources Provided to EPA

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Attachment 1

Scientific Studies Documenting Greenhouse Gas Emissions from Dams and Reservoirs

2021

- Dailson Bertassoli Jr. et al., *How Green can Amazon Hydropower be? Net Carbon emission from the largest hydropower plant in Amazonia*, 7 Sci. Advances (June 25, 2021), https://www.science.org/doi/10.1126/sciadv.abe1470.

- John Harrison et al., *Year 2020 Global Distribution and Pathways of Reservoir Methane and Carbon Dioxide Emissions According to the Greenhouse Gas From Reservoirs (G-res) Model*, 35 Glob. Biogeochemical Cycles (June 2021), https://doi.org/10.1029/2020GB006888.

- Stephen Jane et al., *Widespread deoxygenation of temperate lakes*, 594 Nature 66 (June 2, 2021), https://www.nature.com/articles/s41586-021-03550-y.

- Philipp Keller et al., *Global carbon budget of reservoirs is overturned by the quantification of drawdown areas*, 14 Nature Geoscience 402 (May 13, 2021), https://www.nature.com/articles/s41561-021-00734-z.

2020

- Jake Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs: Controls and Upscaling*, 125 J. Geophysical Rsch. Biogeosciences 1 (Oct. 15, 2020), https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019JG005474.

- Bridget Deemer et al., *Data from: Greenhouse gas emissions from reservoir water surfaces: a new global synthesis*, Dryad Dataset (Jan. 6, 2020), https://datadryad.org/stash/dataset/doi:10.5061/dryad.d2kv0.

2019

- Ilissa Ocko & Steven Hamburg, *Climate Impacts of Hydropower: Enormous Differences among Facilities and over Time*, 53 Envtl. Sci. & Tech. 14,070 (Nov. 13, 2019), https://pubs.acs.org/doi/10.1021/acs.est.9b05083.

- Rafael Almeida et al., *Reducing greenhouse gas emissions of Amazon hydropower with strategic dam planning*, 10 Nature Commc'ns (Sept. 19, 2019), https://www.nature.com/articles/s41467-019-12179-5.

- Jake Beaulieu et al., *Eutrophication will increase methane emissions from lakes and impoundments during the 21st century*, 10 Nature Commc'ns (Mar. 26, 2019), https://www.nature.com/articles/s41467-019-09100-5.

- Rafael Marcé et al., *Emissions from dry inland waters are a blind spot in the global carbon cycle*, 188 Earth-Sci. Reviews 240 (Jan. 2019), https://www.sciencedirect.com/science/article/pii/S0012825218301971?via%3Dihub.

- Bradford Hager, *Documentation of the Carbon Footprint of Hydro Québec's Hydropower*, https://drive.google.com/file/d/1eq7QMjPx1X-Tzsl7vmtJpmfUJBMPkJ9r/view.

2018

- Ming Fai Chow et al., *Assessment of Greenhouse Gas (GHG) Emission from Hydropower Reservoirs in Malaysia*, 2 Proceedings 1380 (Nov. 6, 2018), https://www.mdpi.com/2504-3900/2/22/1380.

- Sarian Kosten et al., *Extreme drought boosts CO_2 and CH_4 emissions from reservoir drawdown areas*, 8 Inland Waters 329 (July 27, 2018), https://www.tandfonline.com/doi/full/10.1080/20442041.2018.1483126?cookieSet=1.

- Cuihong Song et al., *Cradle-to-grave greenhouse gas emissions from dams in the United States of America*, 90 Renewable & Sustainable Energy Revs. 945 (July 2018), https://www.sciencedirect.com/science/article/abs/pii/S1364032118302235.

- Georgios Samiotis et al., *Greenhouse gas emissions from two hydroelectric reservoirs in Mediterranean region*, 190 Envtl. Monitoring & Assessment (May 26, 2018), https://link.springer.com/article/10.1007/s10661-018-6721-4.

- Tonya DelSontro et al., *Greenhouse gas emissions from lakes and impoundments: Upscaling in the face of global change*, 3 Limnology & Oceanography Letters 64 (Mar. 26, 2018), https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lol2.10073.

- Timo Räsänen et al., *Greenhouse gas emissions of hydropower in the Mekong River Basin*, 13 Envtl. Res. Letters (Mar. 1, 2018), https://iopscience.iop.org/article/10.1088/1748-9326/aaa817.

2017

- Yves Prairie et al., *Greenhouse Gas Emissions from Freshwater Reservoirs: What Does the Atmosphere See?*, 21 Ecosystems 1058 (Nov. 8, 2017), https://link.springer.com/article/10.1007/s10021-017-0198-9.

- Taylor Maavara et al., *Global perturbation of organic carbon cycling by river damming*, 8 Nature Commc'ns (May 17, 2017), https://www.nature.com/articles/ncomms15347.

2016

- Bridget Deemer et al., *Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis*, 66 BioSci. 949 (Oct. 5, 2016), https://academic.oup.com/bioscience/article/66/11/949/2754271.

- Laura Scherer & Stephan Pfister, *Hydropower's Biogenic Carbon Footprint*, PLoS ONE (Sept. 14, 2016), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0161947.

- Jake Beaulieu et al., *Estimates of reservoir methane emissions based on a spatially balanced probabilistic-survey*, 61 Limnology & Oceanography S27 (June 24, 2016), https://aslopubs.onlinelibrary.wiley.com/doi/10.1002/lno.10284/.

- Philip Fearnside, *Greenhouse gas emissions from Brazil's Amazonian hydroelectric dams*, 11 Envtl. Res. Letters (Jan. 27, 2016), https://iopscience.iop.org/article/10.1088/1748-9326/11/1/011002.

2015

- Felipe A M de Faria et al., *Estimating greenhouse gas emissions from future Amazonian hydroelectric reservoirs*, 10 Envtl. Res. Letters (Dec. 17, 2015), https://iopscience.iop.org/article/10.1088/1748-9326/10/12/124019/pdf.

- Philip Fearnside, *Emissions from tropical hydropower and the IPCC*, 50 Envtl. Sci. & Policy 225 (June 2015), https://www.sciencedirect.com/science/article/abs/pii/S1462901115000519?via%3Dihub.

- M.P. Fedorov et al., *Reservoir Greenhouse Gas Emissions at Russian HPP*, 49 Power Tech. & Eng'g 33 (Apr. 25, 2015), https://link.springer.com/article/10.1007/s10749-015-0569-3.

2014

- A. Maeck et al., *Pumping methane out of aquatic sediments – ebullition forcing mechanisms in an impounded river*, 11 Biogeosciences 2925 (June 5, 2014), https://bg.copernicus.org/articles/11/2925/2014/.

2013

- Edgar Hertwich, *Addressing Biogenic Greenhouse Gas Emissions from Hydropower in LCA*, 47 Envtl. Sci. & Tech. 9604 (Aug. 2, 2013), https://pubs.acs.org/doi/10.1021/es401820p.

- Andreas Maeck et al., *Sediment Trapping by Dams Creates Methane Emission Hot Spots*, 47 Envtl. Sci. & Tech. 8130 (June 25, 2013), https://pubs.acs.org/doi/abs/10.1021/es4003907.

2012

- Cristian Teodoru et al., *The net carbon footprint of a newly created boreal hydroelectric reservoir*, 26 Glob. Biogeochemical Cycles (May 17, 2012), https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2011GB004187.

- William West et al., *Effects of algal and terrestrial carbon on methane production rates and methanogen community structure in a temperate lake sediment*, 57 Freshwater Biology 949 (Feb. 28, 2012), https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2427.2012.02755.x.

- William Steinhurst et al., Synapse Energy Econs., *Hydropower Greenhouse Gas Emissions: State of the Research* (Feb. 15, 2012), https://www.synapse-energy.com/sites/default/files/SynapseReport.2012-02.CLF+PEW.GHG-from-Hydro.10-056.pdf.

2011

- Nathan Barros et al., *Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude*, 4 Nature Geoscience 593 (July 31, 2011), https://www.nature.com/articles/ngeo1211.

2009

- Günter Gunkel, *Hydropower – A Green Energy? Tropical Reservoirs and Greenhouse Gas Emissions*, 37 Clean Soil Air Water 726 (Sept. 15, 2009), https://onlinelibrary.wiley.com/doi/10.1002/clen.200900062.

2008

- Philip Fearnside, *Hydroelectric Dams as "Methane Factories": The Role of Reservoirs in Tropical Forest Areas as Sources of Greenhouse Gases*, 12 Oecologia Australis (2008), https://www.semanticscholar.org/paper/HYDROELECTRIC-DAMS-AS-%E2%80%9CMETHANE-FACTORIES%E2%80%9D%3A-THE-ROLE-Fearnside/a4454cf836d9543cc3f087e47457749207d943d0.

2007

- Katey Walter et al., *Methane bubbling from northern lakes: present and future contributions to the global methane budget*, 365 Philosophical Transactions of the Royal Soc'y (May 18, 2007), https://royalsocietypublishing.org/doi/10.1098/rsta.2007.2036.

- Ivan Lima et al., *Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective*, 13 Mitigation & Adaptation Strategies for Glob. Change 193 (Mar. 2, 2007), https://link.springer.com/article/10.1007/s11027-007-9086-5.

2006

- Intergovernmental Panel on Climate Change, *App. 3, CH4 Emissions from Flooded Land: Basis for Future Methodological Development, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry and Other Land Use* (2006), https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

2005

- Philip Fearnside, *Do Hydroelectric Dams Mitigate Global Warming? The Case of Brazil's CuruÁ-una Dam*, 10 Mitigation & Adaptation Strategies for Glob. Change 675 (Oct. 2005), https://link.springer.com/article/10.1007/s11027-005-7303-7.

- Alain Tremblay et al., *Greenhouse Gas Emissions – Fluxes and Processes: Hydroelectric Reservoirs and Natural Environments* (2005), https://link.springer.com/book/10.1007/978-3-540-26643-3.

2000

- David Rosenberg et al., *Global-Scale Environmental Effects of Hydrological Alterations: Introduction*, 50 BioScience 746 (Sept. 1, 2000), https://academic.oup.com/bioscience/article/50/9/746/269195.

- Vincent St. Louis et al., *Reservoir Surfaces as Sources of Greenhouse Gases to the Atmosphere: A Global Estimate*, 50 BioScience 766 (Sept. 1, 2000), https://academic.oup.com/bioscience/article/50/9/766/269391.

1997

- Philip Fearnside, *Greenhouse-gas emissions from Amazonian hydroelectric reservoirs: the example of Brazil's Tucuruí Dam as compared to fossil fuel alternatives*, 24 Envtl. Conservation 64 (March 1997), https://www.cambridge.org/core/journals/environmental-conservation/article/abs/greenhousegas-emissions-from-amazonian-hydroelectric-reservoirs-the-example-of-brazils-tucurui-dam-as-compared-to-fossil-fuel-alternatives/08E7CBA68DA4EBF76B84633D9F49C05B.

1995

- Philip Fearnside, *Hydroelectric Dams in the Brazilian Amazon as Sources of 'Greenhouse' Gases*, 22 Envtl. Conservation 7 (1995), https://www.cambridge.org/core/journals/environmental-conservation/article/abs/hydroelectric-dams-in-the-brazilian-amazon-as-sources-of-greenhouse-gases/B02E5246EF25F78DD96E05E9EBCC79CD.

Attachment 2

Greenhouse Gas Emissions from Dams and Reservoirs in the US

Mark Easter, Independent Consultant

March 19, 2022

Following is a summary of seventeen identified emissions source and sub source categories, by EPA GHG inventory sector, with an indication whether generalizable emissions models currently exist that can be utilized either in GHG inventories or life cycle assessments or other analyses that assess scope 1, 2, or 3 emissions:

Table 1. Greenhouse gas emissions sources and sub sources from Reservoir Systems.

Emissions Sector	Emissions source category	Emissions sub source categories	Do generally applicable emissions models exist?	Yearly or one-time emissions?	Citations
Industrial Processes	Mineral Products	CO_2 from Cement Production	yes	One-time at beginning of life cycle.	[1]
Energy	Fossil Fuel Combustion for Mining and Dam Construction	CO_2	yes	One-time at beginning of life cycle.	[5]
Energy	Fossil Fuel for Dam and Reservoir Operations	CO_2	yes	Yearly over the life cycle until dam removal and remediation.	[5]

[1] U.S. Environmental Protection Agency. 2021. Inventory of Greenhouse Gas Emissions and Sinks 1990-2019. https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf?VersionId=yu89kg1O2qP754CdR8Qmyn4RRWc5iodZ, viewed on 16 November 2021.

Emissions Sector	Emissions source category	Emissions sub source categories	Do generally applicable emissions models exist?	Yearly or one-time emissions?	Citations
Energy	Biogenic emissions from hydropower turbines	CH_4	no	Yearly over the life cycle until dam removal and remediation.	[2] [3] [4] [5] [6]
Land Use and Forestry	Surface Emissions from Lakes and Reservoirs	CO_2, CH_4, N_2O	yes	Yearly over the life cycle until dam removal and remediation.	[7] [8]
Land Use and Forestry	Wetlands and Riparian Forest Degradation	CO_2, CH_4, N_2O	no	Yearly over the first several decades after dam construction.	[12]

[2] Fearnside, P. (1995). Hydroelectric Dams in the Brazilian Amazon as Sources of 'Greenhouse' Gases. *Environmental Conservation, 22*(1), 7-19. doi:10.1017/S0376892900034020

[3] Tremblay et al. (2005). *Greenhouse Gas Emissions - Fluxes and Processes: Hydroelectric Reservoirs and Natural Environments.* Germany: Springer, 2005. https://www.springer.com/gp/book/9783540234555

[4] Gunkel, G. (2009), Hydropower – A Green Energy? Tropical Reservoirs and Greenhouse Gas Emissions. Clean Soil Air Water, 37: 726-734. https://doi.org/10.1002/clen.200900062

[5] Teodoru, Cristian *et al.* (2012). The Net Carbon Footprint of a Newly Created Boreal Hydroelectric Reservoir, *Global Biogeochemical Cycles, May 2012*, at 1. The net carbon footprint of a newly created boreal hydroelectric reservoir

[6] Steinhurst, William, *et al.* (2012). Hydropower Greenhouse Gas Emissions, *Synapse Energy Econ.. 12.* https://www.synapse-energy.com/sites/default/files/SynapseReport.2012-02.CLF+PEW.GHG-from-Hydro.10-056.pdf

[7] Scherer, Laura & Stephan Pfister, (2016). Hydropower's Biogenic Carbon Footprint, *PLOS ONE*, September 14, 2016. https://doi.org/10.1371/journal.pone.0161947

[8] Deemer, Bridget R., John A. Harrison, Siyue Li, Jake J. Beaulieu, Tonya DelSontro, Nathan Barros, José F. Bezerra-Neto, Stephen M. Powers, Marco A. dos Santos, J. Arie Vonk, (2016). Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis, *BioScience*, Volume 66, Issue 11, 1 November 2016, Pages 949–964, https://doi.org/10.1093/biosci/biw117, viewed on 16 November 2016.

Emissions Sector	Emissions source category	Emissions sub source categories	Do generally applicable emissions models exist?	Yearly or one-time emissions?	Citations
Land Use and Forestry	Reservoir Banks	CO_2, CH_4 N_2O	no	Yearly over the life cycle until dam removal and remediation.	[9] [10]
Land Use and Forestry	Dam and Reservoir Decommissioning and Restoration	CO_2, CH_4, N_2O	no	One-time after dam removal and site restoration.	[11] [12]
Land Use and Forestry	Loss of ecosystem function (carbon sequestration)	CO_2	no	One-time after dam construction and inundation, and then potentially yearly over the life cycle until dam removal and remediation.	[5]

As shown in the table above, only seven of these seventeen emissions sources have been quantified to the extent that generalized emissions models can be applied in a greenhouse gas inventory at the country level. The fact that emissions are dispersed across multiple sectors, and that many of the identified emissions have yet to be fully quantified, has created the impression that dams, reservoirs, and their associated land uses, which prominently includes hydropower, are low-carbon or even zero-carbon enterprises. This perception is made even worse when the

[9] Keller, P.S., Marcé, R., Obrador, B. *et al.* (2021) Global Carbon Budget of Reservoirs is Overturned by the Quantification of Drawdown Areas. *Nat. Geosci.* https://www.nature.com/articles/s41561-021-00734-z, viewed on 16 November 2016.
[10] Marcé, R. *et al.* (2019) Emissions from Dry Inland Waters are a Blind Spot in the Global Carbon Cycle. *Earth Sci. Rev.* 188, 240–248. https://doi.org/10.1016/j.earscirev.2018.11.012, viewed on 16 November 2016.
[11] Hertwich EG.(2013). Addressing biogenic greenhouse gas emissions from hydropower in LCA. Environ Sci Technol. 2013 Sep 3;47(17):9604-11. doi: 10.1021/es401820p.
[12] Song, C, K Gardner, S Klein, SP Souza, W Mo. 2018. Cradle to Grave Greenhouse Gas Emissions from Dams in the United States of America. Renewable and Sustainable Energy Reviews 90:945-956. https://doi.org/10.1016/j.rser.2018.04.014

magnitude of emissions are diluted or downplayed by attributing them to other co-occurring uses for reservoirs, such as recreation or flood control. When the emissions are examined in aggregate, however, the evidence clearly indicates that the emissions from dams and reservoirs are very high.

To illustrate the potential overall magnitude of greenhouse gases (GHGs) from dams and reservoirs (hereinafter referred to as "reservoir systems"), consider the emissions from one single source category – that of reservoir surfaces. Deemer *et al.* (2016, 2020) developed generalized greenhouse gas inventory emissions that may be applied to greenhouse gas inventories of reservoirs based on their trophic states (oligotrophic, mesotrophic, and eutrophic)[13]. Using the US Army Corps of Engineers National Inventory of Dams as a primary data source for the area of water bodies that are technically classified as reservoirs[14] the total reservoir surface area in the inventory was calculated at 12,471,527 hectares (30,804,671 acres). This estimate of surface area is likely conservatively small, for the following reasons:

1) It does not include the SOO Locks on the St. Mary's River downstream of Lake Superior. The National Inventory of Dams includes the surface area of Lake Superior associated with the locks, which skews the inventory upwards. Eutrophication and downstream impacts associated with the locks are not incorporated into this assessment.
2) At the time the version of the national inventory of dams was downloaded (October, 2021) more than 21,823 of the 91,457 records did not contain a record of surface area for the reservoir associated with the dam. A simple linear regression technique that predicts surface area from NID storage in the dataset indicates that approximately 6 million acres of reservoirs are not accounted for in the assessment.

In order to assess the proportion of dams in the different trophic classes, this analysis utilized the EPA 2012 National Lakes Assessment[15], which indicates that reservoirs in the U.S. fall into the relative fractions of trophic classes shown in the table below. Combining that with the emission factors produces the following results:

[13] Trophic State Index. 2021. https://en.wikipedia.org/wiki/Trophic_state_index, viewed 16 November 2021.
[14] US Army Corps of Engineers. 2021. National Inventory of Dams. https://nid.usace.army.mil/ords/f?p=105:1, viewed 16 November 2021.
[15] US Environmental Protection Agency. 2016. National Lakes Assessment for 2012. https://www.epa.gov/sites/default/files/2016-12/documents/nla_report_dec_2016.pdf, page 12, viewed on 16 November 2021.

Surface Emissions	fraction	area (ha)	Emission factor	units	Emissions (Mg CO2e/yr)
Totals	***1***	***12,471,527***			***459,405,494***
oligotrophic	0.10	1,247,153	1087	mg $CO_2e/m^2/day$	4,948,141
mesotrophic	0.35	4,365,034	3782	mg $CO_2e/m^2/day$	60,256,244
eutrophic	0.34	4,240,319	15745	mg $CO_2e/m^2/day$	243,687,959
hypereutrophic	0.21	2,619,021	15745	mg $CO_2e/m^2/day$	150,513,151

In summary, the total surface emissions estimated from this analysis is 459 MMT CO2e/yr, shown in the figure below in comparison with other U.S. greenhouse gas emissions sectors.

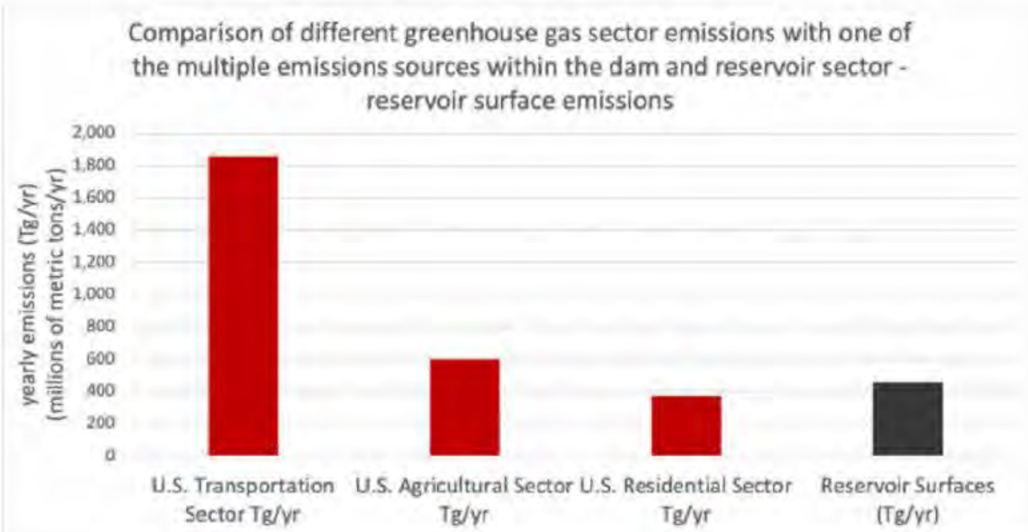

Figure 1. Comparison of U.S. reservoir surface emissions with other U.S. Emissions Source Categories. Sources: U.S. EPA Greenhouse Gas Inventory Data Explorer, U.S. Army Corps of Engineers National Inventory of Dams, U.S. EPA National Lakes Assessment, and Deemer et al. (2016, 2020). Note: Depending on the type of dam and reservoir operations, total emissions will include additional known emissions sources, including hydroelectric turbines, fuel used for dam and reservoir construction and operations, cement used in dam construction, reservoir banks, lost or damaged downstream forests and wetlands disrupted by dam operations, deforestation before inundation, lost carbon sequestration opportunities after inundation, and ecosystem carbon losses after inevitable dam decommissioning.

In addition to the likely under-estimate of the total surface area of reservoirs in the Corps of Engineers National Dam Inventory, this estimate of total emissions from reservoir surfaces is likely conservatively small for other reasons. No separate emissions factor has been calculated for hypereutrophic water bodies, and so the emission factor for eutrophic water bodies was used to estimate emissions for hypereutrophic water bodies. Considering that emissions increase with the eutrophic state of the water body, combined with the fact that more than a fifth of U.S. water bodies are classified by the National Lakes Assessment as hypereutrophic, this calculated emission factor of 459 million metric tons of CO2e per year from reservoir surfaces is likely much higher. If combined with the other sixteen emissions source categories across the complete life cycle of a reservoir system, the total emissions elevate reservoir systems into one of the most significant greenhouse gas emissions categories in the U.S.

This analysis compares favorably with other studies. Total per-area emissions average 36.8 Mg CO2e/ha/yr for U.S. reservoirs, which is comparable to the Deemer *et al.* analyses showing emissions of 24.9 Mg CO2e/ha/yr for a subsample of reservoirs internationally. The higher fraction of U.S. reservoirs in eutrophic or hypereutrophic states, compared with that fraction internationally, is the driving factor for a higher per-area analysis.

It is notable to point out that these emissions, on a per-area basis, are among the highest for any non-urban land use in the U.S. For example, the highest emissions from agricultural lands are likely from cropland on drained organic soils (35 Mg CO_2e/ha)[16] [17].

Once they are quantified in a way that can be implemented in GHG inventories, the GHG emissions from currently unquantified emissions sources (hydropower turbines, reservoir banks, inevitable dam decommissioning, loss of ecosystem function, loss of ecosystem carbon and nitrogen downstream of dams) are likely to significantly increase the inventoried emissions from reservoirs and emissions attributed to hydropower. Emissions from dam decommissioning

[16] IPCC. 2013. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Chapter 2: Drained Inland Organic Soils. https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_separate_files/WS_Chp2_Drained_Inland_Organic_Soils.pdf, viewed 16 November 2021.

[17] It is important to note that the emissions from land use change are currently quantified in annual EPA GHG inventory, however the total land use change resulting from the construction of the current inventory of dams in the United States was largely complete by 1990, the baseline year of the U.S. GHG inventory.

could be very high.[18] The loss of terrestrial ecosystem carbon sequestration due to inundation largely remains unquantified. One recent study in Oct. 2021, addressed aspects of this issue[19].

Some parties have argued dams and reservoirs simply move carbon around and do not result in net emissions over their lifecycle. There is an increasing body of evidence, codified in the bibliography provided, that casts great doubt upon that assertion. Studies that tout the benefits of reservoirs or low emissions from hydropower all share at least one of the following problems:

- Emissions from hydropower turbines are quantified using faulty methods that can lead to a substantial undercounting of GHG concentrations upstream of hydropower turbines[20]. This can lead to major under-estimation of off-gassed GHG emissions relative to the trace gas emissions downstream of turbines.

- Measurements not taken at appropriate time steps, or missing measurements during critical periods, such as when temperate and boreal reservoirs "turn" in the spring and fall, can lead to significant undercounting of total yearly GHG emissions[21].

- Critical components of life cycle emissions, such as inevitable dam decommissioning, ecosystem carbon and nitrogen losses downstream due to flow alterations, dam construction, or other emissions source categories have not been included[22].

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[18] Cuihong Song *et al.*, *Cradle-to-Grave Greenhouse Gas Emissions from Dams in the United States of America*, 90 Renewable & Sustainable Energy Reviews 945 (2018), https://www.sciencedirect.com/science/article/abs/pii/S1364032118302235, viewed 16 November 2021.

[19] https://www.nature.com/articles/s41561-021-00845-7, viewed 16 November 2021.

[20] UNESCO and International Hydropower Association. 2010. GHG Measurement Guidelines for Freshwater Reservoirs. https://www.hydropower.org/publications/ghg-measurement-guidelines-for-freshwater-reservoirs, viewed 16 November 2021.

[21] Deemer, Bridget R., John A. Harrison, Siyue Li, Jake J. Beaulieu, Tonya DelSontro, Nathan Barros, José F. Bezerra-Neto, Stephen M. Powers, Marco A. dos Santos, J. Arie Vonk, (2016). Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis, *BioScience*, Volume 66, Issue 11, 1 November 2016, Pages 949–964, https://doi.org/10.1093/biosci/biw117, viewed 16 November 2021.

[22] Cuihong Song *et al.*, *Cradle-to-Grave Greenhouse Gas Emissions from Dams in the United States of America*, 90 Renewable & Sustainable Energy Reviews 945 (2018),

To summarize:

- Scientists have identified at least seventeen sources of greenhouse gas emissions from reservoir systems, which occur across multiple greenhouse gas inventory categories, including energy, industrial processes, and land use & forestry.
- Only seven emissions sources from reservoir systems are currently accounted for in the US EPA annual greenhouse gas inventory.
- The fact that so many emissions sources are uncounted, and the ones that are counted are distributed across multiple emissions categories, creates the impression that emissions are relatively small compared with other types of land use, industrial processes, or energy sources.
- Critical steps need to be taken to correct this GHG undercounting bias from reservoir systems, including:
    - o Incorporate currently available scientific methods and evidence into the US EPA annual greenhouse gas inventory to fill existing inventory gaps, beginning with reservoir surface emissions and lost carbon sequestration
    - o Initiate studies to collect the data necessary to construct general models that can be applied in a general way to the remaining missing GHG sources, including emissions from hydropower turbines and reservoir banks, inevitable dam decommissioning and reservoir site remediation, disrupted wetlands and riparian forests due to altered downstream flow regimes, and lost carbon sequestration potential after dam construction and reservoir inundation.

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https://www.sciencedirect.com/science/article/abs/pii/S1364032118302235, viewed 16 November 2021.

Scientific Literature Describing Greenhouse Gas Emissions from Dam and Reservoir Systems

2021

Bertassoli, D. J., Sawakuchi, H. O., de Araújo, K. R., de Camargo, M. G. P., Alem, V. A. T., Pereira, T. S., Krusche, A. V., Bastviken, D., Richey, J. E., & Sawakuchi, A. O. (2021). How Green can Amazon Hydropower be? Net Carbon Emission from the Largest Hydropower Plant in Amazonia. *Science Advances*, *7*(26). https://doi.org/10.1126/sciadv.abe1470

Harrison, John, Yves T. Prairie, Sara Mercier-Blais, Cynthia Soued. (2021) Year-2020 Global Distribution and Pathways of Reservoir Methane and Carbon Dioxide Emissions According to the Greenhouse Gas from Reservoirs (G-res) Model. *Global Biogeochemical Cycles*, doi: 10.1029/2020GB006888

Jane, S.F., Hansen, G.J.A., Kraemer, B.M. *et al.* (2021) Widespread Deoxygenation of Temperate Lakes. *Nature* 594, 66–70 https://doi.org/10.1038/s41586-021-03550-y

Keller, P.S., Marcé, R., Obrador, B. *et al.* (2021) Global Carbon Budget of Reservoirs is Overturned by the Quantification of Drawdown Areas. *Nat. Geosci.* Global carbon budget of reservoirs is overturned by the quantification of drawdown areas

2020

Beaulieu, J, et al.; (2020) Methane and Carbon Dioxide Emissions From Reservoirs, *Journal of Geophysical research. Biogeosciences*, Vol.125 (12), p.n/a, doi: Methane and carbon dioxide emissions from reservoirs: Controls and Upscaling

Deemer, Bridget R. et al. (2020), Data from: Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis, Dryad, Dataset, https://doi.org/10.5061/dryad.d2kv0

2019

Almeida, R.M., Shi, Q., Gomes-Selman, J.M. *et al.* (2019) Reducing Greenhouse Gas Emissions of Amazon Hydropower with Strategic Dam Planning. *Nat Commun* 10, 4281. https://doi.org/10.1038/s41467-019-12179-5

Beaulieu, J.J., DelSontro, T. & Downing, J.A. (2019) Eutrophication will Increase Methane Emissions from Lakes and Impoundments during the 21st Century. *Nat Commun* 10, 1375. https://doi.org/10.1038/s41467-019-09100-5

Hager, PhD, Cecil Green and Ida Green Professor of Earth Sciences Department of Earth, Atmospheric and Planetary Sciences Massachusetts Institute of Technology Documentation of the Carbon Footprint of Hydro Québec's Hydropower https://drive.google.com/file/d/1eq7QMjPx1X-Tzsl7vmtJpmfUJBMPkJ9r/view

Marcé, R. et al. (2019) Emissions from Dry Inland Waters are a Blind Spot in the Global Carbon Cycle. *Earth Sci. Rev*. 188, 240–248. https://doi.org/10.1016/j.earscirev.2018.11.012

Ocko, Ilissa B. and Steven P. Hamburg, (2019) Climate Impacts of Hydropower: Enormous Differences among Facilities and over Time, *Environmental Science & Technology* 2019 *53* (23), 14070-14082 DOI: 10.1021/acs.est.9b05083 https://www.eenews.net/assets/2019/11/15/document_ew_01.pdf

2018

Chow, M.F.; Bakhrojin, M.A.b.; Haris, H.; Dinesh, (2018), A.A.A. Assessment of Greenhouse Gas (GHG) Emission from Hydropower Reservoirs in Malaysia. *Proceedings* 2018, *2*, 1380. https://doi.org/10.3390/proceedings2221380

DelSontro, T., J. Beaulieu, AND J. Downing. (2018), Greenhouse Gas Emissions from Lakes and Impoundments: Upscaling in the Face of Global Change. *Limnology and Oceanography Letters*. John Wiley & Sons, Inc., Hoboken, NJ, 3(3):64-75. https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.1002/lol2.10073

Kosten, S. et al. (2018). Extreme Drought Boosts CO2 and CH4 Emissions from Reservoir Drawdown Areas. *Inland Waters* 8, 329–340. https://doi.org/10.1080/20442041.2018.1483126

Prairie YT, Alm J, Beaulieu J, et al. (2018). Greenhouse Gas Emissions from Freshwater Reservoirs: What Does the Atmosphere See?. *Ecosystems*; 21(5):1058-1071. https://doi.org/10.1007/s10021-017-0198-9

Räsänen, Timo A. et al. (2018). Greenhouse Gas Emissions of Hydropower in the Mekong River Basin, *Environ. Res. Lett.* 13 034030 https://iopscience.iop.org/article/10.1088/1748-9326/aaa817

Samiotis G, Pekridis G, Kaklidis N, Trikoilidou E, Taousanidis N, Amanatidou E. (2018). Greenhouse Gas Emissions from two Hydroelectric Reservoirs in Mediterranean Region. *Environ Monit Assess. May 26;190(6)*:363. doi: 10.1007/s10661-018-6721-4

Song, C. et al., (2018). *Cradle-to-Grave Greenhouse Gas Emissions from Dams in the United States of America, 90 Renewable and Sustainable Energy Reviews 5.* https://www.researchgate.net/publication/324993878_Cradle-to-grave_greenhouse_gas_emissions_from_dams_in_the_United_States_of_America

2017

Maavara, T., R. Lauerwald, P. Regnier, P.Van Cappellen. (2017) Global Perturbation of Organic Carbon Cycling by River Damming. *Nature Communications*, 8: 15347 DOI: 10.1038/ncomms15347

2016

Beaulieu, J.J., McManus, M.G. and Nietch, C.T. (2016), Estimates of Reservoir Methane Emissions based on a Spatially Balanced Probabilistic-survey. Limnol. Oceanogr., 61: S27-S40. https://doi.org/10.1002/lno.10284

Deemer, Bridget R., John A. Harrison, Siyue Li, Jake J. Beaulieu, Tonya DelSontro, Nathan Barros, José F. Bezerra-Neto, Stephen M. Powers, Marco A. dos Santos, J. Arie Vonk, (2016). Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis, *BioScience*, Volume 66, Issue 11, 1 November 2016, Pages 949–964, "https://doi.org/10.1093/biosci/biw117

Fearnside, P. (2016) Greenhouse Gas Emissions from Brazil's Amazonian Hydroelectric Dams, *Environ. Res. Lett.* 11 011002. doi: 10.1088/1748-9326/11/1/011002

Scherer, Laura & Stephan Pfister, (2016). Hydropower's Biogenic Carbon Footprint, *PLOS ONE*, September 14, 2016. https://doi.org/10.1371/journal.pone.0161947

2015

De Faria, Felipe A M, Jaramillo, Paulina, Sawakuchi, Henrique O, Richey, Jeffrey E, & Barros, Nathan (Dec 2015). Estimating Greenhouse Gas Emissions from future Amazonian Hydroelectric Reservoirs. *Environmental Research Letters, 10(12), 13.* https://iopscience.iop.org/article/10.1088/1748-9326/10/12/124019/pdf

Fearnside, Philip. 2015. Emissions from Tropical Hydropower and the IPCC. Environmental Science and Policy 50:225-229. doi: 10.1016/j.envsci.2015.03.002
Fedorov, M.P., Elistratov, V.V., Maslikov, V.I. *et al.* 2015. Reservoir Greenhouse Gas Emissions at Russian HPP. Power Technol Eng 49, 33–39. https://doi.org/10.1007/s10749-015-0569-3

2014

Maeck, A., Hofmann, H., and Lorke, A. (2014). Pumping Methane out of Aquatic Sediments – Ebullition Forcing Mechanisms in an Impounded River, Biogeosciences, 11, 2925–2938, https://doi.org/10.5194/bg-11-2925-2014

2013

Hertwich EG.(2013) Addressing Biogenic Greenhouse Gas Emissions from Hydropower in LCA. Environ Sci Technol. 2013 Sep 3;47(17):9604-11. doi: 10.1021/es401820p.

Maeck, Andreas, Tonya DelSontro, Daniel F. McGinnis, Helmut Fischer, Sabine Flury, Mark Schmidt, Peer Fietzek, and Andreas Lorke, (2013) Sediment Trapping by Dams Creates Methane Emission Hot Spots, *Environmental Science & Technology 2013 47 (15),* 8130-8137
doi: 10.1021/es4003907

2012

Steinhurst, William, et al. (2012). Hydropower Greenhouse Gas Emissions, *Synapse Energy Econ.. 12.* https://www.synapse-

energy.com/sites/default/files/SynapseReport.2012-02.CLF+PEW.GHG-from-Hydro.10-056.pdf

Teodoru, Cristian et al. (2012). The Net Carbon Footprint of a Newly Created Boreal Hydroelectric Reservoir, *Global Biogeochemical Cycles, May 2012*, at 1.
West, W. E. et al. (2012). Effects of Algal and Terrestrial Carbon on Methane Production Rates and Methanogen Community Structure in a Temperate Lake Sediment." *Freshwater Biology* 57, 949-955. **https://www3.nd.edu/~sjones20/ewExternalFiles/Westetal2012_FWB.pdf**

2011

Barros, N., Cole, J., Tranvik, L. et al. (2011). Carbon Emission from Hydroelectric Reservoirs Linked to Reservoir Age and Latitude. *Nature Geosci 4, 593–596.*https://doi.org/10.1038/ngeo1211

2009

Gunkel, G. (2009), Hydropower – A Green Energy? Tropical Reservoirs and Greenhouse Gas Emissions. Clean Soil Air Water, 37: 726-734. https://doi.org/10.1002/clen.200900062

2007

Walter, Katey, Laurence Smith, and Stuart Chapin. (2007) Methane bubbling from northern lakes: present and future contributions to the global methane budget. *Phil. Trans. R. Soc. A.*3651657–1676. http://doi.org/10.1098/rsta.2007.2036

2006

Intergovernmental Panel on Climate Change (IPCC) (2006), Appendix 3 — CH4 Emissions from Flooded Land: Basis for Future Methodological Development, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_p_Ap3_WetlandsCH4.pdf

2005

Fearnside, P. (2005) Do Hydroelectric Dams Mitigate Global Warming? The Case of Brazil's CuruÁ-una Dam. *Mitig Adapt Strat Glob Change* 10, 675–691.. https://doi.org/10.1007/s11027-005-7303-7
Tremblay et al. (2005). Greenhouse Gas Emissions – Fluxes and Processes: Hydroelectric Reservoirs and Natural Environments. Germany: Springer, 2005. https://www.springer.com/gp/book/9783540234555

2000

Rosenberg, David M., Patrick McCully and Catherine M. Pringle, (2000). Global-Scale Environmental Effects of Hydrological Alterations: Introduction, *BioScience*, *Volume 50, Issue 9, September 2000*, Pages 746–751, https://doi.org/10.1641/0006-3568(2000)050[0746:GSEEOH]2.0.CO;2

St. Louis, Vincent L., Carol A. Kelly, Éric Duchemin, John W. M. Rudd, David M. Rosenberg, (2000). Reservoir Surfaces as Sources of Greenhouse Gases to the Atmosphere: A Global Estimate. *BioScience, Volume 50, Issue 9, September,* Pages 766–775, https://doi.org/10.1641/0006-3568(2000)050[0766:RSASOG]2.0.CO;2

1997

Fearnside, P. (1997). Greenhouse-Gas Emissions from Amazonian Hydroelectric Reservoirs: The Example of Brazil's Tucuruí Dam as Compared to Fossil Fuel Alternatives. *Environmental Conservation, 24*(1), 64-75. doi:10.1017/S0376892997000118

1995

Fearnside, P. (1995). Hydroelectric Dams in the Brazilian Amazon as Sources of 'Greenhouse' Gases. *Environmental Conservation, 22*(1), 7-19. doi:10.1017/S0376892900034020

Attachment 3

The Petitioners have provided EPA via USB flash drive the following documents cited in the Patagonia et al. Petition to Add Dams and Reservoirs to the Greenhouse Gas Reporting Program.

1. Press Release, White House, Joint US-EU Press Release on the Global Methane Pledge (Sept. 18, 2021).

2. Dino Grandoni & Tony Romm, *White House doubles down on executive action as Democrats weigh trimming Hill climate plan*, Wash. Post, Oct. 19, 2021.

3. Angela Jones, Cong. Rsch. Serv., IF11754, *In Focus: EPA's Greenhouse Gas Reporting Program* (Nov. 16, 2021).

4. EPA, Greenhouse Gas Reporting Program (GHGRP), Historical Rulemakings, https://www.epa.gov/ghgreporting/historical-rulemakings.

5. U.S. Energy Info. Admin., Hydropower explained, https://www.eia.gov/energyexplained/hydropower/.

6. Matt McGrath, *Climate change: IPCC report is 'code red for humanity,'* BBC News, Aug. 9, 2021.

7. EPA, Sources of Greenhouse Gas Emissions, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

8. IPCC, *App. 3, CH_4 Emissions from Flooded Land: Basis for Future Methodological Development, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry and Other Land Use* (2006).

9. IPCC, *Chapter 7: Wetlands, in 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry and Other Land Use* (2019).

10. Philip Fearnside, *Hydroelectric Dams as "Methane Factories": The Role of Reservoirs in Tropical Forest Areas as Sources of Greenhouse Gases*, 12 Oecologia Australis (2008).

11. IPCC, *Chapter 7: Wetlands, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol. 4: Agriculture, Forestry and Other Land Use* (2006).

12. Jake Beaulie et al., *Estimates of reservoir methane emissions based on a spatially balanced probabilistic-survey*, 61 Limnology and Oceanography S27 (2016).

13. EPA, Bubbling Up: Methane from Reservoirs Presents Climate Change Challenge, The EPA Blog (Sept. 8, 2016).

14. Bridget Deemer et al., *Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis*, 66 BioSci. 949 (Nov. 2016).

15. Laura Scherer & Stephan Pfister, *Hydropower's Biogenic Carbon Footprint*, PLoS ONE (Sept. 14, 2016).

16. Jake Beaulieu et al., *Methane and Carbon Dioxide Emissions from Reservoirs: Controls and Upscaling*, 125 J. Geophysical Rsch. Biogeosciences 1 (2020).

17. Walter Dodds et al., *Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages*, 43 Envtl. Sci. & Tech. 12 (2009).

18. Marielle Saunois et al., *The Global Methane Budget 2000–2017*, 12 Earth Sys. Sci. Data 1561 (2020).

19. Ivan Lima et al., *Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective*, 13 Mitigation & Adaptation Strategies for Global Change 193 (2008).

20. A. Levasseur et al., *Improving the accuracy of electricity carbon footprint: Estimation of hydroelectric reservoirs greenhouse gas emissions*, 136 Renewable & Sustainable Energy Revs. (2021).

21. Cuihong Song et al., *Cradle-to-grave greenhouse gas emissions from dams in the United States of America*, 90 Renewable & Sustainable Energy Revs. 7 (2018).

22. Philipp Keller et al., *Global Carbon Budget of Reservoirs is Overturned by the Quantification of Drawdown Areas*, 14 Nature Geoscience 402 (2021).

23. IPCC, *Chapter 11: Agriculture, Forestry and Other Land Use (AFOLU), in Climate Change 2014: Mitigation of Climate Change* (2014).

24. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

25. Bureau of Reclamation, Hydropower Program, https://www.usbr.gov/power/.

26. Tenn. Valley Auth., Hydroelectric, https://www.tva.com/energy/our-power-system/hydroelectric.

27. Bonneville Power Admin., Clean Energy: The Northwest way of life, https://www.bpa.gov/learn-and-participate/community-education/hydropower-101/clean-energy.

28. Cal. Energy Comm'n, Renewable Energy Resources, https://www.energy.ca.gov/programs-and-topics/topics/renewable-energy/renewable-energy-resources.

29. Cal. Energy Comm'n, Hydroelectric Power, https://www.energy.ca.gov/data-reports/california-power-generation-and-power-sources/hydroelectric-power.

30. N.Y. State Energy Rsch. & Dev. Auth., Clean Energy Standard, https://www.nyserda.ny.gov/all-programs/programs/clean-energy-standard.

31. Press Release, N.Y. State Energy Rsch. & Dev. Auth., During Climate Week, Governor Hochul Announces Major Green Energy Infrastructure Projects to Power New York City With Wind, Solar and Hydropower From Upstate New York and Canada (Sept. 20, 2021).

32. Xcel Energy, Hydro Energy, https://co.my.xcelenergy.com/s/energy-portfolio/hydro.

33. Colo. Pub. Utils. Comm'n, Proceeding No. 21A-0141E, Brooke Trammell Direct Test. (Mar. 31, 2021).

34. Stanley Porter et al., *Utility Decarbonization Strategies*, Deloitte Insights (Sept. 21, 2020).

35. Nat'l Hydropower Ass'n, https://www.hydro.org/.

36. Int'l Hydropower Ass'n, Clean Energy Systems, https://www.hydropower.org/what-we-do/clean-energy.

37. Theresa Smith, *Pumped Storage Hydropower Critical for Future Clean Energy Systems*, Power Eng'g Int'l (Sept. 20, 2021).

38. Sammy Roth, *Environmental Disaster or Key to a Clean Energy Future? A New Twist on Hydropower*, L.A. Times, Mar. 5, 2020.

39. Rebecca Leber, *It's Time to Freak Out About Methane Emissions*, Vox (Nov. 3, 2021, 4:14 PM), https://www.vox.com/22613532/climate-change-methane-emissions.

40. Sam DeFabrizio et al., *Curbing Methane Emissions: How Five Industries Can Counter a Major Climate Threat*, McKinsey Sustainability (Sept. 23, 2021).

41. The Climate Registry, About Us, https://www.theclimateregistry.org/who-we-are/about-us/.

42. The Climate Registry, Water-Energy Nexus Registry, History, https://www.theclimateregistry.org/waterenergynexusregistry/about/history/.

43. The Climate Registry, Programs and Services, Water-Energy Nexus Registry, https://www.theclimateregistry.org/programs-services/california-water-energy-nexus-registry/.

44. The Climate Registry, Water-Energy Nexus Registry, https://www.theclimateregistry.org/waterenergynexusregistry/.

45. Fact Sheet, The White House, President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies (Apr. 22, 2021).

46. Fact Sheet, The White House, President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability (Dec. 8, 2021).

47. Brad Plumer & Winston Choi-Schagrin, *Major Climate Action at Stake in Fight Over Twin Bills Pending in Congress*, N.Y. Times, Oct. 10, 2021.

48. Matt McGrath, *Climate Change: Curbing Methane Emissions Will 'Buy Us Time,'* BBC News, Aug. 11, 2021.

49. Lisa Friedman, *More Than 30 Countries Join U.S. Pledge to Slash Methane Emissions*, N.Y. Times, Oct. 11, 2021.

50. Fact Sheet, The White House, President Biden Tackles Methane Emissions, Spurs Innovations, and Supports Sustainable Agriculture to Build a Clean Energy Economy and Create Jobs (Nov. 2, 2021).

51. Chris Mooney et al., *Countries' Climate Pledges Built on Flawed Data, Post Investigation Finds*, Wash. Post, Nov. 7, 2021.

From:	Klumpp,Elizabeth C (BPA) - AIR-WSGL
Sent:	Monday, April 25, 2022 11:44 AM
To:	Warner,Joshua P (BPA) - AIR-7; Leary,Jill C (BPA) - LN-7; Godwin,Mary E (BPA) - LN-7; Armentrout,Scott G (BPA) - E-4; Sweet,Jason C (BPA) - EW-4; Egerdahl,Ryan J (BPA) - PGPR-5; Todd,Wayne A (BPA) - PGA-6; Kaseweter,Alisa D (BPA) - AI-7; Marker,Douglas R (BPA) - AIR-7
Subject:	RE: Modernizing hydropower on the Snake River

I've heard unofficially from Ecology that Washington's Dept. of Ecology lead spoke with CARB's lead and agreed that emissions from at least western reservoirs isn't worth tracking. We'll see.

From: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Sent: Wednesday, April 20, 2022 5:31 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Armentrout,Scott G (BPA) - E-4 <sgarmentrout@bpa.gov>; Sweet,Jason C (BPA) - EW-4 <jcsweet@bpa.gov>; Egerdahl,Ryan J (BPA) - PGPR-5 <rjegerdahl@bpa.gov>; Todd,Wayne A (BPA) - PGA-6 <watodd@bpa.gov>
Cc: Klumpp,Elizabeth C (BPA) - AIR-WSGL <ecklumpp@bpa.gov>
Subject: FW: Modernizing hydropower on the Snake River

I hesitate sharing this, but because it is copied to LSRDOptions (Murray/Inslee) and the CEQ inbox I thought I should.

Share it with others if you think they need to see it.

Let me know if you need anything more.

Josh

From: steven hawley <sjhawley@me.com>
Sent: Wednesday, April 20, 2022 2:59 PM
To: Scott Levy <redfishbluefishfilm@icloud.com>
Cc: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>; Simpson.concept@mail.house.gov; info@lsrdoptions.org; salmon@ceq.eop.gov
Subject: Re: Modernizing hydropower on the Snake River

Hi Scott, Hello Josh,
I'm attaching a petition that was just filed in March of this year with the EPA. Signed by 130 conservation organizations and businesses, it requests that the EPA add dams and reservoirs to its greenhouse gas inventory program. There is no doubt that the Snake River Dams, and the FCRPS more generally are significant contributors to greenhouse gas emissions in the Pacific Northwest, and I would venture to guess that within a few years' time, we will know exactly how much methane these dams are polluting the atmosphere with each year. Recent research has established that dams and reservoirs worldwide have a carbon dioxide equivalent footprint equal to that of Germany, the world's fourth largest GHG polluter. In the meantime, the federal agencies that manage the FCRPS should stop making the spurious claim that energy from any Columbia Basin dams is "carbon free." An excerpt from the petition:

These scientific studies show that individual dams and reservoirs emit large amounts of GHGs every year. For example, Hoover Dam and Lake Mead (which is a reservoir and not a natural lake) emit approximately 12.3 million metric tons of carbon dioxide equivalent

(CO_2e) annually. These emissions include 3.1 million metric tons of CO_2e attributable to hydropower infrastructure and generation. Kentucky Lake (which is also a reservoir and not a natural lake) emits over 1.8 million metric tons per year of CO_2e, including 407,000 metric tons attributed to hydropower infrastructure and generation. These emissions exceed the annual GHG emissions from coal- and gas-fired power plants with similar generation capacity, and these emissions are equivalent to the GHG emissions of hundreds of thousands, even millions, of gas-powered vehicles. In addition, the collective GHG emissions of all dams and reservoirs across the United States are significant. Notably, a 2020 scientific study co-authored by an EPA researcher estimated that reservoirs in Ohio are the state's fourth largest anthropogenic source of methane emissions.

Steve

On Apr 20, 2022, at 2:01 PM, Scott Levy <redfishbluefishfilm@icloud.com> wrote:

Josh,

I see that Bonneville is continuing to promote Lower Snake River hydropower as "carbon-free energy".

> "Ice Harbor and the other three other dams on the lower Snake River provide low-cost, carbon-free energy to the Pacific Northwest…"
> — Modernizing hydropower on the Snake River USACE Press Release

This statement runs opposite to what the Pacific Northwest National Laboratories tells us regarding methane emissions being emitted by the Lower Snake Reservoirs.

> "Gas efflux due to ebullition was greater in comes located within reservoirs than in coves within the free flowing Hanford Reach, and CH4 efflux exceeded that of CO2. CH4 ebullition varied widely across sampling locations, ranging from 10.5 to 1039 mg CH4/(m^2 day) in Lower Monumental Dam reservoir and 482 mg CH4/(m^2 day) in Priest Rapids Dam reservoir. The magnitude of CH4 efflux due to ebullition was relatively high, falling with the range recently reported for other temperate reservoirs around the world, **further suggesting that this CH4 source should be considered in estimates of global greenhouse gas emissions**."
> — Evaluating greenhouse gas emissions from hydropower complexes on large rivers in Eastern Washington

These two statements should coincide and the government really should provide the truth with a unified voice. When I buy a peanut-free or a gluten-free product, I expect it to be as the label states it to be.

Contradicting oneself is often difficult to justify, and continuing to remain silent on this discussion is becoming more and more unacceptable.

Sincerely,

Scott Levy
bluefish.org
promoting an open and **honest dialogue** concerning the plight of Idaho's wild Salmon and Steelhead.

cc: Council on Environmental Quality, Congressman Mike Simpson, Senator Patty Murray and Governor Jay Inslee.

From: Kaseweter,Alisa D (BPA) - AI-7
Sent: Monday, June 6, 2022 1:55 PM
To: Gordon,Peter S (BPA) - E-4
Cc: Zelinsky,Benjamin D (BPA) - E-4; Calvert,Paula P (BPA) - E-4
Subject: RE: Dams and Reservoirs Targeted by Patagonia Petition to EPA for GHG Reporting - NHA Forming Working Group and Hired Consultants

Thanks, Peter. I'm reaching out to Sonya, who is currently on leave. My initial impression is anything we do here would need to be coordinated with DOE. DOE has contracted PNNL to do a study on reservoir emissions, but results were several years in the making last I saw. Our best available information is still what is in the CRSO.

From: Gordon,Peter S (BPA) - E-4 <psgordon@bpa.gov>
Sent: Monday, June 6, 2022 1:21 PM
To: Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Subject: Dams and Reservoirs Targeted by Patagonia Petition to EPA for GHG Reporting - NHA Forming Working Group and Hired Consultants

All,

In today's NHA Regulatory Affairs meeting, NHA staffer Cameron Schilling highlighted Patagonia's petition on March 31 for EPA rule making to include dams and reservoirs in EPA required GHG reporting.

In response to counter Patagonia, NHA also indicated that it:

- has retained Troutman Pepper for legal counsel,
- hired HDR for scientific and technical consulting services, and that
- Cameron is forming a small industry working group of interested members to develop a path forward for NHA.

I am passing this along in case there needs to be coordination or an integrated response, but leave that in your hands as the leads on these topics. There may be others who need to be looped in as well.

Cameron has asked that people just reach out to him directly.

For reference, below is a related NHA methane paper and some related discussion from last among the federal family.

Peter

From: Webster-Wharton,Stacy T (BPA) - PGA-6 <stwebsterwharton@bpa.gov>
Sent: Monday, June 14, 2021 11:19 AM
To: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>; Chennell,Mildrid A (BPA) - PGPL-5 <machennell@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Johnson,Kimberly O (BPA) - PGAF-6 <kojohnson@bpa.gov>; Jule,Kristen R (BPA) - EWP-4 <krjule@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Sweet,Jason C (BPA) - EW-4 <jcsweet@bpa.gov>; Webster-Wharton,Stacy T (BPA) - PGA-6

<stwebsterwharton@bpa.gov>; Gordon,Peter S (BPA) - E-4 <psgordon@bpa.gov>; Kathryn Tackley (Kathryn.L.Tackley@usace.army.mil) <Kathryn.L.Tackley@usace.army.mil>; eric rothwell <erothwell@usbr.gov>; Chris Eder (ceder@usbr.gov) <ceder@usbr.gov>
Subject: RE: NHA Methane paper

FYI if you have not seen this article yet in Clearing Up on more recent methane modeling in reservoirs.

New Modeling Finds Reservoir Methane Emissions Higher Than Thought | Environment | newsdata.com

Stacy Webster-Wharton, PE
Environmental Engineer/Strategist, PGA
BONNEVILLE POWER ADMINISTRATION
stwebsterwharton@bpa.gov
P: 503-230-3102 C: (b)(6) [redacted]
she/her/hers

From: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>
Sent: Wednesday, December 2, 2020 1:40 PM
To: WQ Team <WQTeam@BPASite1.bpa.gov>; Gordon,Peter S (BPA) - E-4 <psgordon@bpa.gov>; Kathryn Tackley (Kathryn.L.Tackley@usace.army.mil) <Kathryn.L.Tackley@usace.army.mil>; eric rothwell <erothwell@usbr.gov>; Chris Eder (ceder@usbr.gov) <ceder@usbr.gov>
Subject: NHA Methane paper

Team
As I mentioned earlier this week, methane will likely be a new issue of concern from hydropower dam reservoirs. Please see my email below and attached NHA paper with BPA edits. When the paper is peer reviewed and issued as final I will forward to you all.

Please excuse any duplicate emails, I was having System problems.

Thank you
Agnes

From: Lut,Agnes (BPA) - E-4
Sent: Monday, November 23, 2020 12:06 PM
To: Dennis Cakert (NHA) <dennis@hydro.org>
Cc: Kaseweter,Alisa D (BPA) - DI-7 <alkaseweter@bpa.gov>
Subject: RE: NHA prep for 2021

Hi Dennis,
Please find attached in track changes BPA's suggested edits to NHA's hydro GHG paper you shared. I wanted to make a couple of points for your consideration.

First, you may want to include an opening paragraph that sets the stage as per your email below. See yellow highlighted text below. It's a good opener on why NHA is writing this paper.

The second point is that the hydropower dams also provide valuable integration services for other renewable resources like wind and solar and are positioned to help states like Oregon and Washington reach their GHG emission reduction goals, a point that was omitted from NHA's paper. You may want to consider adding this point as a beneficial element of hydro in terms of the nation meeting its climate change goals.

Lastly, when we completed the CRSO EIS we evaluated methane releases from our reservoirs. Bottom line is that the federal reservoirs emit significantly less methane than dams in other regions. https://www.nwd.usace.army.mil/CRSO/Final-EIS/#top See page 1022 of 1576 in Chapter 3. In addition take a look at Appendix G and T of the CRS EIS and search for "methane". The response to comments Appendix T does a good job of summarizing our findings and the various arguments surrounding reservoir methane emissions.

Thank you, and Happy Thanksgiving.
Agnes

From: Dennis Cakert (NHA) <dennis@hydro.org>
Sent: Monday, November 16, 2020 10:40 AM
To: Lut,Agnes (BPA) - E-4 <axlut@bpa.gov>
Subject: [EXTERNAL] NHA prep for 2021

Hi Agnes,

I am hoping for your feedback on two unrelated items before the year is over:

First, attached is a survey regarding expected investment in hydropower assets the next few years. We're hopeful the survey results will demonstrate that hydropower is a robust and active marketplace, not merely cement in the ground. This information will help us move the ball on a number of issues.

Second, attached is a first draft of NHA's whitepaper on hydropower and greenhouse gases. Given the change in administration, NHA needs to be prepared to address the methane question in 2021. Any feedback is greatly appreciated.

Both are items of importance to the NHA Board heading into 2021. If you have any questions I'd be happy talk anytime.

Sincerely,

Dennis Cakert
Manager of Regulatory Affairs and Market Policy
National Hydropower Association
601 New Jersey Ave. NW Suite 660
Washington, D.C. 20001
202.697.2404

From:	James,Eve A L (BPA) - PG-5
Sent:	Monday, June 27, 2022 7:19 AM
To:	Godwin,Mary E (BPA) - LN-7; Kaseweter,Alisa D (BPA) - AI-7; Olive,J Courtney (BPA) - LP-7; Pytlak,Erik S (BPA) - PGPW-5
Cc:	Leary,Jill C (BPA) - LN-7; Zelinsky,Benjamin D (BPA) - E-4; Koehler,Birgit G (BPA) - PG-5
Subject:	RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content
Attachments:	2022-06-24_PowerComments_meg_6.25.22-eaj.docx

Attached is a version where I try to answer your questions Mary- let me know if I missed anything or if it still isn't clear.

Thanks,
Eve

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Saturday, June 25, 2022 2:03 PM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Here are my edits, comments and a few questions for Eve and one for Alisa (p. 1).

This is looking great.

Thanks,
Mary

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Friday, June 24, 2022 2:06 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Hi Mary and Jill-

(b)(5) [redacted]

Thanks,
Eve

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Friday, June 24, 2022 1:43 PM
To: Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

A few edits from me. Thanks!

From: Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Sent: Friday, June 24, 2022 9:48 AM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

This is way outside my understanding, so I couldn't really provide any substantive input/edits. Here are just a few nits for readability (I know this is a very rough draft so I figure y'all will clean that stuff up later).

Best,
Courtney

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Friday, June 24, 2022 6:58 AM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Thank you so much, Eve!

(b)(5)

[redacted]

-Erik

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Thursday, June 23, 2022 2:59 PM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Attached is the draft version that includes language from the email chain below- please feel free to add anything I missed.

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Thursday, June 23, 2022 2:56 PM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Yes, please. Thank you, Eve!

Thanks,
Mary

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Thursday, June 23, 2022 2:49 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Mary- I grabbed this language and included it in the Power Comments draft. Would you like me to send that around to this group for editing?

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Thursday, June 23, 2022 2:48 PM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Mary, Eve expertly answered my highlighted question (email she sent at 1:49pm yesterday). They did indeed put something together.

-Erik

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Thursday, June 23, 2022 2:41 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Thanks Erik and Alisa, this seems like a great start. It would be great to pull this content into a Word document so that we can start editing.

Eve – please note the question from Erik highlighted below.

Thanks,
Mary

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Wednesday, June 22, 2022 1:41 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5) [redacted]

-Erik

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Wednesday, June 22, 2022 12:47 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5) [redacted]

(b)(5)

[redacted]

Alisa

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Wednesday, June 15, 2022 1:26 PM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney

(BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5) [redacted]

-Erik

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Wednesday, June 15, 2022 1:17 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5) [redacted]

Thanks,
Mary

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Wednesday, June 15, 2022 12:28 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Hello, Mary and Alisa. Responses below to the highlighted sections.

(b)(5) [redacted]

-Erik

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Wednesday, June 15, 2022 11:00 AM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Thanks, Mary. This is bad timing as I'm on AL tomorrow through Tuesday, but I'll try to fit in reading these sections and getting some comments back to you on Wednesday or early Thursday.

I'm also including Erik as he can help with some of this review. Erik, see the highlighted pages below where I think your input would be helpful.

Alisa

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Tuesday, June 14, 2022 1:54 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Hi Alisa,

(b)(5) [redacted]

(b)(5)

[redacted]

Thanks,
Mary

Mary E. Godwin
Attorney-Adviser
Office of General Counsel
Bonneville Power Administration
905 NE 11th Avenue
Portland, OR 97232
(503) 230-4750

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(b)(5)

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[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

From:	Kaseweter,Alisa D (BPA) - AI-7
Sent:	Tuesday, June 28, 2022 8:11 AM
To:	James,Eve A L (BPA) - PG-5
Subject:	RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Looks good to me. Thanks!

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Tuesday, June 28, 2022 7:49 AM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5)
[redacted]

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Monday, June 27, 2022 1:13 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

WA – RCW 19.405.030
OR – Oregon laws 2016, Chapter 28, Section 1

From: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>
Sent: Monday, June 27, 2022 12:58 PM

To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Hi Alisa,
(b)(6) [redacted] so I am tagging in – I think a source would be helpful for our comments.

Thanks for tracking it down,
Jill

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Monday, June 27, 2022 8:25 AM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Mary, Oregon and Washington's no coal laws are in fact derived from state statute. Let me know if you want the source, but it is widely known.

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Monday, June 27, 2022 7:19 AM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Attached is a version where I try to answer your questions Mary- let me know if I missed anything or if it still isn't clear.

Thanks,
Eve

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Saturday, June 25, 2022 2:03 PM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Here are my edits, comments and a few questions for Eve and one for Alisa (p. 1).

This is looking great.

Thanks,
Mary

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Friday, June 24, 2022 2:06 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Hi Mary and Jill-

(b)(5) [redacted]

Thanks,
Eve

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Friday, June 24, 2022 1:43 PM
To: Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

A few edits from me. Thanks!

From: Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Sent: Friday, June 24, 2022 9:48 AM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

This is way outside my understanding, so I couldn't really provide any substantive input/edits. Here are just a few nits for readability (I know this is a very rough draft so I figure y'all will clean that stuff up later).

Best,
Courtney

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Friday, June 24, 2022 6:58 AM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Thank you so much, Eve!

(b)(5)
[redacted]

-Erik

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Thursday, June 23, 2022 2:59 PM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Attached is the draft version that includes language from the email chain below- please feel free to add anything I missed.

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Thursday, June 23, 2022 2:56 PM
To: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Yes, please. Thank you, Eve!

Thanks,
Mary

From: James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Sent: Thursday, June 23, 2022 2:49 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Mary- I grabbed this language and included it in the Power Comments draft. Would you like me to send that around to this group for editing?

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Thursday, June 23, 2022 2:48 PM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney

(BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Mary, Eve expertly answered my highlighted question (email she sent at 1:49pm yesterday). They did indeed put something together.

-Erik

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Thursday, June 23, 2022 2:41 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Thanks Erik and Alisa, this seems like a great start. It would be great to pull this content into a Word document so that we can start editing.

Eve – please note the question from Erik highlighted below.

Thanks,
Mary

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Wednesday, June 22, 2022 1:41 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5)

[redacted]

(b)(5) [redacted]

-Erik

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Wednesday, June 22, 2022 12:47 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5) [redacted]

(b)(5) [redacted]

Alisa

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Wednesday, June 15, 2022 1:26 PM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5) [redacted]

-Erik

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Wednesday, June 15, 2022 1:17 PM
To: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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(b)(5)

[redacted]

Thanks,
Mary

From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Wednesday, June 15, 2022 12:28 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Hello, Mary and Alisa. Responses below to the highlighted sections.

(b)(5)

[redacted]

-Erik

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Wednesday, June 15, 2022 11:00 AM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: RE: Privileged: Review of draft Inslee-Murray Report Climate Change Content

Thanks, Mary. This is bad timing as I'm on AL tomorrow through Tuesday, but I'll try to fit in reading these sections and getting some comments back to you on Wednesday or early Thursday.

I'm also including Erik as he can help with some of this review. Erik, see the highlighted pages below where I think your input would be helpful.

Alisa

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Tuesday, June 14, 2022 1:54 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>
Subject: Privileged: Review of draft Inslee-Murray Report Climate Change Content

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Hi Alisa,

(b)(5)

[redacted]

[redacted]

Thanks,
Mary

Mary E. Godwin
Attorney-Adviser
Office of General Counsel
Bonneville Power Administration
905 NE 11th Avenue
Portland, OR 97232
(503) 230-4750

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From:	Leary,Jill C (BPA) - LN-7
Sent:	Tuesday, July 5, 2022 2:43 PM
To:	Koehler,Birgit G (BPA) - PG-5; Welch,Julee A (BPA) - LP-7; Greene,Richard A (BPA) - LP-7; Pruder Scruggs,Kathryn M (BPA) - E-4; Godwin,Mary E (BPA) - LN-7; Zelinsky,Benjamin D (BPA) - E-4; Sullivan,Leah S (BPA) - EWP-4; Hausmann,Benjamin J (BPA) - EWL-4; James,Eve A L (BPA) - PG-5; Chan,Allen C (BPA) - LT-7; Anasis,John G (TFE)(BPA) - TOOP-DITT-2; Kaseweter,Alisa D (BPA) - AI-7; Olive,J Courtney (BPA) - LP-7; Calvert,Paula P (BPA) - E-4
Cc:	Armentrout,Scott G (BPA) - E-4
Subject:	RE: Privileged: Current Draft of Bonneville Comments on the draft Inslee-Murray Report
Attachments:	Draft Bonneville Comments on Inslee-Murray Draft Report 7 5 2pm.docx

Katie combined versions, so please use this one Birgit, then I will review after you, thanks.

From: Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>
Sent: Tuesday, July 5, 2022 2:42 PM
To: Welch,Julee A (BPA) - LP-7 <jawelch@bpa.gov>; Greene,Richard A (BPA) - LP-7 <ragreene@bpa.gov>; Pruder Scruggs,Kathryn M (BPA) - E-4 <kpruder@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Sullivan,Leah S (BPA) - EWP-4 <lssullivan@bpa.gov>; Hausmann,Benjamin J (BPA) - EWL-4 <bjhausmann@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Chan,Allen C (BPA) - LT-7 <acchan@bpa.gov>; Anasis,John G (TFE)(BPA) - TOOP-DITT-2 <jganasis@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Cc: Armentrout,Scott G (BPA) - E-4 <sgarmentrout@bpa.gov>
Subject: RE: Privileged: Current Draft of Bonneville Comments on the draft Inslee-Murray Report

I'll take a look next. For version control, I'll copy Julee's edits into the one with Allen's edits since Julee's edits are fairly straight-forward

From: Welch,Julee A (BPA) - LP-7 <jawelch@bpa.gov>
Sent: Tuesday, July 5, 2022 1:10 PM
To: Greene,Richard A (BPA) - LP-7 <ragreene@bpa.gov>; Pruder Scruggs,Kathryn M (BPA) - E-4 <kpruder@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Sullivan,Leah S (BPA) - EWP-4 <lssullivan@bpa.gov>; Hausmann,Benjamin J (BPA) - EWL-4 <bjhausmann@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>; Chan,Allen C (BPA) - LT-7 <acchan@bpa.gov>; Anasis,John G (TFE)(BPA) - TOOP-DITT-2 <jganasis@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Cc: Armentrout,Scott G (BPA) - E-4 <sgarmentrout@bpa.gov>
Subject: RE: Privileged: Current Draft of Bonneville Comments on the draft Inslee-Murray Report

Privileged Attorney-Client Communication

Jill and I worked on the paragraph flagged for us on p. 3. One edit and comment in the attached for that section.

Thanks,
Julee

From: Greene,Richard A (BPA) - LP-7 <ragreene@bpa.gov>
Sent: Tuesday, July 5, 2022 11:19 AM
To: Pruder Scruggs,Kathryn M (BPA) - E-4 <kpruder@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Sullivan,Leah S (BPA) - EWP-4 <lssullivan@bpa.gov>; Hausmann,Benjamin J (BPA) - EWL-4 <bjhausmann@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>; Chan,Allen C (BPA) - LT-7 <acchan@bpa.gov>; Anasis,John G (TFE)(BPA) - TOOP-DITT-2 <jganasis@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Welch,Julee A (BPA) - LP-7 <jawelch@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Cc: Armentrout,Scott G (BPA) - E-4 <sgarmentrout@bpa.gov>
Subject: RE: Privileged: Current Draft of Bonneville Comments on the draft Inslee-Murray Report

Attorney Client Priv.

My edits to the power rates section...

From: Pruder Scruggs,Kathryn M (BPA) - E-4 <kpruder@bpa.gov>
Sent: Tuesday, July 5, 2022 7:08 AM
To: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Sullivan,Leah S (BPA) - EWP-4 <lssullivan@bpa.gov>; Hausmann,Benjamin J (BPA) - EWL-4 <bjhausmann@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>; Greene,Richard A (BPA) - LP-7 <ragreene@bpa.gov>; Chan,Allen C (BPA) - LT-7 <acchan@bpa.gov>; Anasis,John G (TFE)(BPA) - TOOP-DITT-2 <jganasis@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Welch,Julee A (BPA) - LP-7 <jawelch@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Cc: Armentrout,Scott G (BPA) - E-4 <sgarmentrout@bpa.gov>
Subject: RE: Privileged: Current Draft of Bonneville Comments on the draft Inslee-Murray Report

Hi all,
Wow, impressive! I made a few minor suggestions for style:

- Pointed out a few spots to spell out acronyms on first use
- Pointed out a few spots to use consistent names (such as Bonneville instead of BPA)
- Made a couple of recommendations where we might consider explaining jargon (such as 125% TDG gas cap spill.)

From: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Sent: Saturday, July 2, 2022 11:30 AM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Zelinsky,Benjamin D (BPA) - E-4 <bdzelinsky@bpa.gov>; Sullivan,Leah S (BPA) - EWP-4 <lssullivan@bpa.gov>; Hausmann,Benjamin J (BPA) - EWL-4 <bjhausmann@bpa.gov>; James,Eve A L (BPA) - PG-5 <eajames@bpa.gov>; Koehler,Birgit G (BPA) - PG-5 <bgkoehler@bpa.gov>; Greene,Richard A (BPA) - LP-7 <ragreene@bpa.gov>; Chan,Allen C (BPA) - LT-7 <acchan@bpa.gov>; Anasis,John G (TFE)(BPA) - TOOP-DITT-2 <jganasis@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Welch,Julee A (BPA) - LP-7 <jawelch@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Cc: Pruder Scruggs,Kathryn M (BPA) - E-4 <kpruder@bpa.gov>; Armentrout,Scott G (BPA) - E-4 <sgarmentrout@bpa.gov>
Subject: Privileged: Current Draft of Bonneville Comments on the draft Inslee-Murray Report

(b)(5) [redacted]

Thanks again,
Mary

Mary E. Godwin
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Department of Energy

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208-3621

ENVIRONMENT, FISH AND WILDLIFE

July 11, 2022

In reply refer to: E-4

ATTN: Kramer Consulting and Ross Strategic Consulting Team,

This serves as Bonneville Power Administration (Bonneville) comments to Senator Murray and Governor Inslee on the draft *Lower Snake River Dams: Benefits Replacement Study* report (Draft Report). Bonneville provided input into the draft report on the power replacement analysis completed in the 2020 Columbia River System Operations (CRSO) Environmental Impact Statement (EIS) and Bonneville's comments focus on key technical points contained in the Draft Report and for inclusion in the Final Report.

Bonneville markets and transmits the hydropower generated at thirty-one Federal Columbia River Power System (FCRPS) projects, including the four lower Snake River dams.[1] Bonneville, is one of four Power Marketing Administration's and is part of the U.S. Department of Energy. Bonneville operates as a not-for-profit federal entity, selling cost-based electrical power and transmission services to benefit the Pacific Northwest, including the public bodies and cooperatives that serve domestic and rural consumers. In providing these services, Bonneville balances multiple public duties and purposes, including: assuring the Pacific Northwest has an adequate, efficient, economical and reliable power supply; promoting energy conservation and the use of renewable resources; respecting and upholding its relationship with Tribal Nations; and, acting in a manner consistent with the program developed by the Northwest Power and Conservation Council by protecting, mitigating, and enhancing fish and wildlife in the Columbia River basin that are affected by the development and operations of the federal facilities from which Bonneville markets power.[2]

[1] The Columbia River System (CRS) is a subset of the 31 FCRPS dams and includes 14 projects operated as a coordinated water management system. The 14 CRS projects are comprised of 12 Corps projects and two Bureau of Reclamation ("Reclamation") projects located throughout the Pacific Northwest in the states of Idaho, Oregon, Montana, and Washington. BPA markets and transmits the hydropower generated from these 14 projects. These projects are operated in a coordinated manner for purposes specifically authorized by Congress, including flood risk management, navigation, fish and wildlife conservation, hydropower generation, recreation, irrigation, and municipal and industrial water supply, but the authorized projects vary by project. The four lower Columbia projects are part of the CRS.

[2] 16 U.S.C. § 839. Unlike most federal agencies, Bonneville does not receive annual congressional appropriations; instead, the agency is self-financed from revenues received from the sale of power and transmission services. Bonneville utilizes this revenue to not only pay for the continuing costs associated with its programs (including power, transmission, and fish and wildlife investments and maintenance) but also to repay the United States Treasury for the power share of the original federal investment used to construct the Federal Columbia River Power System. The Bonneville Administrator must operate the agency in a manner that allows it to recover its costs "in accordance with sound business principles." 16 U.S.C. § 839e(a)(1). This includes the objectives of setting the lowest possible rates for Bonneville services, while enabling Bonneville to make timely repayments to the Treasury and simultaneously fulfilling multiple public purposes for the benefit of the Pacific Northwest.

The U.S. Army Corps of Engineers (Corps) operates and maintains these four projects for multiple congressionally authorized purposes including flood risk management, navigation, hydropower generation, fish and wildlife conservation, irrigation, recreation, water quality, and municipal and industrial water supply though not every facility is authorized for every one of these purposes. While the Corps is congressionally authorized to operate these four projects for multiple purposes, Bonneville is the federal agency Congress authorized to market and transmit the power generated at these facilities. In return, Bonneville is required to pay, either directly to the Corps, or as a reimbursement to the U.S. Treasury, (1) all costs associated with power-specific operations and assets (e.g., turbines); and (2) a share of "joint costs," which benefit or mitigate, for all purposes of the facility (e.g., fish mitigation, water quality).

Bonneville's comments are separated into six sections: 1) General comments on the Executive Summary and Context and Purpose; 2) Technical comments on the Power Information; 3) Technical comments on Transmission Analysis; 4) Technical comments on Fish Information; 5) Technical comments on Water Quality Information and 6) Clerical Error Correction.

Sincerely,

SCOTT G. ARMENTROUT
EVP, Environment, Fish and Wildlife

1) General comments on the Executive Summary and Context and Purpose

On page 2 of the Draft Report, congressional authorization and numerous other activities are identified as needed for the U.S. Army Corps of Engineers (Corps) to pursue breaching the four lower Snake River dams (LSRD). The Corps would also need appropriations for any necessary studies and work to prepare for breaching and for the actual action of breaching the dams in order to avoid costs being passed to Bonneville ratepayers and increasing rates.

On page 9 of the Draft Report, the Corps is identified as releasing the 2020 CRSO Final EIS. The Bureau of Reclamation (Reclamation) and Bonneville Power Administration were co-lead agencies in this release with the Corps. The Draft Report also states that the flex spill agreement is included in the preferred alternative, however, the preferred alternative does identify components of the 2019-2021 Spill Operations Agreement, but the agreement itself was not included in the preferred alternative. The agreement was superseded by the joint issuance of the 2020 CRSO EIS Record of Decision by the Corps, Reclamation, and Bonneville.

On page 10 of the Draft Report, a chart contains reference to the Stay Agreement in the Columbia River System litigation and states this was intended "to allow time to develop & begin implementing a long-term comprehensive solution to Snake River salmon restoration." This is not an accurate characterization of the Stay Agreement language. The Stay Agreement states: "The Agreement provides an interim compromise while the Parties work together to develop and begin implementing a long-term comprehensive solution that, if successful, may resolve all claims in this litigation." There is no reference to the Snake River specifically because the litigation issues are broader than the Snake River.

Page 17 describes mitigation measures for an alternative analyzed in the CRSO EIS, Multiple Objective Alternative 3, but does not include the description from Chapter 5 of the implementation issues. Additionally, it is unclear from the report if these mitigation measures are included in the estimated costs in the report, so please clarify.

Related to the CRSO EIS, when a reference is as large as the 2020 CRSO EIS, we recommend citing the specific pages and paragraphs and not the entire document. Referencing specific pages and paragraphs would allow the reader to evaluate the basis for conclusions and the results presented. Specifically, on page 18, the Draft Report references several personal communications related to the breach of the Elwha Dams, sediment sampling in the lower Snake River, and geologic structure of the riverbed of the lower Snake River. Bonneville recommends that the Final Report include reference to the scientific documents or reports that contain data related to these points so that the public can review those documents or reports and inform themselves regarding this data.

2) Technical comments on the power information

The conclusion in the Draft Report that it is feasible and within the stated costs to replace the hydropower generation from the LSRD is based on several critical assumptions:

1. Emerging technology (such as long-term battery storage, hydrogen generation or nuclear small modular reactors) will be available at commercial scale and effective.
2. Necessary transmission infrastructure will be built and accessible.
3. All necessary resources will be built - including resources that may only be needed a few days a year during extreme weather events and, possibly, not needed every year.
4. Winter electric demand (e.g., for space heating) will not increase significantly on average with new policies for economy-wide decarbonization.

On page 5 of the Draft Report, the "Energy" paragraph notes that the "three main studies that describe potential LSRD energy replacement portfolios"[3] found energy replacement portfolios to replace energy if the four LSRD are removed, but does not consider that large renewable energy projects are already needed to meet demand as a result of the impacts from clean energy laws to retire coal and decrease natural gas generation. Removing the four LSRD would require even more large renewable energy project development and result in further increases to rates on top of the already elevated baseline. At least two of the studies cited in the Draft Report include more coal generation than current state laws permit.[4] The 2018 NWEC study included more coal generation than currently allowed, and the 2020 CRSO EIS also included more coal generation as an assumption in its primary analysis. However, the 2020 CRSO EIS included coal sensitivity studies with reduced regional coal generation and without any coal generation to address future reductions in coal generation.[5]

In addition, the statement on page 6 that contrasts the 2020 CRSO EIS to the Simpson proposal on the grounds that the Simpson proposal "was based on discussions with several hundred individuals presenting various interests in the LSRD…" inaccurately represents the level of public input into the 2020 CRSO EIS. This statement fails to acknowledge the efforts of thousands of individuals who submitted comments during their attendance at public meetings throughout the Columbia River Basin and thousands of individuals, states, tribes, and organizations that submitted written comments on the draft EIS. There were a number of state and tribal cooperating agencies, who worked directly with the federal agencies in developing the 2020 CRSO EIS. The comments from cooperating agencies informed the scope of the analysis in the 2020 CRSO EIS, the approach to the analysis, and the final conclusions.

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[3] The 2020 Columbia River System Operations (CRSO) Environmental Impact Statement (EIS), the 2018 Northwest Energy Coalition (NWEC) Lower Snake River Dams Replacement Study (2018 NWEC Study), and the 2022 Lower Snake River Dam Replacement Update (Energy Strategies). The 2022 Energy Strategies report is based on the 2018 NWEC study, and it is not clear to Bonneville if the 2022 Energy Strategies report updated coal assumptions.
[4] RCW 19.405.030; (2019); O.R.S. § 757.518 (2021).
[5] Before the Final Report is drafted, the authors should also review and incorporate the findings in the 2022 Energy GPS Study (released after the Draft Report was issued for comments).

On page 22, the Draft Report states that "Future projections in dam operations at [The] Dalles Dam further downstream on the Columbia River predict large daily swings in release of water ranging from 100,000 and 400,000 cubic feet per second." This is not a realistic operation of the Columbia River System given important operational constraints. Bonneville staff worked closely for years on the development and use of the classic GENESYS resource adequacy model and intend to work in this same manner on the redeveloped GENESYS resource adequacy model with the Northwest Power and Conservation Council (Council). Bonneville sees great potential in this model as a way to blend hourly operations of the regional hydropower system with the evolving renewable and power market landscape. However, Bonneville does not think the redeveloped GENESYS resource adequacy model has been thoroughly tested enough to rely upon it in the Draft Report's analysis. Bonneville supports the Council's recommendation for the regional hydropower operators and Council staff to keep evaluating the reliability of the hydro peaking flexibility in the redeveloped GENESYS resource adequacy model, both with the existing and evolving hydropower system. The future projections of flows at The Dalles Dam projecting large daily flow swings that do not meet operational constraints should not be considered realistic operations in the Draft Report.

The Draft Report should describe what water assumptions are depicted from the 2019 White Book for Figure 10. It appears that Figure 10 is showing a 2019 projection for 2022 if the water conditions are those of the critical water period. The Draft Report should note that if water conditions in 2022 are average and wet years, then the LSRD would generate more, which provides generation that is used to meet load or sell on the market. Without identifying that this figure applies only to the critical water year, 1937 water conditions, this figure could confuse the public that the dams generate this amount on average. Additionally, the figure caption should also mention that this is 2019 projection of 2022 generation. The load data in the White Book changes by water year due to some Bonneville customers that have a variable portion of load that is related to the water conditions. In addition, the average monthly load in the White Book and in Figure 10 does not show the peak demand for extreme weather events. The peak demand is important because this is the amount of energy the system will need to be able to provide for reliability.

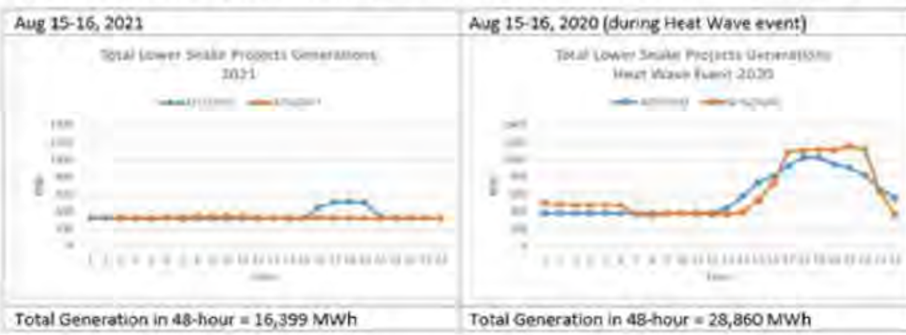
Moving on to page 53 of the Draft Report, Bonneville requests the following corrections and clarifications:

- The Draft Report lists the nameplate capacity of the LSRD as 3,033 MW of energy. Hydropower facilities traditionally operate above nameplate and closer to overload capacity which is approximately 15% above nameplate capacities (referred to as "peak generation values"). This is why the Federal Energy Regulatory Commission uses these peak generation values in hydropower project licensing. We request the Draft Report use the information provided in the 2020 CRSO EIS: a capacity value of 3,483 MW for the LSRD.
- The Draft Report states that "The LSRD produced just under 1,600 MW of energy during a recent extreme weather event." The Draft Report should note that this was for a summer event when flows on the lower Snake River are typically lower. During the winter, when the Northwest has peak load demand, the LSRD typically have more flow in order to meet these

peak load demands, as well provide necessary peaking capability and carry system reserves (on order of 300 MW).

- The Draft Report states "For 2022, BPA projects that the LSRD have a 120-hour capacity of 3,143 MW of energy in January." The initial version of the 2019 White Book contained inaccurate 120-hr metric values for the individual hydropower projects in Table 2.4. Once the issue was discovered, Bonneville removed this data, corrected it and republished the 2019 White Book without the monthly values. However, this error did not impact the 120-hr **total** hydropower system metrics in the 2019 White Book, which would be an appropriate data point for the Draft Report to use.
- The 2020 CRSO EIS Table 3-162 of historical Sustained Ramping Capability shows that the LSRD can produce high peak generation in winter when demand is high and is a better reference for the winter capability.
- While heat waves can occur throughout the summer, the most challenging heat waves from a power perspective most commonly occur in late summer. Fortunately, although the LSRD have declining flows and generation during summer months, spill for fish passage reduces to surface collector flow only in mid-August because juvenile fish passage is largely complete and Bonneville is able to request operations that shape more generation into hours of peak demand during late summer heat waves. The Energy Strategies Study cited in the Draft Report shows data from August 2021 when the region was not experiencing a heat event so the LSRD generation was relatively stable. During heat events, Bonneville has been able to request operations at the LSRD that shaped generation into critical peak demand hours, as it did during the west coast heat wave event of August 15-16, 2020 as evidenced in the graphic above.

Page 55 of the Draft Report states in the "Low power rates" section that "Additionally, surplus



energy that the LSRD provide can be sold on energy markets, which can lead to higher revenues for BPA if sold during ideal market conditions." The use of the word "additionally" is not accurate. The statement suggests that Bonneville's power rates are set and *then* Bonneville sells surplus energy for additional "higher revenue." Bonneville sets its power rates to recover its total system costs, and in doing so, *includes* a forecast of its surplus sales. Thus, Bonneville's power rates are low because they are set assuming that, on average, Bonneville will sell a certain amount of surplus power at a projected market price. The statement that surplus power from the LSRD can be sold on the open market is generally accurate but it should be noted that Bonneville uses the entirety of the Federal system (inclusive of the output from the LSRD) to make such sales. Finally, the statement that Bonneville can achieve higher revenues with surplus sales is generally accurate, though these sales not only increase Bonneville's revenues, but also generally reduce the price of energy on the open market in the Pacific Northwest.

Pages 54 to 58 of the Draft Report cites studies that focused on regional energy demand, reservoir emissions, and potential wind pattern changes in a warming climate. These studies do not fully capture the complexities in these three critical areas, and rightfully highlight the need for additional studies in these areas. There are considerable observational and modeling uncertainties that must be taken into account when attempting to project climate-driven energy demand, reservoir emissions and renewable energy generation (from wind and solar generation) and need more comprehensive study. A good example of such an effort is documented in the River Management Joint Operating Committee (RMJOC)II climate change study, which advanced the state-of-the-science by better capturing future temperature, precipitation and streamflow uncertainties from not only a changing climate, but also from modeling uncertainties and sometimes uncertain or unavailable observational data. The RMJOC-II study was relied upon in the 2020 CRSO EIS, and is used by Bonneville and other regional utilities to provide best available information on climate change impacts in the Columbia River basin. The drafters of the final report should consider incorporating the RMJOC-II climate change study[6] in its analysis.

For example, the Draft Report mentions methane emissions from reservoirs, citing only to one specific study (Miller et al.), which does not provide a comprehensive look at this subject. The 2020 CRSO EIS Appendix G contains a full literature review of methane emissions from reservoirs, including review of the Miller et al. study. The 2020 CRSO EIS analysis concluded that comprehensive assessments of site-specific characteristics for each reservoir, notably climate (wind, precipitation, temperature) and drainage basin characteristics (residence time, organic matter inputs) would be needed to fully understand the methane emissions from any particular reservoir, which should include considerations of climate change impacts. Methane emissions are specific to the local characteristics of the reservoir and its operation, and those in the western United States, particularly the Columbia River Basin, have been shown to be a minor player in contributing to the national and global budgets of GHG emissions. This is an area that needs further scientific review and Bonneville is aware of a U.S. Department of Energy and Pacific Northwest National Laboratory (PNNL) initiative to further look into methane emissions from reservoirs.

The Draft Report acknowledges the decarbonization goals of Oregon and Washington, which include aggressively reducing reliance on fossil fuels in the coming decades to achieve a carbon-free power for these states by 2040 (OR) and 2045 (WA). At the same time, these states are seeking to electrify other sectors, shifting greater demand to the electricity sector that needs to simultaneously be decarbonizing. Likewise, the Administration's policy targets achieving 100% clean electricity by

[6] https://www.bpa.gov/-/media/Aep/power/hydropower-data-studies/rmjoc-ll-report-part-l.pdf

2035 and with similar goals for electrification. The Draft Report acknowledges that interviews with experts highlighted the need for a demonstrable replacement portfolio for fossil-fuel-based generation before replacing dams and evaluating a replacement in light of future needs (p. 52). As included in the "coal sensitivity" analysis in the 2020 CRSO EIS, a large number of coal plants have been retired or are slated for retirement in the coming years.

Many questions exist about how deep decarbonization of the electricity sector will be achieved reliably and cost-effectively. A large amount of renewable generation, storage, and conservation measures will need to be implemented in the coming years to achieve these goals, and complete elimination of fossil fuels will likely require breakthrough technology. Not only does hydropower generate carbon-free electricity, but it is also used to integrate variable carbon-free generation, such as wind and solar. As the region adds more wind and solar to replace fossil-fuel generation, the importance of reliable generation ramping capabilities will increase. Breaching the LSRD while there are still fossil fuel generators on the grid will only exacerbate the timeframe and costs of achieving these decarbonization goals. The timeframe and costs for the states of WA and OR to achieve their carbon-free electricity and electrification goals should be evaluated as part of a holistic assessment of breaching the LSRD. In fact, Northwest RiverPartners and Energy GPS Consulting recently published a study detailing the impact of breaching the lower Snake River dams on the cost and timeframe of meeting these goals.[7]

Page 59 of the Draft Report states that "to meet future regional power needs the NWPCC projects that by 2040 over 350,000 MW of renewables will need to be developed across the larger Western Interconnection." It should be noted that actual resource builds in the Western Electricity Coordinating Council (WECC) are way below this Council forecast:

[7] ENERGY GPS CONSULTING (EGPSC), LLC, LOWER SNAKE RIVER DAMS POWER SUPPLY REPLACEMENT ANALYSIS, 2022. Retrieved from https://nwriverpartners.org/wp-content/uploads/2022/06/EGPSC_LSRD-Power-Cost-Replacement-Study_6_29_2022_Final.pdf.

However, many statements throughout the Draft Report suggest that alternative resources are ready and able to replace the LSRD at this time.

The Draft Report describes well how markets allow for more efficient use of energy produced once capacity is built in the West Coast Integration section (page 62). However, these initiatives help distribute energy efficiently, but do not **create** energy or capacity. Market participants have to enter the market ready to meet their own capacity requirements so it does not reduce the need or cost for additional capacity. Bonneville would like the Draft Report to clarify the Western Resource Adequacy Program and Energy Imbalance Market will not solve resource adequacy, but rather will require utilities to be resource adequate.

Bonneville would like to correct some errors or add clarifying language on pages 67- 69:

- The statement on page 67 "The 2020 CRSO EIS forecasts that this replacement portfolio would lead to a 13.8% loss of load probability (LOLP)" is incorrect. Without the replacement resources, the LOLP is 13.8 percent, but it is 6.6 percent with the replacement portfolio. This same conclusion needs to also be corrected on page 68.
- It should be noted that the 2022 Energy Strategies Study does not replace all of the sustained peaking from the LSRD and relies on market purchases. Therefore, reliability (the ability to keep the lights on) is not maintained in the Energy Strategies study. The replacement portfolio in the 2022 Energy Strategies Study also includes a demand response program. It should be noted that many demand response programs have a limited number of call options per year which limits their ability to provide peak capacity during every event where it is needed. Additionally, the replacement portfolio during times of energy shortfalls, as described in the 2022 Energy Strategies Study, adds batteries, which do not provide capacity in times when energy is also constrained, such as multi-day weather events during low flow conditions. This is because current utility scale batteries only have four hours of sustained capacity and then they must use an energy source to recharge. There would need to be a technology breakthrough to increase the sustained capacity before batteries would be a valid winter capacity resource in the Northwest. The conditions in the Southwest are different, with capacity shortfalls in the summer evenings while there may be surplus during summer days to recharge batteries.
- Bonneville would like to provide clarity in the rate increases contained in the 2020 CRSO EIS. These rate increases are based on resource replacement portfolios needed to maintain reliability ***only*** and were not one-to-one replacements of the services provided by the LSRD.

3) Technical comments on the transmission analysis

A. General Clarifications and Comments

Bonneville requests the following clarifications:

- Regional Load v. Bonneville Load: Section 7 of the Draft Report seems to use Regional Load and Bonneville's load interchangeably, but those terms have different meanings. Bonneville understands Regional Load to refer to the demand of the entire Pacific Northwest, but Bonneville's load to refer only to those purchasing energy and transmission services from Bonneville. For example, the Draft Report states that the "output of the federal Columbia River hydroelectric system matches or exceeds *regional demand* over the course of the year." *Id.* at 52 (emphasis added). That statement refers to Figure 10, which shows Federal resources and "Total *Federal* Demand," but is labeled as a comparison of "*regional* resources compared to *regional* power demand." *Id.* at 53. The Draft Report should clarify what the intent of Figure 10 is (Regional Load v. Bonneville Load). In addition, even though the Draft Report says that the output of the Federal System matches or exceeds regional demand over the course of the year, Figure 10 clearly shows that not to be the case.
- The Draft Report notes a 120-hour capacity of the LSRDs of 3143MW. *Id.* at 53. Bonneville requests the Draft Report include analysis of what resources (wind, solar and batteries) it would take to replace this 120-hour capacity.
- On page 54 of the Draft Report, the last sentence in the paragraph on Transmission Services and Grid Resiliency would be more accurate if it stated: "Due to the location of the LSRD within the transmission interface, the LSRD allow power managers to distribute energy efficiently throughout the Pacific Northwest grid in order to *maintain the reliability of the transmission system and to minimize power costs*."
- On page 55 of the Draft Report:
    - The third paragraph, second sentence should state: "The LSRD provide additional grid resiliency services like flexible capacity, frequency response and regulation, voltage control, *and inertia*."
    - Use of the word "oscillate" in the third sentence is technically incorrect. Replace it with the word "ramp." In addition, the phrase "automatic generation controls" is redundant with the fourth sentence of the paragraph, and should be combined. The sentence should state: "Hydropower projects like the LSRD do not always operate at full capacity, they can easily *ramp* up and down in energy production to meet loads in real time by allowing more or less water to pass through turbines *to meet loads in real-time by automatically allowing the energy system to safely respond to large swings in either load or generation.*"
- On page 59 of the Draft Report, the relationship between the capacity of the Pacific Northwest to the Western Interconnection should be described as the 63,000MW of nameplate capacity in the Northwest as nearly one quarter of all the nameplate capacity in the Western Interconnection. The current wording implies that the generation in the

Pacific Northwest is not included as part of the total capacity in the Western Interconnection.

- The first sentence on page 61 of the Draft Report needs to be clarified. The sentence should provide, "Current battery technology does not have the ability to provide peaking support continuously over multiple days to address prolonged winter cold snaps or summer heat events. Furthermore, batteries add to system load when charging."
- The fourth paragraph of page 61 should clarify that there are a limited number of locations where a pumped storage facility can be sited due to the need to construct both an upper and a lower reservoir.
- The first paragraph of page 63 inaccurately states that BPA is part of the Western Resource Adequacy Program (WRAP). BPA has participated in the development of the WRAP, but the agency has not made a formal decision to officially join the WRAP. This paragraph should be modified to reflect this current state of BPA engagement.
- On page 68 of the Draft Report, the last sentence of the first paragraph states that the Energy Strategies "study suggests that 100% replacement of [the LSRD] capability may not be necessary or cost effective because there could be additional peaking capabilities already within the existing infrastructure." It is unclear where these peaking capabilities exist, and whether the study accounted for peak load levels that could be expected during a severe winter storm or summer heat event. The capacity of the LSRD has been relied upon in the past during those types of events, so the report should clarify where unused capacity is located in the current system to replace that.
- Page 72, table 14 states that the Energy Strategies study anticipates that the costs of transmission upgrades, grid connections, and other system upgrades will be small. Bonneville, as the operator of the Federal Columbia River Transmission System (FCRTS), disagrees with this assumption based on its experience operating and maintaining the FCRTS as well as integrating and interconnecting renewable resources. Transmission costs can be significant due to the cost of materials, construction, land acquisition, and permitting process. Furthermore, there is often substantial opposition to new transmission projects by various stakeholders, which increases project costs and can delay or even result in the cancellation of a project. Thus, the report should explain what the Energy Strategy assumption is based on and acknowledge the costs may not be small.

B. Adequacy of Replacement Resources

Bonneville agrees with following statements on page 52 of the Draft Report: "First, a replacement portfolio should be in place and demonstrating that it is producing energy and providing services to the grid before the dams were breached to avoid significant impacts to the regional energy system and the communities it serves. Second, in addition to evaluating a one-to-one replacement portfolio, an option for replacing the energy attributes of the LSRD should be evaluated that optimizes the ability to meet the Pacific Northwest region's current and future needs, not just what the LSRD currently provide and when they provide it." Draft Report at 52.

Bonneville does not believe the Draft Report adequately analyzes the attributes of alternative energy resources and the risks of using those resources to maintain the reliability of the Federal Columbia River Power System. There does not appear to be any analysis on the extent alternative resources could replace the energy and capacity of the LSRD if the region experiences extreme peak conditions, such as if the region is experiencing a sustained cold snap in the winter. When the region experiences sustained cold snaps, wind production is usually extremely low and solar production is also likely to be low due to shorter daylight periods, frequent cloud cover, and panels potentially covered by snow and ice. Bonneville has relied heavily on the LSRD when these conditions have occurred in the past to maintain regional reliability. There is substantial uncertainty that the proposed replacement portfolio of resources could perform to the same level of reliability and the Draft Report should make this uncertainty clear.

A plan to address LOLP by the addition of evolving technologies needs to be quantified so that risks and costs are clearly understood. Specifically, an estimate of the amount of new resources that are anticipated to be on the grid and the timing should be included so that informed decisions can be made. Reliability could be seriously compromised if large numbers of conventional resources, like the LSRD, are retired based on the assumption that the new technologies are available to replace them, but the anticipated deployment of these technologies is delayed for any reason. Many factors could cause these delays, including supply chain issues, legal or regulatory challenges, or problems with the technology itself. The Draft Report should make clear reliance on technologies that are not in use and proven could increase reliability issues in the region.

It is also important to account for differences in how emerging technologies may perform in the Pacific Northwest versus other regions, such as the Pacific Southwest. The Pacific Northwest typically has more volatility in wind and solar. Wind is driven largely by weather fronts in the Pacific Northwest versus diurnal wind patterns in the Pacific Southwest that are the result of daily heating and cooling effects. Solar is also more volatile in the Pacific Northwest due to more frequent cloud cover. Because of the more predictable weather patterns, batteries provide an effective compliment in areas such as the Pacific Southwest. As discussed above, a battery provides capacity when it is charged, but is a load when it needs to be recharged. Hence, the battery recharge has a direct impact to the regional load profile, and predictable weather patterns help to ensure enough capacity is available during times of recharge to meet both actual consumer load and battery recharge requirements.

4) Technical comments on the Fish Information

Bonneville suggests a few clarifications to the Executive Summary and Section 4 of the Draft Report. The purpose of including selected graphics in this response are to illustrate where areas in the final report can be improved upon, although not necessarily needed for inclusion in final report.

Bonneville recommends clarification in the illustration of LSRD construction and their impacts, specifically the historical impacts to salmon and steelhead abundance before 1960. On page 3 (and page 20) of the Draft Report, there is a statement that "*Salmon and steelhead have declined by over*

90% compared to their pre-dam abundances in the Columbia and Snake River system." Figure 1 shows that while fish numbers have indeed decreased dramatically, the vast majority of the decrease happened long before the construction of the LSRD and even well before the first dam was constructed in the CRS For the purposes of understanding the impacts of the LSRD on Snake River salmon and steelhead populations, the authors should clarify the baseline in which they are applying the 90% decline. For example, is it just prior to the start of Ice Harbor Dam construction, which began in 1955 (i.e. abundance in 1954), or is it a broader historical timeframe and context (i.e. abundance in 1855), before the losses in salmon and steelhead populations that were recorded during commercial harvest exploitation, mining, agriculture and logging practices.[8]

On page 4 of the Draft Report, please elaborate on the source of information that supports the statement, "*Breaching the LSRD could increase tribal harvest by 29% annually and would have the highest likelihood of removing salmon from ESA listing and maintaining treaty and trust obligations compared to other alternatives.*" The reference to the potential 29% increase in tribal harvest is presented as if the estimate is supported by the Comparative System Survival (CSS) and NOAA life cycle models, yet later in the document (page 30, paragraph 4) is credited to CRITFC's Energy Vision for the Columbia River Basin.

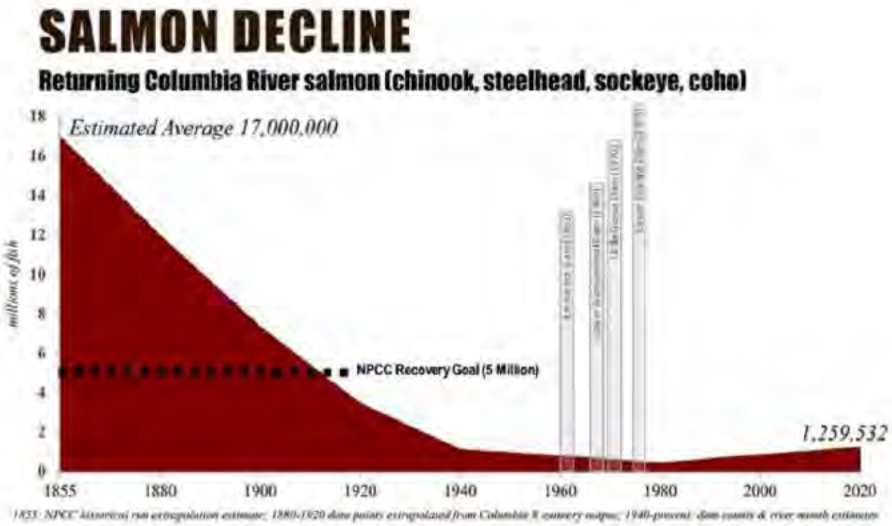


Figure 1. Estimated number of returning Columbia River salmon (chinook, steelhead, sockeye and coho), 1855-2022. Source of graphic: ***Energy Vision for the Columbia River Basin*** presented by *Columbia River Inter-Tribal*

[8] See Figures 1 and 2 for additional context.

Fish Commission to the *Northwest Power and Conservation Council*, March 13, 2022.[9] Completion period of lower Snake River hydro projects overlaid.

The LSRD have undergone significant structural and operational changes over the past three decades to improve fish passage for ESA-listed salmon and steelhead at each project, both downstream fish operations for juveniles and upstream passage for adults. Bonneville suggests the final report illustrate the notable modifications that have been made at the projects and across the Columbia River System to benefit juvenile salmon and steelhead. Some of these modifications include: the installation of spillway flow deflectors in the immediate tailrace of some projects, such as Ice Harbor Dam, to reduce total dissolved gas when spilling water (i.e., we can spill more water today before exceeding state water quality standards); the addition of surface spill structures to pass more juvenile fish downstream through non-powerhouse routes; and site-specific prescribed deep spill operations to further increase non-powerhouse passage routes and meet site-specific survival performance standards of 96% or higher for spring migrants moving towards the ocean, and reductions in both avian and fish predators. All of these improvements have increased direct and indirect survival of juvenile fish through the Columbia River System during their freshwater migration experience.

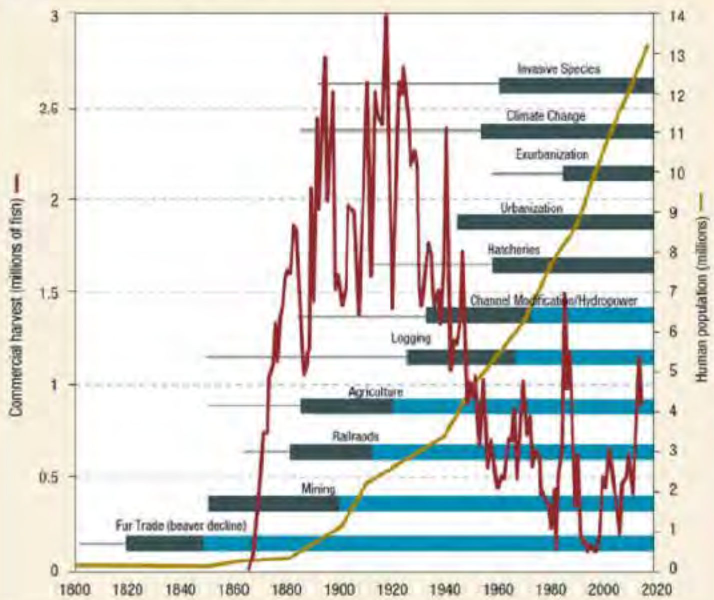
Within the last five years, increased spill operations have been implemented above performance standard spill,[10] that have resulted in an increase of spill from roughly 30-50% to 60-90% or more of the river on an average year at each project to improve downstream fish passage.[11] The intended benefit of increased spill operations is to return more adult salmon, although not enough time has passed for the benefits of these operations to be fully evaluated. Adult salmon and steelhead from these groups of juvenile fish that experienced increased spill operations of up to 125% total dissolved gas (TDG) in 2020-2022, have not yet completed their full life cycle return to the Snake River and tributaries.

For adult salmonids, additional improvements have been made in the lower Snake River to improve upstream passage conditions. These range from improved management of flow augmentation that annually provides cooler water to the mainstem Snake River to reduce water temperatures in the summer months to adult ladders retrofitted with cooling water pumps at two of the four LSRD to improve upstream passage conditions. Investigations are underway to determine if there are innovative measures that can be applied to the other two locations and monitoring continues in the ladders that have been retrofitted to evaluate the success of these water quality improvements. Although the dams are a contributing factor in diminishing salmon returns, the factors involved in these declines are much more varied and complex. The Draft Report does not adequately describe or acknowledge the significant investments and improvements that have been made to fish passage on

[9] *See* Memorandum to Northwest Power and Conservation Council (dated April 2, 2022) of The Columbia River Inter-Tribal Fish Commission's (CRITFC) 2022 Energy Vision for the Columbia River Basin (https://www.nwcouncil.org/fs/17714/2022_04_2.pdf)
[10] Spill levels developed under previous NOAA biological opinions.
[11] *See* U.S. Army Corps of Engineers *Fish Passage Plan* and *Appendix E, Fish Operations Plan* for planned spill by project and actual spill and total project outflow (kcfs) at https://pweb.crohms.org/report/projdata.htm

the lower Snake River dams. Bonneville request the Draft Report be updated to reflect these investments and improvements.

The factors that have shaped both the historical decline and the current status of salmon returns are difficult to measure, but not to identify. Figure 2 illustrates the historical context of decreasing abundance of Pacific Northwest salmon and steelhead with abiotic factors and increasing human population and commercial harvest.



Data sources: Columbia River commercial harvest numbers from ODFW, WDFW, and ISAB (2015); human population growth from U.S. Census data for Oregon, Washington, and Idaho; and hatchery timeframe from National Research Council (1998). Records of commercial landings do not completely reflect historical abundance but are used here because historical numbers for salmon and steelhead abundance do not exist.

Figure 2. Human population growth and activities in Columbia Basin compared to commercial landings of salmon and steelhead. Source: Phase 1 Marine Fisheries Advisory Committee (MAPFAC) Report, ***Goals to Restore Thriving Salmon and Steelhead to the Columbia River Basin*** (Figure 3 page 17, adapted from Penaluna et al. 2016).[12]

[12] *See* THE COLUMBIA BASIN PARTNERSHIP TASK FORCE PHASE 1 REPORT (*Goals to Restore Thriving Salmon and Steelhead to the Columbia River Basin*) and PHASE 2 REPORT (*A Vision for Salmon and Steelhead: Goals to Restore Thriving Salmon and Steelhead to the Columbia River Basin*) retrieved from: https://www.fisheries.noaa.gov/vision-salmon-and-steelhead-goals-restore-thriving-salmon-and-steelhead-columbia-river-basin

The presence of the LSRD has been one of many limiting factors for migratory fishes in the Pacific Northwest. However, the temporally-limited impact of the dams, while significant, may be minor compared to the more broadly impactful consequences of ocean conditions and ocean predation. Figure 3 shows the many variables used by NOAA to assess ocean conditions experienced by salmonids during their marine life stage. These ocean condition figures have been shown to be positively correlated with salmon returns.

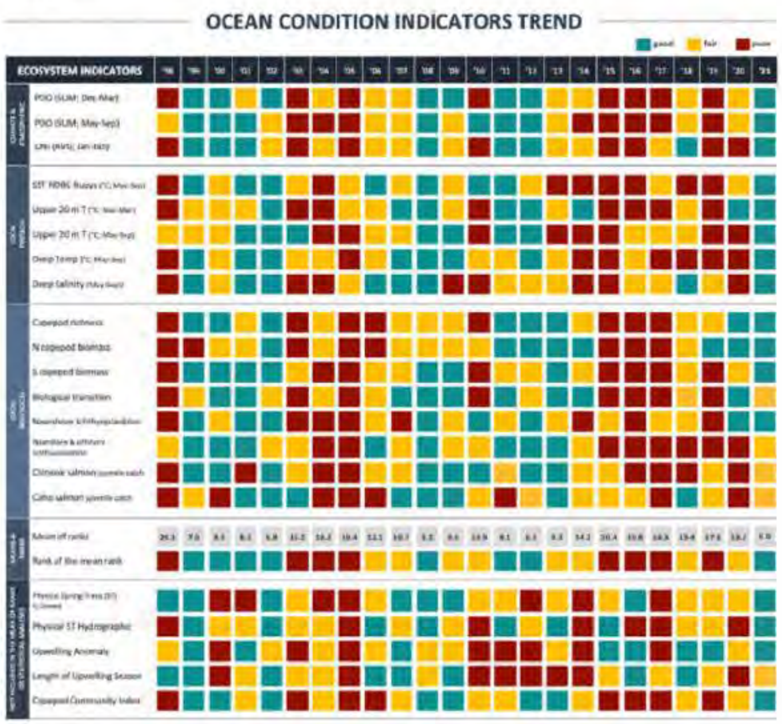


Figure 3. The number of climatic and atmospheric, local physical, and local biological indicators used to characterize the ocean conditions that may affect the growth and survival of juvenile salmon in the northern California Current. The figure compares data across all years sampled, and each indicator is ranked and color-coded based on whether they are "good," "bad," or "neutral" for juvenile salmon growth and survival. Source: [Ocean Conditions Indicators Trends | NOAA Fisheries]

With the 2021 ocean conditions being the most favorable to salmon and steelhead since 2008, the potential for strong salmon returns is evident. And based on 2022 returns so far, this is indeed the case. The spring Chinook runs have exceeded preseason forecasts at Bonneville *and* Lower Granite dams. The spring Chinook run was the highest since 2015 and well above the 10 year average.[13] The 2022 sockeye run is ongoing but is not only above the 10-year average, it is also the second highest return of adults since fish counting began at Bonneville Dam in 1938. While the Columbia River System fish passage systems have been continually and incrementally improved, the most influential set of environmental variables on these returns are the ocean conditions within which these fish reside for the majority of their lives.

While the entirety of regional agencies and tribes seek to find appropriate metrics with which to gauge current status and trends in fish population health, there is the potential to apply inappropriate significance to certain metrics. Smolt to adult returns (SAR) and quasi-extinction thresholds (QET) are two such metrics, both of which have been highlighted in the Executive Summary and Section 4, pages 3 and 20-25 of the Draft Report. The use of SARs, while informative, risks the over estimating hydrosystem impacts, while ignoring the larger effect of ocean conditions as previously mentioned. For example, *if* the hydrosystem had very little impact on outmigrating salmonids, *but* these fish encountered three years of poor ocean conditions, then the resulting SARs could be very low even with little direct impact from the hydrosystem. The method of how SAR estimates are calculated can also be misleading – the start and finish lines need to be defined and if different, conclusions should be presented with caution. Furthermore, rather than comparing SARs of John Day River fish that have passed only three dams to those of Snake River salmon that pass up to eight dams, the authors should consider looking at comparisons of upper Columbia River (UCR) fish, such as UCR sockeye salmon that pass a similar number of dams (nine in total) when compared to SR sockeye salmon.

A similar situation can occur when applying QET as a definitive metric, which is sensitive to the population size, number of adult spawners chosen, timeframe selected (i.e. number of years), and other interacting variables and assumptions applied, such as reduced latent mortality (See example of Grande Ronde major population group (MPG) and Upper Grande Ronde population in Figure 4).[14] A multitude of environmental variables can add uncertainty to the value of QET from the ocean to spawning habitat degradation or losses *and* improvements. Ocean conditions are a major driver of salmon and steelhead abundance and therefore the final report should include additional materials that reflect the uncertainty ocean conditions impose on the benefits expected to be received after the breaching of LSRD.[15, 16]

[13] *See* Fish Passage Center website (www.fpc.org) for pre-season run forecasts, current run-timing and adult return counts, and historical run-timing and adult return counts.
[14] *See* 2020 NMFS Columbia River System Biological Opinion (Appendix C)
[15] See Ocean Ecosystem Indicators of Pacific Salmon Marine Survival in the Northern California Current | NOAA Fisheries
[16] Crozier LG, McClure MM, Beechie T, Bograd SJ, Boughton DA, Carr M, et al. (2019) *Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem.* PLoS ONE 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

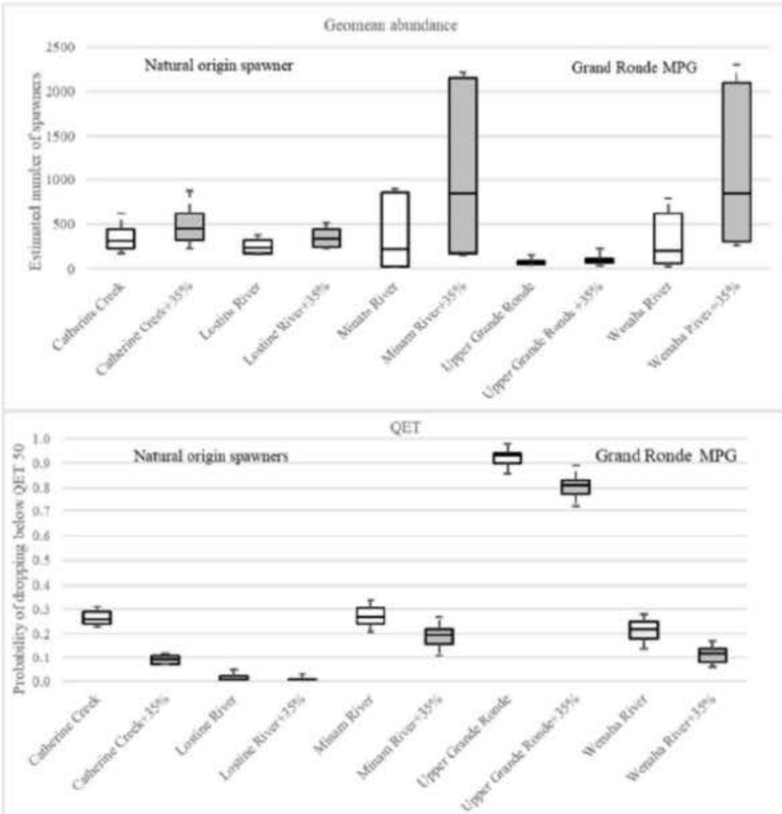


Figure 4. Life cycle model projections of median abundance and Quasi-Extinction Risk thresholds of 50 (spawning adults) for the Grande Ronde River MPG populations of naturally producing fish in 24 years (year 15 to 24). Estimates assume a 35% increase in survival per CSS model, which includes reductions in latent mortality. Source: 2020 NMFS Columbia River System Biological Opinion, Figure 2.2-11b (page 2-230).

On page 28 of the Draft Report, the Plan for Analyzing and Testing Hypotheses (PATH) is cited. Please consider referencing a more recent scientific review since the PATH analysis was conducted using data from the 1980s and 1990s and completed in 2001.[17] Since then, the LSRD (and other CRS dams) have undergone major modifications that have improved fish passage and survival studies using new technologies have substantially improved our understanding of fish passage dynamics.

[17] Marmorek et al. 2001.

5) Technical comments on the water quality information.

On page 65, the collective heat load allocation given to the Columbia and lower Snake River dams is incorrect. The U.S. Environmental Protection Agency's Columbia and Lower Snake Rivers Temperature Total Maximum Daily Load (TMDL) assigns 0.1°C as the dams' cumulative heat load allocation. Of the remaining 0.2°C, EPA did not assign a portion to climate change, which they acknowledge is a primary component of cumulative impacts contributing to temperature impairments.

Additionally, the Draft Report should acknowledge operational changes may be conducted to meet state water quality standards and the TMDL heat load requirements, any changes must take into consideration the dams' congressionally authorized purposes, which include hydropower, navigation, and recreation. The Corps works toward achieving the allocation and improving temperature conditions for migrating salmonids by implementing actions that are not solely focused on operational changes, including managing water temperature in fish ladders. Further, due to vertical mixing at run-of-river dams, such as the LSRD, there is very limited ability for water to temperature stratify where distinctly colder water is located at depth similar to what occurs at Dworshak Dam. During the summer, the Corps utilizes Dworshak Dam's cold water flows with the goal to manage water temperatures at or below Washington's 68°F (20°C) water quality criterion downstream on the lower Snake River.

6) Clerical error correction:

On page 97, Eve James' name is incorrectly listed as James Eve and should be corrected to Eve James.

Organization	Name
AgNorthwest	[illegible]
AgNorthwest	Dennis Wright
AgNorthwest	[illegible]
American Cruise Lines	Kristin Meira
American Queen Steamboat Company	Andrea Mickelson
American Whitewater	Tom O'Keefe
Ben Franklin Transit	Ed Frost
Benton PUD	Lori Sanders
Benton PUD	Rick Dunn
BNSF Railway	Johan Hellman
Bonneville Power Administration	James Eve
Bonneville Power Administration	Liz Klumpp
Bonneville Power Administration	Robert Diffley
Bureau of Reclamation	Eric Rothwell

Columbia River System Operations
Final Environmental Impact Statement

Appendix G
Air Quality and Greenhouse Gases

Table of Contents

List of Tables

List of Figures

The following appendix contains four sections related to the evaluation of air quality and Greenhouse Gas (GHG) for the Columbia River Systems Operations (CRSO) EIS. Chapter 1 provides information regarding pollutant emissions management in the Pacific Northwest. Chapter 2 provides a detailed evaluation of methane emissions related to hydroelectric project reservoirs. Chapter 3 describes society's willingness to pay to avoid climate-related impacts associated with an additional unit of a GHG in the atmosphere, also known as the Social Cost of Carbon (SCC). Chapter 4 describes regional haze, Class I Areas and wind speed trends. Chapter 5 evaluates the Columbia River Basin as a source of emissions of methane to the atmosphere.

CHAPTER 1 - AIR QUALITY STANDARDS AND GREENHOUSE GAS TARGETS

Table 1-1 characterizes the human health and environmental concerns related to each of the six criteria pollutants.

Table 1-1. Criteria Air Pollutants: Adverse Health and Environmental Effects

Pollutant	Description and Sources	Health and Environmental Effects
Carbon Monoxide (CO)	CO is formed by the incomplete combustion of fossil fuels and by atmospheric photochemical reactions. CO emissions primarily come from incomplete combustion in mobile sources.	CO exposure reduces blood's ability to carry oxygen to body tissues (hypoxia). Reduced oxygen availability can cause cardiovascular events; exposure is especially dangerous for people with impaired cardiovascular systems. CO exposure may adversely affect other key body functions.
Lead (Pb)	Lead is primarily emitted from industrial processes such as iron and steel processing and from combustion of leaded aviation gasoline.	Lead exposure has neurotoxic effects, especially in young children. Multiple studies show an inverse relationship between blood lead levels and children's IQ even at low blood lead levels. Lead contaminates surface soils and harms plants and other organisms.
Nitrogen Dioxide (NO_2)	NO_2 is primarily emitted from combustion processes such as electric utility fuel combustion and industrial fuel combustion as well as from highway and off-highway vehicles.	NO_2 exposure can cause respiratory symptoms including airway inflammation and decreased lung function. Ecologically, NO_2 deposition results in acidification, excess nutrient enrichment, low dissolved oxygen, harmful algal blooms, and loss of aquatic vegetation. NO_2 also degrades visibility.
Ozone (O_3)	Ground-level ozone is formed through reactions of volatile organic compounds (VOCs) with pollutants such as nitrogen oxides (NO_x) and CO in the presence of sunlight.	Ozone exposure is associated with respiratory symptoms such as asthma exacerbation. Ozone is also harmful to plants, causing cellular damage and plant death. Ozone directly contributes to global climate change.
Particle Pollution $PM_{2.5}$-PM_{10}/[1]	Primary PM is directly emitted from sources, such as vehicles and construction sites. Secondary PM is formed from chemical reactions with gases (e.g. organic carbon, sulfates) emitted from power plants, industrial facilities, and vehicles.	Exposure to $PM_{2.5}$ can cause respiratory symptoms such as asthma exacerbation, as well as cardiovascular events. Environmental effects include visibility impairment and deposition of particulate matter which can result in toxic pollutants accumulating in organisms and ecosystems via vegetation, soils, and surface water.
Sulfur Dioxide (SO_2)	SO_2 is primarily emitted from fossil fuel combustion at electric utilities and other industrial facilities. Other sources of emissions include large ships, non-road diesel equipment that burns sulfur-containing fuels, and wildfires in the Pacific Northwest.	SO_2 exposure causes adverse respiratory effects such as bronchoconstriction and decreased lung function. Asthmatics in particular are sensitive to SO_2 exposure. SO_2 deposition on ecosystems results in acidification, excess nutrient enrichment, and increased mercury methylation and ultimate mercury contamination. SO_2 also degrades visibility.

Note: 1PM2.5 includes particles with an aerodynamic diameter less than or equal to 2.5 microns, and PM10 includes particles with an aerodynamic diameter less than or equal to 10 microns.
Sources: CO: USEPA 2010a Pb: USEPA 2006; USEPA 2008 NO2: USEPA 2010b O3: USEPA 2015 PM: USEPA 2012 SO2: USEPA 2010c

Table 1-2 provides the current National Ambient Air Quality Standards (NAAQS) and state-level ambient air quality standards (AAQS).

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Table 1-2. National and State Ambient Air Quality Standards

Pollutant	Primary[1] / Secondary[2]	Averaging Period	NAAQS	OR AAQS	WA AAQS	ID AAQS	MT AAQS	Notes
Carbon Monoxide (CO)	Primary	1 hour	35 ppm	35 ppm	35 ppm	35 ppm	23 ppm	3
		8 hours	9 ppm	9 ppm	9 ppm	9 ppm	9 ppm	3
Lead (Pb)	Both	Rolling 3-mo. avg.	0.15 μg/m³	0.15 μg/m³	0.15 μg/m³	0.15 μg/m³	0.15 μg/m³	5
	--	Quarterly	1.5 μg/m³	1.5 μg/m³	--	--	1.5 μg/m³	6
Nitrogen Dioxide (NO_2)	Primary	1 hour	100 ppb	100 ppb	100 ppb	100 ppb	0.30 ppm	7
	Both	1 year	53 ppb	53 ppb	53 ppb	53 ppb	0.05 ppm	8
Ozone (O_3)	--	1 hour	--	--	--	--	0.10 ppm	4
	Both	8 hours	0.070 ppm	0.075 ppm	0.070 ppm	0.070 ppm	--	9
Particle Pollution $PM_{2.5}$	Primary	1 year	12.0 μg/m³	12.0 μg/m³	12.0 μg/m³	12.0 μg/m³	--	10
	Secondary	1 year	15.0 μg/m³	15.0 μg/m³	--	15.0 μg/m³	--	10
	Both	24 hours	35 μg/m³	35 μg/m³	35 μg/m³	35 μg/m³	--	11
Particle Pollution PM_{10}	Both	24 hours	150 μg/m³	150 μg/m³	150 μg/m³	150 μg/m³	150 μg/m³	12
	Both	Annual	--	--	--	--	50 μg/m³	13
Sulfur Dioxide (SO_2)	Primary	1 hour	75 ppb	75 ppb	75 ppb	75 ppb	0.50 ppm	14
	Secondary	3 hours	0.5 ppm	0.5 ppm	0.5 ppm	0.5 ppm	--	3
	Primary	24 hours	0.14 ppm	0.10 ppm	0.14 ppm	0.14 ppm	0.10 ppm	3, 15
	Primary	Annual	0.030 ppm	0.020 ppm	0.020 ppm	0.030 ppm	0.02 ppm	15

Notes:

1- Primary Standards: provide public health protection, including sensitive populations such as asthmatics, children, and the elderly
2-Secondary Standards: provide public welfare protection, including protecting against decreased visibility and damage to animals, crops, vegetation, and buildings
3- Not to be exceeded more than once per year
4- State violation when exceeded more than once over any 12-month period
5- Not to be exceeded
6- Non-attainment areas subject to previous standards
7- 98th percentile of 1-hour daily maximum concentration, averaged over 3 years
8- Annual average
9- Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
10- Annual mean, averaged over 3 years
11- 98th percentile, averaged over 3 years
12- Not to be exceeded more than once per year on average over 3 years
13- State violation when 3-year average exceeded
14- 99th percentile of 1-hour daily maximum concentration, averaged over 3 years
15- Previous SO2 standards in effect for certain areas; no longer applicable for areas in attainment status for 1 year
16- State violation when average over four consecutive quarters exceeds standard

Sources: USEPA 2016; USEPA 2018 (SIPS); MT DEQ 2007.

Table 1-3 lists GHG emissions reductions targets for identified counties and municipalities that have plans either announced or passed in the Pacific Northwest. The Affected Environment presents the state specific targets.

Table 1-3. Emissions Reduction Targets for Pacific Northwest Municipalities

County/ Municipality	Targets?	Plan?	Rule & Rule Year	Method[a]	Targeted Industries	Type	Base-line Year	Targets	Source
WASHINGTON									
Bellingham, WA	Yes	Yes	City Council approved the Climate Protection Action Plan, 2007	production	Municipal; Residential; Commercial; Industrial; Transportation; Waste	GHG	2002	7% by 2012 28% by 2020 85% by 2050	Climate Protection Action Plan, 2018
King County, WA	Yes	Yes	Ordinance 17270, Council Motion 14349, May, 2015	consumption & production	Transportation; Industrial; Residential; Commercial; Electric Power & Gas; Agriculture; Waste	MT CO2e	2007	25% by 2020 50% by 2030 80% by 2050	King County Strategic Climate Action Plan, 2015
Seattle, WA	Yes	Yes	Resolution 31312, October 3, 2011 and Resolution 31447, June 17, 2013	production	Building Energy; Land Use; Waste	GHG	n/a	0 net GHG by 2050	Seattle Climate Action Plan, 2013
Olympia, WA	No	Yes	City council votes to create the Climate Action Plan, May 10, 1990	production	Buildings; Vehicle Fleet; Street Lighting; Water/ Sewer; Waste	CO2e	2005		City of Olympia Greenhouse Gas Emissions Inventory, 2008
OREGON									
Beaverton, OR	Yes	Yes	Sustainable Beaverton Strategy (SBS) developed in 2014	consumption & production	Fleet; Natural Gas; Electricity; Commute; Supply Chain; Water	CO2e	2008	75% by 2050	Sustainable Beaverton Strategy, 2014
City of Portland and Multnomah County, OR	Yes	Yes	2009 Climate Action Plan updated in 2015	production	Residential; Commercial; Industrial; Transportation; Waste	GHG	1990	14% by 2013 40% by 2030 80% by 2050	Climate Action Plan Progress Report, 2017

County/ Municipality	Targets?	Plan?	Rule & Rule Year	Method[a]	Targeted Industries	Type	Base-line Year	Targets	Source
Corvallis, OR	Yes	Yes	Climate Action Plan adopted by the Corvallis City Council, December 2016	production	Supply Chain; Commute; Watershed; Waste; Fleet; Electricity; Natural Gas	GHG	1990	75% by 2050	Climate Action Plan Goals, 2015
Eugene, OR	Yes	Yes	Counsel Ordinance 20567 Bill 151, July27, 2016	production	Energy; Agriculture; Land Use; Waste; Health; Urban; Natural Resources	GHG	1990	10% by 2020	Strategic Climate Action Plan, 2015
Lake Oswego, OR	No	No	City Council Voted to Draft Climate Action Plan, 2017	production	Materials; Energy; Transportation	CO2e	2008	60% by 2040	Sustainability Action Plan for City Operations, 2014
Milwaukie, OR	No	No	Draft of Climate Action Plan Committee Charter, February 7, 2018	no inventory	--	--	--	--	Climate Action Plan Committee Charter, 2018
West Linn, OR	Yes	Yes	Sustainable West Linn Strategic Plan – Update 2015	production	City Facilities City Fleet	CO2	2008	80% by 2040[b]	Sustainable West Linn, 2015
MONTANA									
Bozeman, MT	Yes	Yes	Bozeman City Commission in adopted the Community Climate Action Plan in 2011	production	Residential; Commercial; Transportation	CO2e	2008	10% by 2025	Bozeman Climate Action Report, 2010
Missoula, MT	Yes	Yes	Resolution 8174, June 26, 2017	production	Municipal	CO2e	2008	30% by 2017 50% by 2020 100% by 2025	No Report Missoula Greenhouse Emissions Inventory, 2010

County/ Municipality	Targets?	Plan?	Rule & Rule Year	Method[a]	Targeted Industries	Type	Base-line Year	Targets	Source
Whitefish, MT	Yes	Yes	Climate Action Plan approved following a public hearing, April 16, 2018	production	Municipal	GHG	2005	26% by 2025	City of Whitefish Climate Action Plan, 2018
IDAHO									
Boise, ID	No	Yes	Resolution #21500, Blueprint Boise Comprehensive Plan, November 29, 2011.	no inventory	--	--	--	--	Boise's Comprehensive Plan, 2018
Ketchum, ID	Yes	No	Resolution 15-012, March 12, 2015	production	No inventory	GHG	2007	75% by 2030	National Mayors Group Committed to Protecting Climate, 2017

Notes:

[a]Production–based inventory measures GHG produced from activities within administrative boundaries whereas consumption–based emissions inventory measures GHG emitted in the production of goods (both within and outside of the administrative boundary) consumed within administrative boundaries.

[b]Target is only to reduce West Linn City operations emissions, not city-wide emissions.

CHAPTER 2 - ENERGY SECTOR GHG EMISSIONS MODELLING

AURORA is the primary model used in the CRSO GHG emissions analysis. AURORA is a power production cost model, described in Appendix J, *Hydropower*. The quantitative emissions analysis focuses specifically on carbon dioxide (CO_2) emissions. CO_2 is the primary source of GHG emissions from power generation, accounting for over 80 percent of energy-related carbon emissions (EIA 2018). Additionally, the AURORA model emissions reporting is limited to CO_2. This analysis notes that quantifying only the CO_2 emissions may understate total GHG emissions and this point is considered in assessing the intensity of the GHG emissions effects of the action alternatives.

Table 2-1 presents the regional nodes or zones used in the AURORA model. Each of these zones contains a set of power resources from which power is "dispatched" to meet demand for electricity. This analysis focused on emissions from power generation from zones in the Pacific Northwest and across the broader Western Interconnection (as defined in Section 3.7.2), excluding sources in Northern Mexico and Canada.

Table 2-2 presents the detailed emissions outputs of AURORA for each action alternative by month and by region in million metric tons (MMT) CO_2. The analysis relies on 3,200 iterations of the AURORA model (drawn from 80 water years and 40 climate scenarios) to estimate the average dispatch of power resources and thus emissions for the regional power system. The values in the table reflect averages across all 3,200 iterations and represent emissions expected in 2022. The AURORA outputs take into consideration the change in modelled hydropower generation and the resource replacement portfolios of either zero-carbon or conventional least-cost resources. Even under a "zero-carbon" portfolio there is the potential for emissions to increase as other coal or natural gas power plant generation increases to meet load under MO3 and MO4.

Note that the emissions estimates from AURORA in Table 2-2 are for the base case scenario (described below) and that the Pacific Northwest totals presented in this table do not include Jim Bridger and North Valmy power plants, which are included in the "Other Western US" region in the AURORA model instead.

The AURORA CO_2 emissions output is the basis for forecasting emissions from 2022 to 2041. This analysis considers a base case scenario for the mix of resources generating power in the Pacific Northwest over time, as well as two additional scenarios that assess the sensitivity of emissions estimates to alternative assumptions regarding potential future coal plant retirements that have been announced and are described in the NW Council 7th Power Plan Midterm Assessment (2019). The sensitivity analysis scenarios developed by Bonneville for power system reliability analysis (and described in Section 3.7) are as follows:

- The "limited coal retirement" scenario assumes an additional reduction of 2,505 MW of coal power capacity compared to the No Action base case by 2022 (see Table 2-3). This scenario includes potential future coal plant retirements and only limited coal capacity remaining (including Colstrip unit 4 and Jim Bridger units 3 and 4).

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- The "no coal" scenario assumes the retirement of all coal plants operating in the Northwest or serving Northwest loads by 2022.

Table 2-3 compares emissions forecasts for 2022 across the base case under the zero-carbon resource replacement portfolios (as described in Section 3.8).

Table 2-4 displays the full 2022 to 2041 emissions projections for the base case, including both the conventional least-cost and zero-carbon resource replacement portfolios.

The emissions projections for 2022 for the base case analysis rely on the CO_2 emissions from power generation reported by the AURORA model runs with the addition of emissions from Jim Bridger and North Valmy power plants (estimated as the average annual emissions from 2012, 2014, and 2016) as these coal plants are not within the AURORA Pacific Northwest estimate.[1] Emissions projections between 2023 and 2035 rely on average annual decreases in coal generation and increases in natural gas generation observed in dispatch forecasts from the NW Council over the same timeframe based on the NW Council's Regional Portfolio Model (RPM) for the Existing Policy scenario of the 7th Power Plan (NW Council 2016b). The NW Council dispatch data do not extend beyond 2035, therefore emissions between 2036 and 2041 are held constant at 2035 levels (NW Council 2016b).

Table 2-1. AURORA Zones and Regions

AURORA Zone	Region
Avista	Pacific Northwest
Bonneville, ID and MT	Pacific Northwest
Bonneville, OR	Pacific Northwest
Bonneville, WA	Pacific Northwest
Chelan County PUD	Pacific Northwest
Douglas County PUD	Pacific Northwest
Grant County PUD	Pacific Northwest
Idaho Power FE	Pacific Northwest
Idaho Power MV	Pacific Northwest
Idaho Power TV	Pacific Northwest
Northwestern, MT	Pacific Northwest
Olympia	Pacific Northwest
Pacificorp East ID	Pacific Northwest

[1] A considerable fraction of the emissions are associated with generation from two coal plants, Jim Bridger in Wyoming and half of the generation of North Valmy in Nevada. Both lie outside the Pacific Northwest region; however, the NW Council considers them regional resources (NW Council 2016; 2019). All generation from Jim Bridger serves Pacific Northwest customers as does half of North Valmy. While this consumption-based approach contrasts with AURORA production-based emissions estimates, these emissions are included to ensure generation and emissions are consistent with historical NW Council data and forecasts relied on in this analysis (NW Council 2016b; 2019). Over the last three years of available data, the EPA estimated Jim Bridger emitted an average of 14.2 MMT CO2, and 900,000 tons of CO2 for half of North Valmy. However, the analysis considers that by 2022 North Valmy 1 will retire and therefore includes only 474,000 tons of CO2. (USEPA 2018; NW Council 2019).

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AURORA Zone	Region
PACW South	Pacific Northwest
Portland General	Pacific Northwest
Puget Sound Central	Pacific Northwest
Puget Sound North	Pacific Northwest
Seattle CL	Pacific Northwest
Tacoma Power	Pacific Northwest
Balancing Authority of Northern California	California
Imperial Irrigation District	California
Los Angeles Water & Power	California
PG&E Bay Area	California
PG&E North	California
PG&E ZP26	California
Southern California Edison	California
San Diego Gas and Electric	California
Turlock Irrigation District	California
Arizona Public Service	Other Western United States
El Paso Electric	Other Western United States
Nevada North	Other Western United States
Nevada South	Other Western United States
Pacificorp East, UT	Other Western United States
Pacificorp East, WY	Other Western United States
Public Service, CO	Other Western United States
Public Service, NM	Other Western United States
Salt River Project	Other Western United States
Tucson Electric	Other Western United States
Valley Electric Association	Other Western United States
Western Area Power Administration (WAPA), CO	Other Western United States
WAPA, Lower CO	Other Western United States
WAPA, Upper MO	Other Western United States
WAPA, WY	Other Western United States

Table 2-2. Emissions by Region and Month for each CRSO Scenario in Million Metric Tons CO2, Base Case

AURORA Average Monthly Emissions by Region, Month and Scenario, MMT CO_2												
Scenario and Region	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
NAA												
Pacific Northwest	2.2	1.9	1.8	1.4	0.95	0.81	1.6	2.1	2.3	2.2	2.2	2.6
California	3.9	3.2	2.8	2.5	2.5	2.9	4.2	4.5	4.2	4.1	4.0	4.4
Other Western US	8.5	7.4	7.1	6.2	6.5	7.0	10	10	8.9	7.7	7.9	9.4
MO1 Conventional Least-Cost (Difference from No Action)												
Pacific Northwest	-0.024	-0.0047	0.018	0.071	0.087	0.041	0.018	0.051	0.0024	0.016	0.012	0.048
California	-0.015	-0.00082	0.0046	0.023	0.034	0.0051	0.016	0.036	-0.012	0.0012	-0.0035	0.0081
Other Western US	-0.036	-0.006	0.0088	0.041	0.044	0.0093	0.052	0.11	-0.021	0.0051	-0.0046	0.021
MO1 Zero-Carbon (Difference from No Action)												
Pacific Northwest	-0.064	-0.06	-0.034	0.0098	0.025	-0.0051	-0.1	-0.1	-0.11	-0.021	-0.019	0.00033
California	-0.014	-0.0012	-0.002	0.015	0.035	0.016	0.014	0.044	-0.008	-0.025	-0.015	0.0071
Other Western US	-0.03	0.0093	0.018	0.057	0.093	0.051	0.09	0.15	-0.021	-0.06	-0.024	0.025
MO2 (Difference from No Action)												
Pacific Northwest	-0.11	-0.088	0.038	-0.0083	-0.13	-0.068	-0.17	-0.30	-0.11	-0.027	-0.046	-0.085
California	-0.025	-0.016	0.025	-0.013	-0.097	-0.051	-0.048	-0.069	0.02	0.00062	-0.017	-0.024
Other Western US	-0.054	-0.037	0.048	-0.028	-0.12	0.0097	-0.019	-0.16	0.035	0.037	-0.0016	-0.044
MO3 Conventional Least-Cost (Difference from No Action)												
Pacific Northwest	0.27	0.30	0.32	0.41	0.43	0.28	0.37	0.12	0.23	0.21	0.13	0.15
California	0.022	0.020	0.019	0.065	0.14	0.11	-0.007	-0.15	-0.038	-0.017	-0.027	-0.021
Other Western US	0.012	0.036	0.045	0.13	0.19	0.088	-0.13	-0.39	-0.093	-0.09	-0.13	-0.12
MO3 Zero-Carbon (Difference from No Action)												
Pacific Northwest	0.15	0.16	0.17	0.23	0.27	0.16	0.11	-0.12	0.015	0.072	0.024	0.024
California	0.065	0.064	0.060	0.093	0.15	0.11	0.036	-0.091	0.012	-0.0050	-0.0031	0.018
Other Western US	0.12	0.13	0.13	0.22	0.31	0.19	0.032	-0.26	0.015	-0.059	-0.047	0.0021
MO4 Conventional Least-Cost (Difference from No Action)												
Pacific Northwest	-0.00065	0.028	0.58	0.53	0.40	0.28	0.35	0.39	0.18	0.14	0.081	0.12
California	-0.018	-0.0053	0.18	0.12	0.17	0.16	0.07	0.0013	-0.053	0.0037	-0.0064	0.011
Other Western US	-0.070	-0.022	0.35	0.19	0.24	0.19	0.0053	-0.0018	-0.096	-0.034	-0.072	-0.018

AURORA Average Monthly Emissions by Region, Month and Scenario, MMT CO_2												
Scenario and Region	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
MO4 Zero-Carbon (Difference from No Action)												
Pacific Northwest	-0.14	-0.16	0.34	0.24	0.15	0.12	0.045	0.020	-0.12	-0.09	-0.075	-0.036
California	-0.027	-0.014	0.16	0.088	0.11	0.095	0.0094	-0.008	-0.045	-0.052	-0.032	0.0042
Other Western US	-0.10	-0.044	0.35	0.21	0.29	0.19	-0.048	-0.084	-0.21	-0.18	-0.11	-0.033
Preferred Alternative (Difference from No Action)												
Pacific Northwest	-0.039	-0.038	0.017	0.15	0.22	0.11	0.098	0.026	0.00063	-0.023	0.015	0.010
California	-0.013	-0.011	0.0083	0.063	0.11	0.061	-0.015	-0.045	-0.021	-0.0073	0.0060	0.00036
Other Western US	-0.046	-0.026	0.016	0.10	0.14	0.017	-0.12	-0.16	-0.067	-0.060	-0.017	-0.022

Note: Emissions associated with Jim Bridger and North Valmy generation are associated to the "Other Western US" region in the AURORA. Model. All values for MOs reflect the difference relative to the No Action Alternative in MMT CO_2 and are rounded to two significant figures.
Source: AURORA model outputs

Table 2-3. Emissions Forecast for 2022, Base Case

Alternative (Resource Replacement Portfolio)	Base Case without additional coal retirements	
	2022 Emissions (MMT CO_2)	Change in Emissions Relative to Base Case NAA
NAA	36.7	--
MO1 (Zero-Carbon)	36.2	-1.3%
MO2	35.6	-3.0%
MO3 (Zero-Carbon)	37.9	3.5%
MO4 (Zero-Carbon)	37.0	0.83%
PA	37.2	1.5%

Table 2-4. Total Annual Emissions from 2022 to 2041, Base Case

Total Annual Emissions Estimates for Each Alternative, MMT CO_2									
Year	No Action	MO1 (Conventional Least-Cost Replacement)	MO1 (Zero-Carbon Replacement)	MO2	MO3 (Conventional Least-Cost Replacement)	MO3 (Zero-Carbon Replacement)	MO4 (Conventional Least-Cost Replacement)	MO4 (Zero-Carbon Replacement)	PA
2022	36.7	37.0	36.2	35.6	39.9	37.9	39.8	37.0	37.2
2023	36.5	36.9	35.9	35.3	40.5	37.9	39.9	36.8	37.1
2024	36.5	36.8	35.9	35.2	40.5	37.9	39.9	36.7	37.1
2025	36.4	36.8	35.9	35.2	40.5	37.9	39.9	36.7	37.1
2026	36.4	36.8	35.8	35.2	40.5	37.8	39.8	36.6	37.1
2027	36.4	36.8	35.8	35.1	40.5	37.8	39.8	36.6	37.0
2028	36.4	36.7	35.8	35.1	40.5	37.8	39.8	36.6	37.0
2029	36.3	36.7	35.7	35.1	40.5	37.8	39.8	36.5	37.0
2030	36.3	36.7	35.7	35.0	40.5	37.7	39.8	36.5	37.0
2031	36.3	36.7	35.7	35.0	40.5	37.7	39.8	36.5	36.9
2032	36.3	36.6	35.7	35.0	40.5	37.7	39.8	36.4	36.9
2033	36.2	36.6	35.6	35.0	40.5	37.7	39.8	36.4	36.9
2034	36.2	36.6	35.6	34.9	40.5	37.7	39.8	36.4	36.9
2035	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9
2036	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9
2037	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9
2038	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9
2039	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9
2040	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9
2041	36.2	36.6	35.6	34.9	40.6	37.7	39.8	36.4	36.9

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CHAPTER 3 - SOCIAL COST OF CARBON

GHG emissions influence a variety of socioeconomic outcomes related to climate change, including agricultural productivity, human health, flood risk, and infrastructure and fishery damages. The value of reducing levels of GHGs in the atmosphere is the avoided damages that would be generated by a unit of GHG if it were present. Economists express this value in monetary terms representing society's willingness to pay to avoid climate-related impacts associated with an additional unit of a GHG in the atmosphere. This value is defined as the "social cost" of GHGs. The more common term, "social cost of carbon" (SCC), generally pertains to CO2 emissions.

The academic literature and Federal agency guidance on these measures is actively evolving. A Federal Interagency Working Group (IWG) on the Social Cost of GHGs formerly issued guidelines that were updated over time (the most recent was in August 2016) to help agencies assess the climate change-related benefits of reducing carbon emissions and integrate these estimates into their assessments of regulatory impacts in cost-benefit analyses (Interagency Working Group 2016). The Interagency guidance provided a SCC dollar value based on the average of three integrated assessment models (IAMs). The socioeconomic effects of changes in emissions are calculated by multiplying the change in emissions in a given year by that year's SCC value. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across affected years.

The literature identifies an average social cost per ton of carbon dioxide of $42 for the year 2020 (2007 dollars, assuming a discount rate of 3 percent), though the value varies between $12/ton and $123 dollars per ton depending on the carbon distribution scenario and discount rate assumption (Marten et al. 2015). There are differences in the social cost measures for different GHGs due to differences in the "global damage potential" of the GHGs. While global warming potential of GHGs account for the differences in radiative forcing of the gases as compared with CO_2, global damage potential captures the differences across gases in terms of climate-related damages.

Table 3-1 presents the full schedule of SCC estimates for the years 2010 to 2050 from the August 2016 IWG update. The table lists estimates for three discount rates: 5 percent, 3 percent and 2.5 percent as well as an estimate of low-probability high impact outcomes at the 3 percent discount rate. As per best practices the 3 percent discount rate is considered the central estimate. The schedule comes from the August 2016 update to the Social Cost of Carbon. Dollars values are in 2019 US dollars adjusted using the BEA Implicit Price Deflator. The totals are the discounted present values as well as annualized values, each in an independent table.

Table 3-2 presents the total present value estimates of the SCC for each action alternative under the varying discount rate assumptions by multiplying the SCC value estimate from Table 3-1 by the emissions estimate for that specific year. The present values reflect the value of the changes in GHG emissions under each alternative relative to the No Action Alternative in the base case (i.e., these values do not reflect the limited coal or no coal retirement scenarios described above). Table 3-3 annualizes these estimates. All values are presented in millions of 2019 US dollars, rounded to two significant digits.

Table 3-1. Social Cost of Carbon Estimates per Metric Ton CO_2 in 2019 US dollars

	Annual Social Cost per Metric Ton CO_2 Emissions, 2019 Dollars			
Discount Rate Year	5% Average	3% Average	2.5% Average	3% High Impact (95th)
2010	$12.04	$37.31	$60.18	$103.52
2011	$13.24	$38.52	$61.39	$108.33
2012	$13.24	$39.72	$63.80	$111.94
2013	$13.24	$40.93	$65.00	$116.76
2014	$13.24	$42.13	$66.20	$121.57
2015	$13.24	$43.33	$67.41	$126.39
2016	$13.24	$45.74	$68.61	$130.00
2017	$13.24	$46.94	$71.02	$134.81
2018	$14.44	$48.15	$72.22	$139.63
2019	$14.44	$49.35	$73.43	$144.44
2020	$14.44	$50.56	$74.63	$148.05
2021	$14.44	$50.56	$75.83	$151.67
2022	$15.65	$51.76	$77.04	$155.28
2023	$15.65	$52.96	$78.24	$158.89
2024	$15.65	$54.17	$79.44	$162.50
2025	$16.85	$55.37	$81.85	$166.11
2026	$16.85	$56.57	$83.06	$169.72
2027	$18.06	$57.78	$84.26	$172.13
2028	$18.06	$58.98	$85.46	$175.74
2029	$18.06	$58.98	$86.67	$179.35
2030	$19.26	$60.18	$87.87	$182.96
2031	$19.26	$61.39	$89.07	$186.57
2032	$20.46	$62.59	$90.28	$190.18
2033	$20.46	$63.80	$91.48	$193.80
2034	$21.67	$65.00	$92.68	$197.41
2035	$21.67	$66.20	$93.89	$202.22
2036	$22.87	$67.41	$95.09	$205.83
2037	$22.87	$68.61	$97.50	$209.44
2038	$24.07	$69.81	$98.70	$213.05
2039	$24.07	$71.02	$99.91	$216.67
2040	$25.28	$72.22	$101.11	$220.28
2041	$25.28	$73.43	$102.31	$223.89
2042	$26.48	$73.43	$103.52	$227.50
2043	$26.48	$74.63	$104.72	$231.11
2044	$27.69	$75.83	$105.93	$233.52
2045	$27.69	$77.04	$107.13	$237.13
2046	$28.89	$78.24	$108.33	$240.74

	Annual Social Cost per Metric Ton CO_2 Emissions, 2019 Dollars			
Discount Rate Year	**5% Average**	**3% Average**	**2.5% Average**	**3% High Impact (95th)**
2047	$28.89	$79.44	$110.74	$244.35
2048	$30.09	$80.65	$111.94	$247.96
2049	$30.09	$81.85	$113.15	$251.57
2050	$31.30	$83.06	$114.35	$255.18

Table 3-2. Total Discounted SCC Estimates (Present Value) for Each Alternative and Discount Rate, Millions of 2019 US Dollars (2022-2041)

	Total Discounted SCC Estimates (PV), Million 2019 US Dollars			
Alternative (Resource Replacement Scenario)	**Present Value 5% Average**	**Present Value 3% Average**	**Present Value 2.5% Average**	**Present Value 3% 95th**
No Action	$7,900	$31,000	$48,000	$95,000
Difference from No Action				
MO1 (Conventional Least-Cost)	$82	$320	$500	$980
MO1 (Zero-Carbon)	-$130	-$510	-$780	-$1,500
MO2	-$270	-$1,100	-$1,700	-$3,300
MO3 (Conventional Least-Cost)	$900	$3,600	$5,500	$11,000
MO3 (Zero-Carbon)	$310	$1,200	$1,900	$3,700
MO4 (Conventional Least-Cost)	$750	$3,000	$4,600	$9,000
MO4 (Zero-Carbon)	$43	$170	$250	$500
Preferred Alternative	$140	$550	$850	$1,700

Note: Values for all action alternatives are relative to No Action, they represent the difference in the total discounted SCC estimates in 2019 USD. The values are rounded to two significant digits.

Table 3-3. Annualized SCC Estimates for Each Alternative and Discount Rate, Millions of 2019 US Dollars (2022-2041)

	Total Annualized SCC Estimate, Million 2019 US Dollars			
Alternative (Resource Replacement Scenario)	**Present Value 5% Average**	**Present Value 3% Average**	**Present Value 2.5% Average**	**Present Value 3% 95th**
No Action	$600	$2,000	$3,000	$6,200
Difference from No Action				
MO1 (Conventional Least-Cost)	$6.2	$21	$31	$64
MO1 (Zero-Carbon)	-$9.8	-$33	-$49	-$100
MO2	-$21	-$71	-$100	-$210
MO3 (Conventional Least-Cost)	$69	$230	$340	$710
MO3 (Zero-Carbon)	$24	$80	$120	$240
MO4 (Conventional Least-Cost)	$58	$190	$290	$590
MO4 (Zero-Carbon)	$3.3	$11	$16	$33
Preferred Alternative	$11	$36	$53	$110

Note: Values for all action alternatives are relative to No Action, they represent the annualized estimates in 2019 USD. The values are rounded to two significant digits.

CHAPTER 4 - REGIONAL HAZE AND WIND SPEED DATA

EIS Section 3.8.2.1 discusses EPA permitting and regulatory requirements related to air quality and criteria air pollutants. The 1999 Regional Haze Rule call for states to establish goals for improving visibility in national parks and wilderness areas and to develop long-term strategies for reducing emissions of air pollutants that cause visibility impairment (EPA 2019a). The rule provides protection to 156 “Class I Areas” across the country (EPA 2019a). These Class I areas are defined as having special natural, scenic, recreational, or historic value in a national or regional context. The management and improvement of visibility conditions is organized by regional planning organizations, with the Western Regional Air Partnership (WRAP) managing the Western United States. In the Pacific Northwest there are 37 Class I Areas. These include large national parks, including Glacier National Park in Montana (covering over 1 million acres) and Mount Rainier. In addition, the Columbia River Gorge Scenic Area is within the Columbia River Basin. The Gorge is not a Class I Area but has protection as a National Scenic Area and, as such, receives protection along with Class I Areas (OR DEQ 2020).

Haze may be formed by natural air pollutants or air pollutant emissions from anthropogenic sources. Fugitive dust and other small airborne particles generate haze as well as a variety of other particles react with sunlight in the atmosphere to form haze and impair visibility and air quality related values (AQVRs). AQRVs include visibility as well as any other resource that could be adversely affected by changes in air quality including but not limited to cultural, biological or physical resources identified by a Federal land manager in a Class 1 Area. Air pollutant emissions from major sources, such as power plants, may contribute to haze even if they are operating within the requirements of their Prevention of Significant Deterioration (PSD) permits. Near a source of air pollutants, such as a city or power plant, haze is typically a mixture of aerosols (a dispersion of microscopic solid or liquid particles in gaseous media such as smoke or fog) and gases, such as sulfur dioxides and nitrogen dioxides from fossil fuel power plants (EPA 1999).

The EPA and other state agencies that regulate these areas examine haze in terms of a “haze-index,” based on the unit of measurement “deciview.” The higher the deciview, the lower the visibility. Generally, visibility at Class I Areas in the Pacific Northwest has improved since 2000, however some monitors have identified increasing index scores (i.e., worsening visibility) in recent years (OR DEQ 2020). As multiple factors contribute to haze, including wildfires, variations may occur year to year.

Table 4-1 presents the number of Class I areas and the number acres they cover by state. Figure 4-1 presents a map of Class I Areas in the Pacific Northwest and the CRSO Regions.

Table 4-1. Class I Areas in the Pacific Northwest by State

State	Number of Class 1 Areas	Total Acres
Idaho	5	1,363,684
Montana	12	3,040,568
Oregon	12	1,111,372
Washington	8	3,019,420
Total/1	**34**	**8,535,044**

1/ The total number of Class 1 Areas does not sum because some Class 1 Areas cross state borders, for example Yellowstone National Park is Montana, Wyoming and a small part of Idaho. For Class 1 Areas in multiple states, the area is included in the state specific count but not counted multiple times in the total.

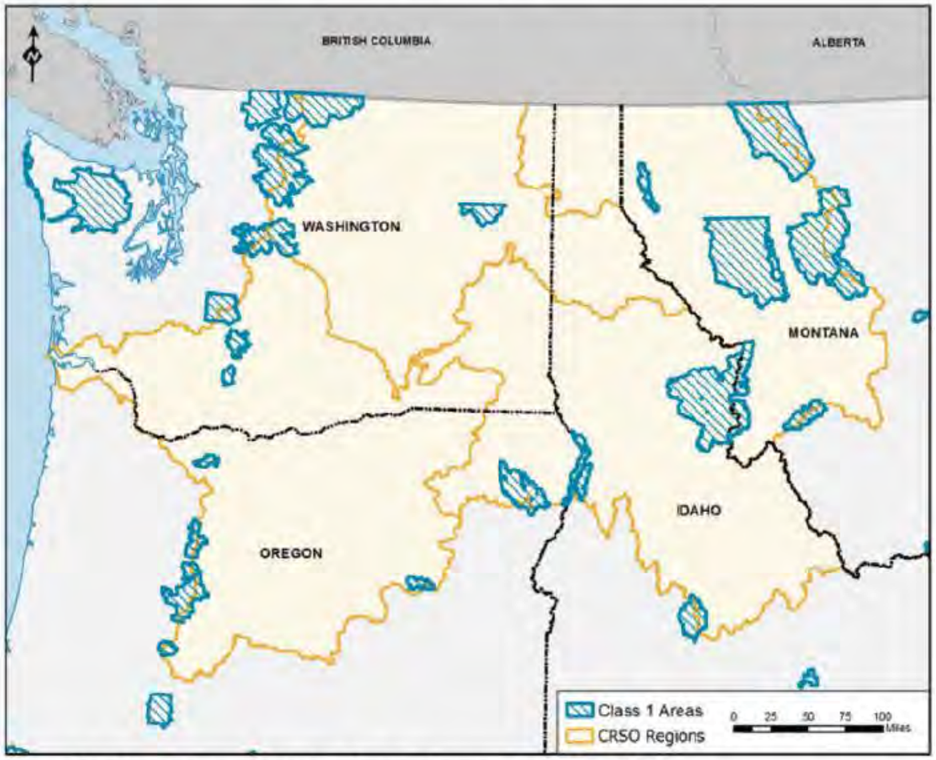

Figure 4-1. Class 1 Areas in the Pacific Northwest and CRSO Regions

The Air Quality analysis also considers regional wind speeds at a variety of meteorological monitors in the Pacific Northwest to evaluate potential windblown fugitive dust effects. This analysis considers the EPA guidance on high-wind events (25 miles per hour) as well as the fugitive dust guidance from the AP-42 emissions factors (potential for wind erosion occurring at 12 miles per hour) to assess the potential for fugitive dust effects due to changes in water elevation as well as other sources of potential dust (e.g., unpaved roads or construction activities).

Table 4-2 presents the list of relevant monitoring stations. Stations were selected based on proximity to CRSO projects and the availability of data. The data on wind speed is from the Midwest Regional climate data portal. The data presented in Tables 4-3 and 4-4 reflect multiple years of wind data from the Midwestern Regional Climate Center cli-MATE program. All records missing either a speed or direction record were excluded. Table 4-3 presents median and mean wind speeds, as well as the 5th and 95th percentiles for the relevant monitoring stations, as well as the percentage of time for “calm” hours (below 1.3 mph), wind speeds above the AP-42 threshold of 12 mph, and wind speeds above the high-wind event threshold of 25 mph.

Table 4-4 presents the monthly breakdown by station. Generally speaking, the results indicate relatively low median and average wind speeds across the region, below both the high-wind event threshold and the lower AP-42 threshold. All the stations do experience occasional speeds above 25 miles per hour; however, occurrences are infrequent, accounting for less than 1 percent of the recorded hourly data analyzed with the exception of at the Dalles. Walla Walla, the Dalles, and Pullman Moscow experience the highest percentage of hours with speeds above 12 miles per hour indicating a higher likelihood for the potential of wind erosion and suspension of sediment at sites near those monitors.

Table 4-2. Meteorological Monitoring Stations Analyzed

Station Name	County and State	Closest CRSO Project(s) and Relative Direction
Dalles	Klickitat, WA	Dalles and John Day
Hermiston	Umatilla, OR	McNary and Ice Harbor
Lewiston	Nez Perce, ID	SE of Lower Granite and W of Dworshak
Kalispell	Flathead, MT	East of Libby and West of Hungry Horse
Pasco Tri-Cities	Franklin, WA	NW of Ice Harbor and N of McNary
Pullman Moscow	Whitman, WA	NE Lower Granite and NW of Dworshak
Lowell/Three Rivers	Idaho, ID	SE of Dworshak
Walla Walla	Walla Walla, WA	Lower Snake

Table 4-3. Mean, Median, 5th and 9th Percentile Wind Speeds for Regional Monitors, Miles per Hour

	Monitoring Station Location							
Percentile	Walla Walla	Dalles	Hermiston	Lewiston	Tri-Cities	Pullman Moscow	Lowell/ Three Rivers	Kalispell
5th	0	0	0	0	0	0	0	0
Median	7	6	6	5	6	7	0	5
95th	17	21	18	15	17	18	6	15

Percentile	Monitoring Station Location							
	Walla Walla	Dalles	Hermiston	Lewiston	Tri-Cities	Pullman Moscow	Lowell/ Three Rivers	Kalispell
Calm Periods (% of all records below 1.3 mph)	12%	27%	18%	25%	24%	25%	69%	38%
Above 12 mph	19%	29%	18%	9%	15%	23%	0.16%	12%
Above 25 mph	0.80%	1.6%	0.86%	0.42%	0.92%	0.81%	0%	0.31%
Mean Wind Speed (excluding calm periods)	9.0	10.9	8.8	7.3	8.5	10.0	4.4	8.1
Maximum Wind Speed	48	40	41	47	47	49	23	44

Table 4-4. Monthly Median, 5th and 9th Percentile Wind Speeds for Regional Monitors, Miles per Hour

Station	Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Walla Walla	5th	0	0	0	0	0	0	0	0	0	0	0	0
Walla Walla	Median	6	7	8	8	8	8	8	8	7	7	6	6
Walla Walla	95th	19	18	20	18	16	16	15	15	15	16	20	21
Dalles	5th	0	0	0	0	0	0	0	0	0	0	0	0
Dalles	Median	3	3	6	9	10	13	14	11	7	5	3	3
Dalles	95th	14	17	21	22	23	24	23	23	21	18	15	14
Hermiston	5th	0	0	0	0	0	0	0	0	0	0	0	0
Hermiston	Median	5	5	7	8	8	8	8	7	6	5	5	5
Hermiston	95th	16	18	21	21	19	20	18	17	16	16	17	16
Lewiston	5th	0	0	0	0	0	0	0	0	0	0	0	0
Lewiston	Median	5	5	6	6	6	6	5	5	5	5	5	5
Lewiston	95th	17	15	16	15	14	14	14	13	13	13	16	16
Tri-Cities	5th	3	3	3	3	3	3	3	3	3	3	3	3
Tri-Cities	Median	6	7	8	8	8	8	7	7	6	6	6	6
Tri-Cities	95th	21	21	22	21	18	18	16	16	16	18	20	18
Pullman Moscow	5th	0	0	0	0	0	0	0	0	0	0	0	0
Pullman Moscow	Median	9	8	9	8	7	6	5	5	6	7	9	9
Pullman Moscow	95th	21	20	20.85	20	17	16	15	15	16	17	20	20
Lowell/Three Rivers	5th	0	0	0	0	0	0	0	0	0	0	0	0
Lowell/ Three Rivers	Median	0	0	0	0	0	0	0	0	0	0	0	0
Lowell/ Three Rivers	95th	6	6	6	6	7	7	6	5	5	5	6	6
Kalispell	5th	0	0	0	0	0	0	0	0	0	0	0	0
Kalispell	Median	0	3	6	7	6	6	5	5	3	3	3	0
Kalispell	95th	15	15	16	17	16	14	15	15	14	14	15	15

CHAPTER 5 - METHANE EVALUATION COLUMBIA RIVER BASIN

5.1 METHANE EVALUATION COLUMBIA RIVER BASIN

5.1.1 Introduction

The greenhouse gas (GHG) methane (CH_4) produced from anthropogenic activities accounts for roughly 40% of global climate forcing (Stocker et al. 2013). An estimate of global methane sources shows that roughly 71% of methane emissions stem from anthropogenic activities, namely the burning of fossil fuels (Figure 5-1). Inland water bodies, including freshwater lakes and manmade reservoirs, can be net emitters of CH_4 and the less potent GHG carbon dioxide (CO_2), particularly in tropical and mid-latitude locations (Demarty and Bastien 2011). Hydroelectric dams can prevent the downstream transport of organic and inorganic carbon (C) as the riverine system conditions are converted into lacustrine systems (Wetzel 2001). It has recently been suggested that the drawdown of reservoirs behind dams is perhaps an important anthropogenic source of GHG emissions to the atmosphere, and thus should be included in global budget estimates (Deemer et al. 2016). A recent synopsis of GHG research studies has concluded that worldwide CH_4 emissions are responsible for 80% of the radiative forcing from reservoir surfaces over a 100-year span and 90% over a 20-year span (Deemer et al. 2016). CH_4 is 25 times more potent than CO_2 at trapping heat per 100 years (Stocker et al. 2013). This report will therefore focus on CH_4 emissions because it is a much more potent GHG than CO_2, however it is important to not discount the production of CO_2 via oxidation, described below.

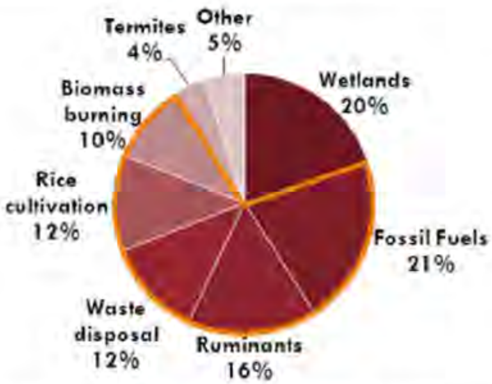

Figure 5-1. Estimates of global sources of methane with anthropogenic sources outlined in orange (Wuebbles and Hayhoe 2002).

To more fully comprehend the environmental conditions that affect CH_4 production, it is helpful to have a fundamental understanding of the underlying chemistry, namely reduction-oxidation (redox) potential and the ensuing reactions. Oxidation involves the loss of electrons from a species and reduction involves the gain of electrons. Oxidation always occurs in conjunction

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with reduction because the net exchange of electrons must balance - the number of electrons lost by one species must equal the number gained by the other, therefore, in any redox reaction one species is always oxidized and another is reduced.

A general redox reaction is as follows:

Oxidized species + e^- + H^+ ↔ reduced species

Redox potential is the tendency of an environment to receive or supply electrons. A solution with a higher (more positive) reduction potential than the new species will have a tendency to gain electrons from the new species (i.e., to be reduced by oxidizing the new species) and a solution with a lower (more negative) reduction potential will have a tendency to lose electrons to the new species (i.e., to be oxidized by reducing the new species). Figure 5-2 shows standard reduction potentials.

An oxic environment has high redox potential because O_2 is available as an electron acceptor. For example, Fe (iron) oxidizes to rust in the presence of O_2 because the iron shares its electrons with the O_2:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

By contrast, an anoxic environment has low redox potential because of the relative absence of O_2.

The net reaction for aerobic oxidation of organic matter (OM) is:

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

In this case, oxygen is the electron acceptor; the reduction half-reaction is:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

CH_4 is produced primarily under anoxic conditions from the degradation of organic matter (OM) by microbes within lake or reservoir sediments. This process, called methanogenesis, is a form of anaerobic respiration and uses C in the form of CO_2 or acetic acid instead of oxygen, as demonstrated in the following reactions:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$

Standard Reduction Potentials in Aqueous Solution at 25⁰C

Stronger oxidizing agent | Weaker reducing agent

Reduction Half-Reaction		$E°$ (V)
$F_2(g) + 2\ e^-$	$\rightarrow 2\ F^-(aq)$	+2.87
$H_2O_2(aq) + 2\ H_3O^+(aq) + 2\ e^-$	$\rightarrow 4\ H_2O(\ell)$	+1.77
$PbO_2(s) + SO_4^{2-}(aq) + 4\ H_3O^+(aq) + 2\ e^-$	$\rightarrow PbSO_4(s) + 6\ H_2O(\ell)$	+1.685
$MnO_4^-(aq) + 8\ H_3O^+(aq) + 5\ e^-$	$\rightarrow Mn^{2+}(aq) + 12\ H_2O(\ell)$	+1.52
$Au^{3+}(aq) + 3\ e^-$	$\rightarrow Au(s)$	+1.50
$Cl_2(g) + 2\ e^-$	$\rightarrow 2\ Cl^-(aq)$	+1.360
$Cr_2O_7^{2-}(aq) + 14\ H_3O^+(aq) + 6\ e^-$	$\rightarrow 2\ Cr^{3+}(aq) + 21\ H_2O(\ell)$	+1.33
$O_2(g) + 4\ H_3O^+(aq) + 4\ e^-$	$\rightarrow 6\ H_2O(\ell)$	+1.229
$Br_2(\ell) + 2\ e^-$	$\rightarrow 2\ Br^-(aq)$	+1.08
$NO_3^-(aq) + 4\ H_3O^+(aq) + 3\ e^-$	$\rightarrow NO(g) + 6\ H_2O(\ell)$	+0.96
$OCl^-(aq) + H_2O(\ell) + 2\ e^-$	$\rightarrow Cl^-(aq) + 2\ OH^-(aq)$	+0.89
$Hg^{2+}(aq) + 2\ e^-$	$\rightarrow Hg(\ell)$	+0.855
$Ag^+(aq) + e^-$	$\rightarrow Ag(s)$	+0.80
$Hg_2^{2+}(aq) + 2\ e^-$	$\rightarrow 2\ Hg(\ell)$	+0.789
$Fe^{3+}(aq) + e^-$	$\rightarrow Fe^{2+}(aq)$	+0.771
$I_2(s) + 2\ e^-$	$\rightarrow 2\ I^-(aq)$	+0.535
$O_2(g) + 2\ H_2O(\ell) + 4\ e^-$	$\rightarrow 4\ OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2\ e^-$	$\rightarrow Cu(s)$	+0.337
$Sn^{4+}(aq) + 2\ e^-$	$\rightarrow Sn^{2+}(aq)$	+0.15
$2\ H_3O^+(aq) + 2\ e^-$	$\rightarrow H_2(g) + 2\ H_2O(\ell)$	0.00
$Sn^{2+}(aq) + 2\ e^-$	$\rightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2\ e^-$	$\rightarrow Ni(s)$	−0.25
$V^{3+}(aq) + e^-$	$\rightarrow V^{2+}(aq)$	−0.255
$PbSO_4(s) + 2\ e^-$	$\rightarrow Pb(s) + SO_4^{2-}(aq)$	−0.356
$Cd^{2+}(aq) + 2\ e^-$	$\rightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2\ e^-$	$\rightarrow Fe(s)$	−0.44
$Zn^{2+}(aq) + 2\ e^-$	$\rightarrow Zn(s)$	−0.763
$2\ H_2O(\ell) + 2\ e^-$	$\rightarrow H_2(g) + 2\ OH^-(aq)$	−0.8277
$Al^{3+}(aq) + 3\ e^-$	$\rightarrow Al(s)$	−1.66
$Mg^{2+}(aq) + 2\ e^-$	$\rightarrow Mg(s)$	−2.37
$Na^+(aq) + e^-$	$\rightarrow Na(s)$	−2.714
$K^+(aq) + e^-$	$\rightarrow K(s)$	−2.925
$Li^+(aq) + e^-$	$\rightarrow Li(s)$	−3.045

Weaker oxidizing agent | Stronger reducing agent

Figure 5-2. Standard reduction potentials at 25°C, where E° (v) = electrode potential at standard state: solutes concentration = 1 mol/L; gases pressure = 1 atm (Wilbraham et al. 2008).

However, a sequence of redox reactions must occur before methanogenesis is possible. Each of these half-reactions involves oxidants, or electron acceptors, which exhibit low redox potentials. In aquatic environments, OM is oxidized as follows, and as summarized in Table 5-1 below, which also denotes the standard reduction potentials of each half-reaction (Schlesinger and Bernhardt 2013):

1) O_2 reduction (aerobic oxidation): availability of O_2 in water is limited by the amount of organic matter present any by how much circulation there is in the water column.
2) NO_3 reduction (denitrification): NO_3 availability typically quickly runs out.
3) Mn reduction and Fe reduction: dependent on soil composition.

4) SO_4 reduction: usually minor in fresh water and more important in marine environments
5) CO_2 reduction (methanogenesis): usually highly available and thus very important in freshwater systems, particularly those rich in OM.

Table 5-1. Sequence of Organic Matter Oxidation Preceding Methanogenesis in Aquatic Environments.

Organic Matter Oxidation Reactions (Reducing Half-Reactions)		
Sequence	**Reaction**	**E° (v)**
1. Reduction of O_2	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+0.812
2. Reduction of NO_3	$2NO_3^- + 6H^+ + 6e^- \rightarrow N_2 + 3H_2O$	+0.747
3. Reduction of Mn^{4+}	$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	+0.526
4. Reduction of Fe^{3+}	$Fe(OH)_3 + 3H^+ + e^- \rightarrow Fe^{2+} + 3H_2O$	-0.047
5. Reduction of SO_4^{2-}	$SO_4^{2}- + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O$	-0.221
6. Reduction of CO_2	$CO_2 + 8H^+ + 8e^- \rightarrow CH_4 + 2H_2O$ -or- $CH_3COOH \rightarrow CH_4 + CO_2$	-0.244

CH_4 produced by microbial anaerobic respiration in benthic substrates can be converted to CO_2 in the overlying water column, as represented by the following reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

CH_4 can undergo reverse methanogenesis within anoxic freshwater or low salinity estuarine sediments, whereby it is anaerobically oxidized via coupling to nitrate and nitrite reduction, thus reducing the emission of CH_4 (Tremblay et al. 2005). This results in a CH_4 sink instead of source, although CO_2 is still produced. However, as stated previously CH_4 is the more potent GHG as it is 25 times better at trapping heat than CO_2.

Anaerobic oxidation occurs via the following reactions:

$$CH_4 + 4NO_3^- \rightarrow CO_2 + 4NO_2^- + 2H_2O$$

$$3CH_4 + 8NO_2^- + 8H^+ \rightarrow 3CO_2 + 4N_2 + 10H_2O$$

The decomposition of organic C by microbes in reservoirs can be a significant source of CH_4 to the atmosphere, but can range substantially depending on water temperature, reservoir age, sediment deposition rates, redox conditions, and the quantity and quality of C delivered to the sediments (Barros et al. 2011; Nguyen et al. 2010; Sobek et al. 2012; West et al. 2012; Falter 2017). Generally, systems that are more nutrient-enriched exhibit higher rates of CH_4 emission, and autochthonous C has been correlated to higher rates of methanogenesis than allochthonous C (Bastviken et al. 2008; West et al. 2012). A key characteristic of reservoirs that emit high levels of CH_4 is the presence of large amounts of flooded OM, particularly under anoxic conditions, and CH_4 production is further increased from continued high inputs of OM and the nutrients nitrogen and phosphorus (Nguyen et al. 2010; Sobek et al. 2012; Harrison et al. 2016).

As mentioned previously, methanogenesis depends on the availability of OM, in the form of either particulate organic matter (POM) and/or dissolved organic matter (DOM), which is then reduced under anaerobic conditions. Recent studies have associated CH_4 production with shallow depth systems, shallow (littoral) areas of reservoir systems, marshlands, embayments (coves), and stream deltas, which provide concentration points for OM and can positively influence methanogenesis (Bastviken et al. 2004; Demarty and Bastien 2011; West et al. 2012; Arntzen et al. 2013; Deemer et al. 2016; Falter 2017). These conditions, particular to each reservoir, result in extensive variability in CH_4 production both between and even within reservoirs. In run-of-river reservoirs, as on the mid-Columbia River, a littoral aquatic macrophyte (AM) bed may have CH_4 production rates per unit area 3 or 4 orders of magnitude greater than in the adjacent deep-water column (Falter 2017). The following table shows principal controllers of CH_4 emissions for reservoirs in general, demonstrating the extensive variables that drive CH_4 emissions (Table 5-2).

Table 5-2. Controllers of CH_4 Emissions to Atmosphere from Reservoirs (Falter 2017).

Controllers of CH_4 Production and Release[1/]	Relationship to CH_4 Production and Release
Reservoir age	CH_4 production sharply drops after 3 years; release of soluble OM and nutrients from flooded terrestrial vegetation tails out to near zero after 30-50 years
Reservoir surface area[b] (size)	CH_4 production (mg CH_4 m^{-2} day^{-1}) higher in small lakes/reservoirs; Dramatically increased in water bodies less than 1 – 2 km^2 (0.3 – 0.7 mi^2).
Lake length	Greater length provides greater shoreline length and potential for littoral development.
Shoreline development (SDL): compares shoreline length to a same area circle	Higher SDL related to potentially higher littoral thus potential sites of CH_4 production and release
Lake orientation	Wind fetch strongly correlated to mixing, thus sediment entrainment and gas diffusion at S/W and A/W interfaces
Hydraulic Retention Time (HRT)	CH_4 production directly correlated w/ HRT; Low HRT water bodies have very low CH_4 emission rates in pelagic waters.
Lake level fluctuation – Load following	CH_4 release from shallow sediments positively correlated with fluctuation frequency magnitude, and rapidity of water surface change.
Year-round top-to-bottom water circulation	Precludes development of anoxia, hence CH_4 production in water column and surficial sediments year-round; anaerobic conditions with accompanying methanogenesis may occur in deeper sediments. Thicker sediment deposits may store more CH_4, subject to release at S/W interface with sufficient currents.

[b] Per Holgerson and Raymond (2016): Small lakes have a high perimeter-to-surface-area ratio and accumulate a higher relative amount of terrestrial carbon. Small lakes also tend to be shallow, which means their terrestrial carbon loads are highly concentrated compared to larger lakes. Lastly, gases produced at the bottom of these lakes are able to surface more so than in larger lakes, due to greater water mixing and shallower waters.

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Controllers of CH_4 Production and Release[1/]	Relationship to CH_4 Production and Release
Winter ice cover	Winter ice cover in a water body can provide a months-long seal of the A/W interface leading to lower under-ice oxygen levels and increased CH_4 accumulation both in the water column and sediments due to anoxic conditions. Large volumes of CH_4 releases can then occur at Spring overturn.
Vertical water stratification	Stratification permits vertical layering and isolation from atmosphere of deeper areas of water column and sediments. Anoxia is enhanced with subsequent CH_4 production.
Near-bottom velocity	CH_4 production in, and release from sediments at S/W interface negatively correlated with near-bottom velocity.
Fine sediment accumulation	CH_4 production is inversely correlated with sediment particle size, i.e., finer sediments can have higher rates of methanogenesis.
Littoral fine, organic-rich sediment	Strongly correlated with near-shore band of OM accumulation, potential CH_4 production, and AM, then release via either: 1) direct diffusion to water [least important], ebullition; or 2) the AM pathway to water. Relative areal coverage determines total CH_4 release of the total reservoir.
Organic content of watershed soils	Aquatic CH_4 production is positively correlated with allochthonous (loading from terrestrial sources) OM inputs to reservoir.
Organic content and nutrients of lake sediments	High CH_4 production is correlated with OM and nutrients of sediments. Drowned timber and terrestrial vegetation extremely important drivers of methanogenesis in early life of reservoir.
Littoral sediment development	Littoral fine sediments tend to be rich in OM and nutrients, correlating with methanogenesis and CH_4 release to water via diffusion, ebullition, or AM piping, yielding the highest rates of CH_4 production in a reservoir per unit area.
Nutrient loading from watershed to reservoirs	CH_4 production increases with non-point watershed nutrient supply (irrigated agriculture, forest practices, and urban runoff).
Nutrient loading to reservoirs	Higher nutrient loading usually leads to higher lake productivity, organic sediments, and CH_4 production.
In-Reservoir (autochthonous) production	Higher autotrophic production provides more OM to sediments for anaerobic decomposition in sediment, thus higher CH_4 production. Autotrophic OM production from within the water body is more efficient at CH_4 production.
Water temperature	Higher water temperatures correlate very strongly with higher CH_4 production
Water transparency	Clearer waters indicate lower plankton but higher potential littoral AM production; balance of resulting OM accrual is dependent on physical characteristics, e.g., steep shorelines limit littoral area, greatly reducing CH_4 production rates.
Rooted aquatic macrophyte (AM) development	Shore bands of AM reduce water velocity which forms, traps, and builds OM- and nutrient-rich benthic sediments. By reducing velocity in thick beds, deeper anoxic sediments conducive to methanogenesis develop.
CH_4 Ebullition to surface	Generally a large factor in CH_4 release to atmosphere in littoral waters < 3 m for several reasons: 1) drawdown-enhanced release of CH_4 from sediments occurs mostly in the drawdown band; 2) OM deposits form there from settling in quiescent water along with high OM production from ABA and AM; 3) AM release bubbles in the shallow littoral ensuring that more CH_4 reaches the surface; and 4) AM piping of gaseous CH_4 to the A/W. In deeper water columns, most of CH_4 bubbles are absorbed and/or oxidized to CO_2 before reaching the A/W interface.
ABA = attached benthic algae	AM = aquatic macrophytes

Controllers of CH_4 Production and Release[1/]	Relationship to CH_4 Production and Release
S/W = sediment/water interface	A/W = air/water interface
OM = organic matter	WS = Watershed of reservoir

1/ Bold type = major forcing factor

CH_4 can be released into the water column via diffusion, bubbling (ebullition), or by plant-mediated transport in the presence of emergent vegetation (Bastviken et al. 2004; Harrison et al. 2016). CH_4 can also be emitted from reservoirs during drawdown periods via degassing at turbines and spillways (Deemer et al. 2016). The graphic below depicts CO_2 and CH_4 pathways in a freshwater reservoir with an anoxic stratum (Figure 5-3):

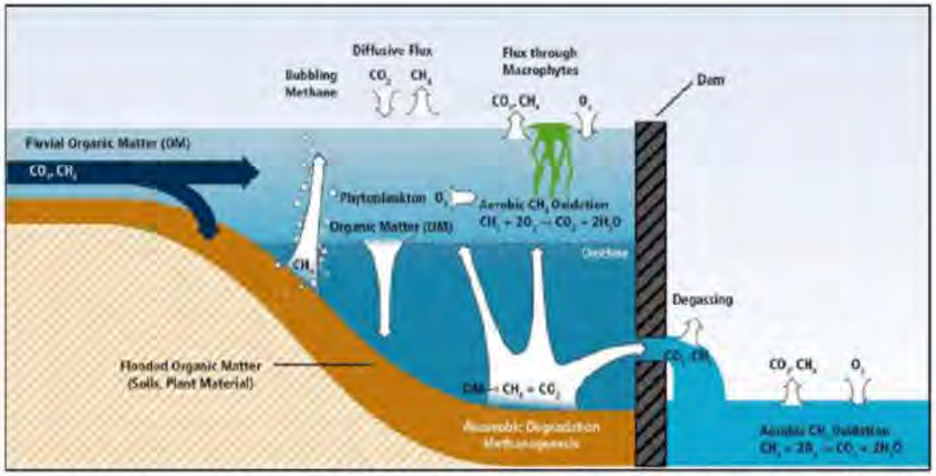

Figure 5-3. Pathways of CO_2 and CH_4 in a freshwater reservoir with an anoxic stratum (Kumar et al. 2012).

Ebullition occurs when CH_4 gas is formed when the partial pressure of all dissolved gases in the pore-water exceeds the ambient pressure and surface tension of the overlying water (Boudreau et al. 2005; Boudreau 2012). Bubbles then develop and enlarge under continued production of CH_4, causing fissures or spaces to form inside the sediment (Boudreau 2012; Johnson et al. 2002). As CH_4 production within the sediment continues, the gas bubbles can grow, combine with other bubbles, and travel upwards through the sediment until they are released into the water column and ultimately into the atmosphere. Figure 5-4 depicts the general pathway of CH_4 production in lakes and reservoirs in forming CH_4 bubbles. Reservoir drawdowns decrease the hydrostatic pressure upon the sediment, which can enable bubbles to move more easily and quickly upward through the sediment, allowing CH_4 ebullition rates to temporarily increase (Maeck et al. 2014). Conversely, in areas where the water is deeper and less disturbed, less CH_4

ebullition occurs because most of CH_4 bubbles are absorbed and/or oxidized to CO_2 before reaching the air. (Beaulieu et al. 2016, Falter 2017).

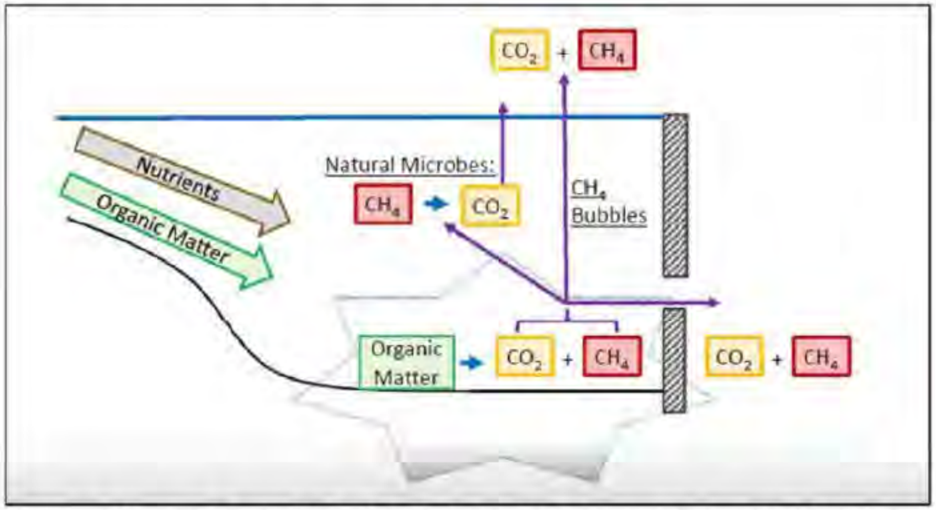

Figure 5-4. Diagram of anaerobic GHG production in lake sediments and resulting formation of CH_4 bubbles within the water column (Northwest Power and Conservation Council 2017).

5.1.2 Methane (CH_4) Emissions Evaluation Framework

The purpose of this report is to provide a preliminary assessment of the potential impacts affecting CH_4 emissions from hydroelectric dam operations within the Columbia River basin. While little research currently exists for this particular geographical area, this is a burgeoning topic of interest and ongoing research initiatives are hoping to capture more information regarding CH_4 emissions from hydroelectric projects in the Pacific Northwest to better inform regional decision makers and dam owner/operators on potential impacts resulting from hydropower operations. In light of the limited data available and time and resource constraints, this report relies on a collection of representative and/or relevant research findings within the field of GHG emission analyses, and as mentioned previously will focus primarily on CH_4 emissions as this is the more potent GHG compared to CO_2.

5.2 LEVEL 1 EVALUATION

5.2.1 River Basin Description

This assessment of GHG emissions encompasses the entire Columbia River basin located south of the U.S.-Canada border, including the mainstem Columbia River and its tributaries, such as the Kootenai and Snake Rivers, located within the Pacific Northwest region (parts of Montana, Idaho, Washington and Oregon). The headwaters of the Columbia and Kootenai Rivers are excluded as these reside in Canada. Figure 2-1 shows the basin and major hydropower projects.

The Columbia River is the fourth largest river in North America as measured by average annual flow and the single largest freshwater source on the west coast. It originates in British Columbia and flows 1,954 km (1,214 mi) through Canada and the United States to the Pacific Ocean. Although only 15 percent of the river's basin lies in Canada, 38 percent of the average annual flow volume originates in Canada. In addition, up to 50 percent of the peak flood waters in the lower Columbia River between Oregon and Washington originate from snowmelt in the Canadian portion of the Columbia River basin. Seasonal unregulated discharge ranges widely from 36,000 cfs to 1,240,000 cfs with an annual mean of 275,000 cfs. The estuarine portion of this immense river, as defined by salt intrusion, ranges from 20 km to 50 km (12 mi to 31 mi) long and the river is tidally influenced all the way upstream to the first hydroelectric project, Bonneville Dam, located 235 km (146 mi) from the estuary mouth (Figure 5-5). Average water depth is 7 m (23 ft), with narrow channels that are dredged to 20–30 m (65–98 ft) deep (Pfeiffer-Herbert et al. 2015).

Within the basin over 60 large hydroelectric projects and their reservoirs are owned and operated by many different entities for multiple purposes (Figure 5-5). The hydroelectric projects located in Eastern Washington, the mid-Columbia mainstem reach, on the Kootenai and Flathead Rivers in Montana, and on the Snake River in Idaho are all within xeric terrain. Many of these reservoirs, along with those located in hydric Western Oregon, have agricultural inputs and are generally not nutrient-limited (Arntzen et al. 2013). However, compared to other U.S. regions, most Pacific Northwest rivers are colder, swifter, and more oxygenated, and thus generally have better water quality with modest levels of nutrient inflow impacts (Arntzen et al. 2013; Falter 2017). Nonetheless, some parts of the basin have substantial drainage areas with significant nutrient loading from agricultural uses, urban/suburban runoff, and treated wastewater, boosting productivity particularly in the mid- and lower-Columbia segments. Conversely, some sections of the basin host ultra-oligotrophic reservoirs (Falter 2017). Overall, most of the reservoirs in the basin are generally oxic although some are known to be anoxic seasonally, such as the Brownlee complex on the Snake River (Arntzen et al. 2013; Nürnberg 2004); anoxic conditions are required for CH_4 production, as noted earlier.

Many Pacific Northwest hydropower complexes employ spring spill operations to aid migratory juvenile fish in accordance with the operative biological opinions and the Clean Water Act. Fish spill operations are conducted at the four lower Snake River and four lower Columbia River dams for the benefit of juvenile fish passage. Fish passage spill is also conducted at Dworshak Dam to provide additional water for flow augmentation and to moderate temperature in the lower Snake River. Such spill operations have the potential to enhance CH_4 outgassing in the tailrace.

Figure 5-5. Columbia River basin showing major federal hydroelectric projects.

Specifically, high CH_4 emission rates may occur if gas levels increase within slow moving river reaches and then is rapidly released downstream at turbulent sites (Lilley et al. 1996; Nürnberg 2004). Drafting reservoirs can also lead to ebullition of CH_4 because the hydrostatic pressure on littoral sediments becomes reduced, enabling CH_4 bubbling directly into the water column instead of undergoing oxidation (Falter 2017). Fluctuating reservoir levels can also contribute to releases of CH_4 from the littoral zone, although most of the drawdown zone typically encompasses the surface waters which do not contain adequate OM and fine sediments necessary for CH_4 production (Falter 2017). This is especially true for projects located in Eastern Washington and Western Idaho (i.e. the Snake River Complex and Dworshak dam).

5.2.2 Summary of Existing Data

While very little data is available for Columbia River hydropower project reservoirs, recent findings show that CH_4 emissions from hydroelectric reservoirs in the basin are relatively low compared to other hydroelectric reservoirs, likely because of the well-oxygenated conditions typically found in the basin, particularly in the mainstem of the river (Kumar et al. 2012; Falter

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2017). Soumis et al. (2004) found a range of emissions between 3.2 – 9.0 mg CH_4 m^{-2} day^{-1} for F.D. Roosevelt Lake, behind Grand Coulee Dam in the upper portion of the basin. Priest Rapids Reservoir, located on the mid-Columbia reach, was found to have very low surface estimates of CH_4: Falter (2017) reported a mean of 0.004 mg CH_4 m^{-2} day^{-1} from the pelagic zone and Arntzen et al. (2013) reported a mean close to zero. The Lower Monumental Reservoir on the Snake River was also found to have comparable mean flux rates (Arntzen et al. 2013; Falter 2017). By comparison, the free-flowing Hanford reach of the Columbia was found to have a mean surface flux of 0.08 mg CH_4 m^{-2} day^{-1} during the fall (Arntzen et al. 2013). These amounts are quite low compared to a global synthesis, whereby Deemer et al. (2016) calculated a mean range of CH_4 emissions from hydroelectric reservoirs worldwide of 24 – 112 mg CH_4 m^{-2} day^{-1} and a mean of 120 mg CH_4 m^{-2} day^{-1} for all reservoirs worldwide.

Conversely, CH_4 production in the littoral zone of the Priest Rapids Reservoir was found to be much higher, with a mean of 362 mg CH_4 m^{-2} day^{-1} (Falter 2017). This large difference between the two reservoir zones is likely due to underestimating CH_4 flux by current gas diffusion methodologies as it is difficult to accurately quantify and thus extrapolate. The high potential for CH_4 production in littoral zones of a water body that is only moderately productive, like Priest Rapids reservoir, is another factor influencing this measurement (Falter 2017). It is important to note that the high ratio of pelagic:littoral area resulted in relatively low overall reservoir-wide mean CH_4 emissions compared to general estimates for reservoirs on a national scale (Falter 2017).

Given evidence from Falter (2017), littoral areas in the Columbia River Basin are expected to be confined to the mid-Columbia River area, an area in which the CRS project reservoirs do not experience considerable changes in under any of the MOs or the Preferred Alternative. While MO3 would result in breaching the four lower Snake River projects, which would result in the loss of the reservoirs behind these projects, the information provide in Falter (2017) indicates that littoral areas are less likely at these sites.

Chapter 3 of the EIS details some of the characteristics of regions through the CRSO study area, including the mid-Columbia region (Region B) where littoral zones are abundant. For example, Table 5-2 profiles the hydrology of reaches in the region, noting that many of these areas are characterized by flat pools at particular times of year, while Section 3.3 describes sediment supply and transport in the same region. More information about the aquatic vegetation and shoreline development that that contributes to CH_4 production in the littoral zones abundant in the mid-Columbia River, is described in detail in Section 3.6 of the EIS.

The Priest Rapids reservoir has very comparable limnology to the Rock Island and Rocky Reach reservoirs directly upstream (Falter 2017). The data for Priest Rapids can be applied toward these reservoirs, thus it is expected that there are very low CH_4 emissions from pelagic waters and sporadic distribution of moderately high CH_4 emission pockets within the littoral sediment accumulation zones and along aquatic macrophyte beds (Falter 2017). By applying the controllers of CH_4 production and emission described previously in Table 1-2 and within other global research results, pelagic methanogenesis is believed to be very low in the Rock Island

and Rocky Reach reservoirs and exceptionally low in oligotrophic water bodies such as nearby Lake Chelan, whose river flows into the Columbia (Deemer et al. 2016; Falter 2017). Given this, there are likely also amplified areas of CH_4 production near sediment deposition zones (i.e., stream deltas, backwater embayment areas, and nearshore deposition areas of organic sediment deposition) and areas with highly productive aquatic macrophyte beds and attached benthic algae populations. These amplified areas likely have high rates of local methanogenesis and may produce greater emissions of CH_4 within the water column and into the atmosphere (Falter 2017). As noted above, both reservoirs' morphometry and hydrology indicate that these potentially high CH_4 emission rates that are expected to occur within the littoral zones are a small portion of the overall reservoir area, suggesting that the CH_4 emissions per reservoir are likely to be low on the regional scale and extremely low on the national and worldwide scales of CH_4 emissions from hydropower project reservoirs (Falter 2017).

For the lower river section, studies have found higher CH_4 oxidation in the lower Columbia River estuary compared to the mainstem and tributaries because of the prevailing saltwater conditions, which results in a net uptake of riverine CH_4 by the estuarine sediment, creating a CH_4 sink (Lilley et al. 1996; Tremblay et al. 2005). Pfeiffer-Herbert et al. (2015) found that nearly a quarter of the riverine CH_4 supply was consumed by methantrophic bacteria within the Columbia River estuary, greatly reducing the potential for CH_4 emissions. Additionally, the estuary experiences rapid flushing due to the sheer volume of discharge from the Columbia River and also tidal action, which both minimize CH_4 production (Pfeiffer-Herbert et al. 2015).

Degassing of CH_4 at hydroelectric projects' forebays and tailraces from water passing through the turbines or spillways is highly variable between each project and appears to also be dependent on the season (Arntzen et al. 2013). Overall, system concentrations of CH_4 in March across Columbia River hydroelectric projects were lower in the tailrace than in the forebay, indicating that the system was a source, with a mean degassing flux of 3.1×10^{-6} t CH_4 d^{-1} (Arntzen et al. 2013). During September, the system was a sink for CH_4, with a mean degassing flux of -5.6×10^{-4} t CH_4 d^{-1} (Arntzen et al. 2013). This also supports Falter's (2017) findings that Lower Monumental and Priest Rapids were sinks for CH_4 at the hydropower projects' outflows.

Ebullition as measured in littoral embayment zones for the mid-Columbia and Snake River hydropower complexes were high in September (mean concentrations of CH_4 were over 7,000 mg L^{-1}) and were roughly an order of magnitude lower in March (Arntzen et al. 2013). These results are to be expected, as higher CH_4 flux coincides with increased temperatures in the summer (DelSontro et al. 2010). Increased summer temperatures also moderately affect hyporheic flux of CH_4 within sediment pore-water in littoral embayments – the system had mean fluxes of 4.2 mg m^{-2} day^{-1} in March and 8.1 mg m^{-2} day^{-1} in September (Arntzen et al. 2013). CH_4 efflux from ebullition was more pronounced in embayment areas within reservoirs than embayments located in the free-flowing Hanford reach segment of the River, as was CH_4 pore-water flux, although the differences in the sediment pore-water values were minor and remained relatively constant seasonally (Arntzen et al. 2013).

There can be wide variation between projects' estimated CH_4 emissions from ebullition: the mean flux for the embayments of the Lower Monumental reservoir on the Snake River ranged from roughly 10.5 – 533 mg CH_4 m^{-2} day^{-1}, and Priest Rapids reservoir embayments had a range of about 176 – 1039 mg CH_4 m^{-2} day^{-1} (Arntzen et al. 2013). Again, it is difficult to accurately estimate and extrapolate CH_4 ebullition flux for a given area using current gas diffusion methodologies and given the extensive range of small-scale site-specific variables that control CH_4 emissions (Falter 2017).

5.3 RECOMMENDATIONS AND CONCLUSIONS

5.3.1 Methane (CH_4) Emissions Summary

The available data presented in this report on surface fluxes of CH_4 emissions from diffusion for the Columbia River hydroelectric project reservoirs, particularly those located on the mainstem or in more arid terrain, demonstrate that the basin's overall contributions to global CH_4 emissions are very small compared to other studies of comparable systems (Table 5-3), although they can be quite high locally. The Columbia basin reservoirs produce CH_4 in the range of one or two orders of magnitude less than current global estimates of surface emissions from reservoirs, even when only including hydroelectric reservoirs (Table 3-1). As discussed previously, relatively cold water temperatures and OM input coupled with well-oxygenated conditions and low water residence times prevalent throughout the basin contribute to low levels of CH_4 emissions in the region (St. Louis et al. 2000; Barros et al. 2011; Kumar et al. 2012; Arntzen et al. 2013; Falter 2017). The emission values seen thus far for the Columbia River system are quite low; indeed, during the fall the system tends to act as a CH_4 sink (Arntzen et al. 2013; Falter 2017). Slightly higher rates of CH_4 emissions from diffusion have been identified at other reservoir settings in the United States, including both run-of-river projects and lakes (Beaulieu et al. 2016, 2018; Bevelhimer et al. 2016).

Table 5-3. Compiled synopsis of CH_4 emissions from diffusion from recent literature.

Literature Synopsis of CH_4 Emissions from Diffusion		
Surface flux amount	**Sample Site Information**	**Source Cited**
120 mg CH_4 m^{-2} d^{-1}	Global reservoirs (all)	Deemer et al. 2016
1.0×10^{11} g CH_4 y^{-1}	Global temperate reservoirs	Barros et al. 2011
24 – 112 mg CH_4 m^{-2} d^{-1}	Global hydroelectric reservoirs	Deemer et al. 2016
1.5 – 12.0 mg CH_4 m^{-2} d^{-1}	Temperate run-of-river reservoir, Switzerland	DelSontro et al. 2010
3.0 – 11.0 mg CH_4 m^{-2} d^{-1}	Wisconsin recreational reservoirs (flooded peatlands)	St. Louis et al. 2000
3.2 – 9.0 mg CH_4 m^{-2} d^{-1}	F.D. Roosevelt Lake, Columbia River (behind Grand Coulee Dam)	Soumis et al. 2004
4×10^{-3} mg CH_4 m^{-2} d^{-1}	Priest Rapids Reservoir	Falter 2017
0 mg CH_4 m^{-2} d^{-1} (350 g CH_4 y^{-1})	Priest Rapids complex	Arntzen et al. 2013
0 mg CH_4 m^{-2} d^{-1} (-0.5 g CH_4 y^{-1})	Lower Monumental complex, Snake River	Arntzen et al. 2013
0.08 mg CH_4 m^{-2} d^{-1}	Hanford Reach, Columbia River (September)	Arntzen et al. 2013

Literature Synopsis of CH_4 Emissions from Diffusion		
Surface flux amount	**Sample Site Information**	**Source Cited**
0.07–6.18 mg CH_4 m^{-2} h^{-1} in tributary areas 0.03–2.18 mg CH_4 m^{-2} h^{-1} in in open water areas	Harsha Lake, Ohio	Beaulieu et al. 2016
2.0 mg CH_4 m^{-2} h^{-1}	Harsha Lake, Ohio	Beaulieu et al. 2018
251-5151 kg CH_4 day^{-1}	Six hydropower reservoirs in the southeastern United States	Bevelhimer et al. 2016

For contributions of CH_4 emissions to the atmosphere via degassing at hydroelectric projects, Arntzen et al. (2013) found that the tailrace acted as a sink seasonally in the fall with an overall net flux of -4.2×10^{-4} t CH_4 d^{-1}, which supports Falter's (2017) finding that the tailraces of hydroelectric complexes along the mainstem were sinks for CH_4. Soumis et al. (2004) also found low emissions of CH_4 emissions via degassing, with values ranging from 0.003 – 0.815 t CH_4 d^{-1} for hydropower project reservoirs in the upper basin (F. D. Roosevelt) and on the Clearwater River (Dworshak), a tributary to the Snake River.

Table 5-4 describes the flux of CH4 emissions from ebullition recorded across recent studies, again comparing other sites to estimates from select CRSO sites. As previously described, ebullition can account for the most significant source of CH_4 emissions from reservoirs. Arntzen et al. (2013) recorded high and extremely variable efflux of CH_4 via ebullition within littoral embayments, ranging from 10.5 to 533 mg CH_4 m^{-2} d^{-1} within Lower Monumental Dam reservoir embayments (mean flux of 324 mg CH_4 m^{-2} d^{-1}) and ranging from 176 to 1039 mg CH_4 $m^{-2}d^{-1}$ within Priest Rapids Dam reservoir (mean flux of 482 mg CH_4 m^{-2} d^{-1}). Arntzen et al. (2013) were careful to note that their study was not designed to estimate reservoir-wide ebullition emissions; as mentioned previously it is very difficult to accurately estimate and extrapolate CH_4 ebullition flux for an entire reservoir, let alone a complete river system, especially one the size of the Columbia River basin. These areas are characterized by water velocity near zero, abundance of aquatic macrophytes, oxic conditions, and high nutrient inputs, which all contribute to CH_4 production. Related research in the CRSO context by Miller et al. (2017) found that ebullition comprises more than 97 percent of emissions from these two hydropower reservoirs. Combined, these estimates from CRS projects suggest considerable variability across sites.

Unlike the diffusion citations, these CRS projects can produce methane from ebullition at levels more consistent with other temperate reservoirs recently studied. Beaulieu et al. (2016) identify ranges of 0 to 136.1 mg CH4 m^2 h^{-1} in the open-water areas and 0 to 186.1 mg CH_4 m^2 h^{-1} in the tributary-areas of Harsha Lake in Ohio. In a more recent study at the same site, Beaulieu et al. (2018) report rates they characterize as among the highest ever reported at a reservoir (mean of 32.3 mg CH4 m^{-2} h^{-1}), however this site (a lake) is very dissimilar to the reservoirs within the CRSO system. At six hydropower reservoirs in the southeastern United States, ebullition rates ranged considerably from 0 to 3834 kg day^{-1}. In similarly temperate European settings, DelSontro et al. (2010) found ebullition values for a Swiss reservoir to be substantially higher at roughly 1,000 mg CH_4 m^{-2} day^{-1}. For reservoirs in France and Germany, Decloux et al.

(2017) extrapolate their findings to estimate total annual ebullition flux of 2.7±2.3 $MgCH^4$ while Maeck et al. (2013) identify emissions ranges of 0 to 4235 mg m^{-2} d^{-1} across ten sites, respectively. Across studies that measure both types of emissions, CH_4 emissions from ebullition are more significant contributors to total emissions than diffusion.

Table 5-4. Compiled synopsis of CH_4 emissions from ebullition from recent literature.

Literature Synopsis of CH_4 Emissions from Ebullition		
Surface flux amount	**Sample Site Information**	**Source Cited**
324 mg CH_4 m^{-2} d^{-1}	Lower Monumental Dam, Snake River, Washington	Arntzen et al. 2013
482 mg CH_4 m^{-2} d^{-1}	Priest Rapids Dam reservoir, Columbia River, Washington	Arntzen et al. 2013
0–136.1 mg CH_4 m^2 h^{-1} in the open-water areas 0–186.1 mg CH_4 m^2 h^{-1} in the tributary-areas	Harsha Lake, Ohio	Beaulieu et al. 2016
32.3 mg CH_4 $m^{-2}h^{-1}$	Harsha Lake, Ohio	Beaulieu et al. 2018
0-3834 kg CH_4 day^{-1}	Six hydropower reservoirs in the southeastern United States	Bevelhimer et al. 2016
1,000 mg CH_4 m^{-2} day^{-1}	Swiss reservoir	Del Sontro et al. 2010
2.7±2.3 mg CH_4 annually	French reservoir	Descloux et al. 2017
0-4235 mg CH_4 m^{-2} d^{-1}	Ten German reservoirs	Maeck et al. 2013

Reservoir drawdown can influence rates of CH_4 ebullition due to a reduction in the hydrostatic pressure on littoral sediments. The magnitude of effects of fluctuating reservoir levels on CH_4 emissions from the littoral zone and riverine areas depends on specific localized site characteristics (Falter 2017); the projects that are typically drafted more deeply during seasonal operations are located in more arid regions of the basin (i.e. the Snake River Complex and Dworshak dam), and thus are less likely to experience large increases in CH_4 emissions during drawdown periods. For these reservoirs that undergo a wider operating range, the fluctuation of the reservoir levels and the age of the projects prevent sufficient amounts of impounded OM needed for increased CH_4 production. These hydroelectric projects are all at least 40 years old, and several studies have found that GHG production is severely reduced or mirrors emissions from natural lakes after ten years (St. Louis et al 2000; Tremblay et al 2004; IPCC 2006; Barros et al 2011). Arntzen et al. (2013) found hyporheic flux of CH_4 within sediment pore-water in littoral embayments to range from approximately 4 – 8 mg m^{-2} day^{-1}, while DelSontro et al. (2010) found peak flux from sediments to be about 40 mg m^{-2} day^{-1} for a temperate hydropower project reservoir in Switzerland. Despite this seemingly high value, DelSontro et al. (2010) estimated the system-wide sediment flux to be only about 15 mg m^{-2} day^{-1}.

5.3.2 Recommendations

Ideally, more data is required to fully assess and verify contributions of CH_4 emissions via the various pathways from hydroelectric reservoirs within the Columbia River basin. Unfortunately, due to time and resource constraints, a full suite of scientific data collection and analyses is simply not feasible at this time. Data and knowledge gaps imperative to quantifying CH_4

emissions from hydroelectric reservoirs in the Columbia River basin and determining their contribution to the global carbon budget are detailed below.

It is critical to incorporate both short and long-term temporal and spatial variability in research efforts, which can be quite difficult to capture due to resource constraints and logistical feasibility. As discussed previously, the amount of CH_4 emitted varies widely among reservoirs (depending on basin-specific characteristics, reservoir morphology, latitude, and climate), within reservoirs (nearshore vs. water column, sample site proximity to dam and location within the water column), and over time (land use changes, reservoir aging, seasonal and daily biological and physical changes such as precipitation, photosynthesis, methanogenesis, and temperature). In addition, individual dam operation should also be considered; operations vary, depending on energy demand, reservoir level, and runoff/precipitation amounts. Average CH_4 diffusive emission values can vary by an order of magnitude in temperate regions, highlighting the need for comprehensive assessments (IPCC 2006).

Despite the difficulties of such an endeavor, quantifying CH_4 emissions from reservoirs is essential because reservoirs can be of substantial size, e.g., Franklin D. Roosevelt Lake, behind Grand Coulee Dam, is considerable at 125 mi^2 (324 km^2). Furthermore, the extensive total surface area of all reservoirs regionally and globally necessitates studying these systems at larger spatial and temporal scales to capture all of the variability in order to establish realistic estimates of CH_4 contributions to the regional and global carbon budgets.

Arguably the most important aspect towards broadening the knowledge base of mechanisms contributing to CH_4 emissions is to conduct comprehensive assessments of site-specific characteristics for each reservoir, notably climate (wind, precipitation, temperature) and drainage basin characteristics (residence time, OM inputs). Climate affects OM inputs and CH_4 production and oxidation (Nguyen et al. 2010; Barros et al. 2011; Sobek et al. 2012; West et al. 2012; Falter 2017); wind, precipitation and temperature likely affect gas exchange rates at the water-atmosphere interface (Bastviken et al. 2008), and it has also been thoroughly demonstrated that warmer temperatures are associated with greater CH_4 emissions (Barros et al. 2011; Demarty and Bastien 2011; Deemer et al. 2016).

Additionally, since increased GHG emissions is positively correlated with warmer temperatures, there will be an ongoing need to study the impacts of climate change on CH_4 processes within temperate hydroelectric reservoirs (IPCC 2006). The IPCC notes that temperature is the main driver affecting reservoirs as a result of climate change, which impacts oxygenation levels, redox potentials, lake stratification mixing rates, growth of biota, and methanogenesis rates (IPCC 2006). Warming trends are likely to prolong and intensify summer thermal stratification which leads to anoxic conditions aiding increased methanogenesis, leading to increased CH_4 production (IPCC 2006; Barros et al. 2011; Demarty and Bastien 2011; Deemer et al. 2016).

Run-of-river hydroelectric projects are regularly used in densely populated areas with poor water quality to improve oxygen conditions or selectively draft cooler water from deeper within the reservoir (Kumar et al. 2012). This strategy could be useful in mitigating against the effects of increased GHG emissions from global climate change impacts. Building new structures that promote degassing, such as stilling basins or aeration weirs, may also help prevent GHG supersaturation at project tailraces (Kumar et al. 2012). The IPCC (2006) recommends proactive risk management as an adaptive measure to address extreme climate events; as precipitation events become more unpredictable, reservoir operations may become more limited in range, particularly for run-of-river projects. Climate change is imperative to consider when assessing GHG production and future mitigation measures.

Wind stress can create turbulence and waves, affect vertical circulation (and contribute to down- or up-welling), and influence transport of OM or dissolved compounds involved in methanogenesis or oxidation, all of which is also dependent on the specific characteristics of the body of water (shape, depth, size) and its surrounding terrain (Bastviken et al. 2004; Falter 2017). Wind direction is particularly important in influencing downwelling or upwelling, which can directly affect CH_4 production. Downwelling favors CH_4 oxidation, as CH_4 is converted into CO_2 due to the heightened availability of oxygen coupled with a decreased supply of OM within the water column, thus reducing CH_4 emissions (Capelle and Tortell 2016). Conversely, upwelling can lead to increased CH_4 emissions as CH_4 from the deeper oxic regions is shuttled to the reservoir surface (Capelle and Tortell 2016). Indeed, coastal upwelling and downwelling were found to be the dominant transport mechanism for CH_4 across the continental shelf of southern British Columbia (Capelle and Tortell 2016). CH_4 measurements at varying water depths, under different weather conditions and in multiple seasons are necessary to determine the role upwelling and downwelling may play for any particular reservoir. These measurements can be difficult to obtain as the data collection must encompass broad spatial and temporal scales in order to capture upwelling or downwelling events, as evidenced by the extremely limited number of studies addressing the role of upwelling and downwelling in CH_4 production.

Land use, type and amount of vegetation cover, along with intensity and frequency of precipitation events can alter OM loading and water residence time, thus affecting CH_4 production and emissions (Bastviken et al. 2004). Reservoirs often have shorter residence times than natural lakes and have more complex in-situ variability because they typically have one or more major inlets compared to naturally occurring lakes (Falter 2017). The reservoir inlets also play into the dynamics of how OM is incorporated into the reservoir, e.g. if it is quickly carried to the deeper anoxic layers, the OM will more readily undergo methanogenesis (Capelle and Tortell 2016). These examples illustrate a need for measuring site-specific residence time and variability around OM inputs.

Another crucial element in understanding and quantifying CH_4 emissions is the adoption of standardized methods. There is a remarkable lack of consistent, standardized methods or protocol for measuring CH_4 emissions. Granted, this is a relatively new field of research - the first IPCC Assessment Report considering GHG contributions to global climate change was published in 1990. Yet after nearly 30 years there is still no standard methodology for measuring CH_4 emissions from reservoirs, particularly ebullition (Lilley et al. 1996; St. Louis et al. 2000; Johnson et al. 2002; Boudreau 2012; Harrison et al. 2016). The suite of environmental variables that contribute to ebullition is not fully understood, and as discussed earlier, emphasis should be placed on comprehensive assessments of site-specific characteristics to capture all variables influencing CH_4 emissions. For instance, in deep reservoirs, CH_4 bubbles typically dissolve in the water column before reaching the surface, unlike in shallow reservoirs (Delsontro et al. 2010). This highlights the idea that estimating CH_4 diffusive emissions should be done on a case-by-case basis until additional knowledge on the dynamics of CH_4 emissions is available.

However significant and promising advancements in monitoring techniques that could be employed to generate emissions estimates have been made in recent years (e.g., Beaulieu et al. 2016). A recent study by Miller et al. (2017) provides an overview of the methods used to measure methane flux at temperate hydropower reservoirs, including the bubble trap, optical detector, echosounder, inverted tunnel, and automated bubble trap.

It is also important to understand the effects of stratification. Methanogenesis is prevalent in persistently stratified tropical reservoirs (Demarty and Bastien 2011), but because of oxidation by methantrophic bacteria in the oxygenated layer of the water column, most of the CH_4 produced in a tropical reservoir is instead emitted to the atmosphere as the less potent GHG CO_2 (Guerin and Abril 2007). While not strictly acting as a CH_4 sink, oxidation does ultimately reduce CH_4 emissions, although GHG is still being produced. Deep tropical reservoirs also allow greater methanotrophic activity in the water column compared to shallow reservoirs, resulting more efficient oxidation of CH_4 and less emission directly to the atmosphere (Lima 2005). Again, measurements should be conducted long- and short-term and across multiple depths and locations to capture temporal and spatial variability.

Turning to the role of hydroelectric projects themselves, more information is needed to fully understand and measure degassing from turbines. CH_4 degassing can occur at the project from turbulence as water passes through the turbines or can occur further downstream. When passing through the turbines, CH_4 gas is exposed to low pressure and high temperature conditions which enables rapid degassing in tropical reservoirs (Kemenes et al. 2007). However, high amounts of CH_4 can remain in the outflow after passing through the turbines; GHG has been measured up to 25 mi (40 km) downstream of a tropical dam (Guerin et al. 2006). These findings point to the need to better understand and quantify degassing that occurs at the turbines and downstream of hydroelectric dams, particularly in temperate regions for which such data is still lacking.

Another consideration that should be included in CH_4 emissions estimates is the concept that age matters: reservoirs produce more GHG in the first ten to twenty years after impoundment (IPCC 2006; Barros et al 2011). Studies of Canadian systems demonstrated that CO_2 emissions from reservoirs over ten years old were on par with emissions from natural lakes and rivers (Tremblay et al 2004). Temperate reservoirs had a significant negative relationship between age and GHG emissions, meaning with increasing age GHG diminished over time (St. Louis et al 2000). Therefore, it is important to incorporate the age of the reservoir in calculations of GHG emissions.

To more accurately estimate CH_4 contributions to the global carbon budget, future research efforts should continue to focus on tropical reservoirs due to the relationship between temperature and high OM with CH_4 emissions and because this is the region with the most potential for future hydroelectric development. It would be very informative and beneficial to the scientific community at large to assess whether reservoirs are net CH_4 sinks or sources by evaluating pre- and post-impoundment values to compare carbon burial in the reservoir versus under pre-impoundment conditions (i.e., carbon burial in the ocean). However, as hydroelectric power is already very highly developed in temperate regions, many hydroelectric dams are nearing the end of their lifespans; consequently, the effects of dam decommissioning on the global carbon budget will be important to study. The major knowledge gaps listed above need to be filled by future research to better understand CH_4 production overall and to better estimate regional and global carbon budgets.

5.3.3 Conclusions

Primary contributing controllers of CH_4 emissions from hydroelectric project reservoirs are geographically and sample site-specific, and include availability of OM, condition of reservoir sediments, reservoir trophic status (dependent upon nutrient inputs, primary productivity, and water temperature), presence of rooted aquatic macrophyte and algal populations, and factors that affect CH_4 ebullition to the reservoir surface, including hydrostatic pressure changes and benthic sediment conditions (Falter 2017). Strong correlations have been identified between reservoir CH_4 emissions and OM and nutrient accumulation in nearshore sediments, nutrient loading in reservoirs (eutrophic conditions), increased water temperatures, and presence of aquatic macrophytes (Bastviken et al. 2004; Demarty and Bastien 2011; West et al. 2012; Arntzen et al. 2013; Deemer et al. 2016; Falter 2017). The available data and comparisons presented in this report support the likelihood that CH_4 emissions are very low from pelagic waters within Columbia River basin hydroelectric project reservoirs. The sporadic distribution of moderately high CH_4 emissions for some reservoirs results from 'hot spots' of littoral sediment accumulation and robust aquatic macrophyte beds. The high ratios of pelagic:littoral area, particularly for Eastern Washington reservoirs, in all probability means overall reservoir-wide CH_4 emissions are low in comparison to reservoirs on a regional or national scale.

Even though the surface flux measurements of Columbia River hydroelectric project reservoirs presented in this report indicate that CH_4 emissions are lower compared to other studies conducted in temperate regions, it's been shown that CH_4 ebullition and pore-water flux in littoral embayments can potentially produce substantial emissions, particularly in the summer. The values reported here may be high relative to surface flux values, but are on par with ebullition and pore-water flux results from recent comparable studies of temperate reservoirs and are much lower than global estimates (DelSontro et al. 2010; Arntzen et al. 2013; Deemer et al. 2016). The implication of these results is that temperate hydroelectric project reservoirs provide a modest source of CH_4 to the atmosphere. Indeed, several studies have found that, in particular, temperate estuarine and river contributions of CH_4 to the global budget are likely minor because of their small footprint (De Angelis and Lilley 1987; Middelburg et al. 2002; Borges and Abril 2012; Pfeiffer-Herbert et al. 2015). This realization coupled with the knowledge that the primary controllers affecting CH_4 emissions are inconsistently present within Columbia River basin reservoirs supports the conclusion that GHG emissions from hydroelectric projects in the Columbia River basin play a relatively minor role in contributing to the global CH_4 and overall GHG emissions budgets.

Indeed, CH_4 emissions from reservoirs compared to total global sources are quite small. In mean estimates of data from the 2000s, global reservoirs, including tropical locations, contributed about 4–5% of CH_4 from anthropogenic sources, and of these, hydroelectric reservoirs contributed about 3–6% of CH_4 emissions (Deemer et al. 2016). However, non-tropical reservoirs have been shown to emit far less CH_4 due to local regional features such as geology, climate, type of flooded soils and vegetation, and hydrologic regime (Figure 5-6; St. Louis et al. 2000); CH_4 emissions from hydroelectric reservoirs in the western United States were reported to be the lowest of those on the continent, compared to eastern Canada and Central/South America (Soumis et al. 2004).

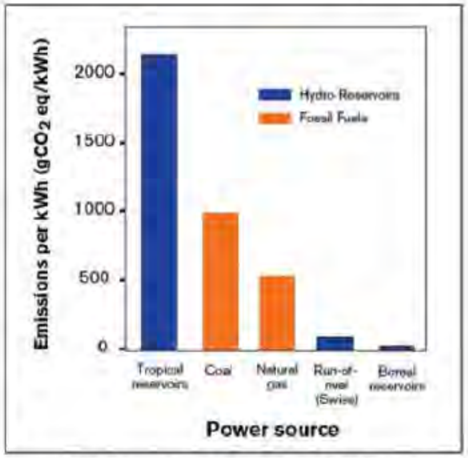

Figure 5-6 Comparison of CO_2 and CH_4 emissions per kilowatt-hour for various power sources
Note: based on one year of data; tropical reservoirs bar represents net average emissions from three Brazilian reservoirs, boreal reservoirs bar represents gross average emissions from five Canadian reservoirs, run-of-river bar represents gross emissions (without degassing) from the Wohlensee reservoir in Switzerland (International Rivers, 2008).

In the United States, ruminant digestion is the largest anthropogenic source of CH_4 (Figure 5-7; EPA 2018). Within the category of electric power production, hydroelectric dams account for a very small portion, second only to petroleum-based generation (gasoline or diesel generators, for example); the value is so small that hydroelectric GHG emissions are not accounted for separately in the EPA's 1990–2016 Draft Inventory of US Greenhouse Gas Emissions and Sinks, but are included with renewable-based generation (Figure 5-8; EPA 2018). Again, CH_4 emissions are specific to the local characteristics of the reservoir and its operation, and those in the western United States, particularly the Columbia River basin, have been shown to be a minor player in contributing to the global budgets of GHG and especially CH_4 emissions compared to worldwide or even solely U.S. sources (Lilley et al. 1996; Soumis et al. 2004; Arntzen et al. 2013; Falter 2017).

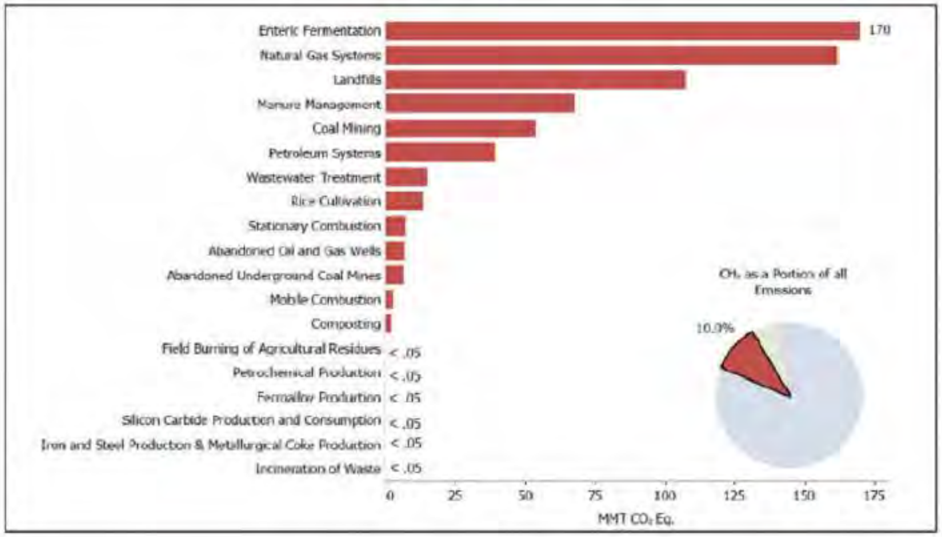

Figure 5-7. Anthropogenic sources of CH_4 emissions (million metric tons of CO2 equivalent) in 2016 (EPA 2018).

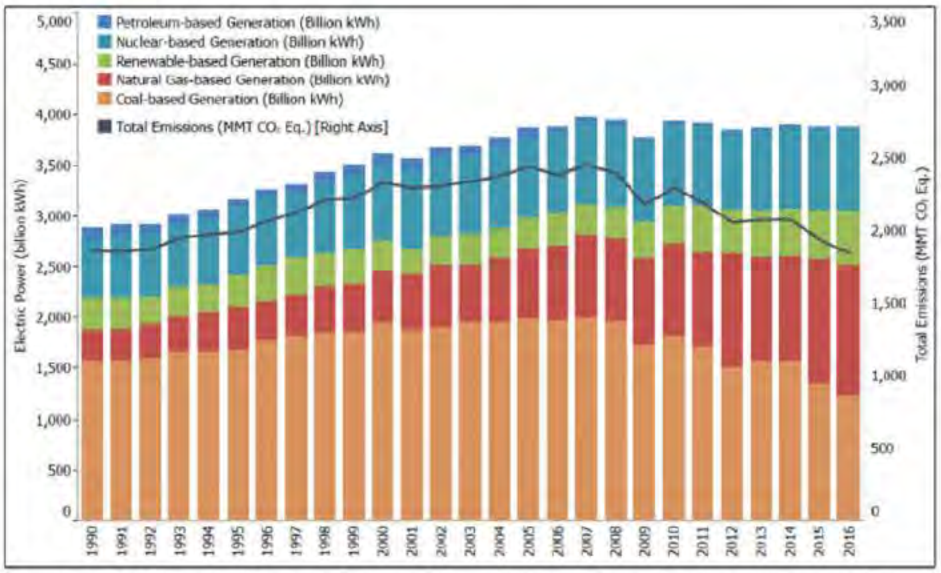

Figure 5-8. Emissions (million metric tons of CO_2 equivalent) from electric power generation; hydroelectric power is included in renewable-based generation, colored green (EPA 2018).

CHAPTER 6 - REFERENCES

Arntzen, E.V., S. Niehus, B.L. Miller, M. Richmond, and A.C. O'Toole. 2013. Evaluating Greenhouse Gas Emissions from Hydropower Complexes on Large Rivers in Eastern Washington. Report to U.S. Department of Energy. Contract DE-AC05-76RL01830. Pacific Northwest National Laboratory. Richland, WA.

Bastviken, D., J. Cole, M. Pace, L. Tranvik. 2004. "Methane Emissions from Lakes: Dependence of Lake Characteristics, Two Regional Assessments, and a Global Estimate." *Global Biogeochemical Cycles* 18(4):1-12.

Bastviken, D., J. J. Cole, M. L. Pace, M. C. Van de Bogert. 2008. "Fates of Methane from Different Lake Habitats: Connecting Whole-Lake Budgets and CH_4 Emissions." *Journal of Geophysical Research: Biogeosciences* 113(G2):1-13.

Barros, N., J. J. Cole, L. J. Tranvik, Y. T. Prairie, D. Bastviken, V. L. Huszar, P. del Giorgio, F. Roland. 2011. "Carbon Emissions from Hydroelectric Reservoirs Linked to Reservoir Age and Latitude." *Nature Geoscience* 4(9):593-596.

Beaulieu, J. J., M. G. McManus, C. T. Nietch. 2016. "Estimates of Reservoir Methane Emissions Based on a Spatially Balanced Probabilistic-Survey." *Limnology and Oceanography* 61(S1):S27-S40.

Beaulieu, J. J., Balz, D. A., Birchfield, M. K., Harrison, J. A., Nietch, C. T., Platz, M. C., & Young, J. L. 2018. Effects of an experimental water-level drawdown on methane emissions from a eutrophic reservoir. *Ecosystems,* 21(4), 657-674.

Bevelhimer, M. S., Stewart, A. J., Fortner, A. M., Phillips, J. R., & Mosher, J. J. 2016. CO2 is dominant greenhouse gas emitted from six hydropower reservoirs in southeastern United States during peak summer emissions. *Water,* 8(1), 15.Borges, A., and G. Abril. 2012. Carbon Dioxide and Methane Dynamics in Estuaries, p. 119–161. *In* E. Wolanski and D. McLusky, eds. Treatise on Estuarine and Coastal Science, Volume 5: Biogeochemistry. Academic Press.

Boudreau, B. P., C. Algar, B. D. Johnson, I. Croudace, A. Reed, Y. Furukawa, K. M. Dorgan, P. A. Jumars, A. S. Grader, B. S. Gardiner. 2005. "Bubble Growth and Rise in Soft Sediments." *Geology* 33(6):517-520.

Boudreau, B. P. 2012. "The Physics of Bubbles in Surficial, Soft, Cohesive Sediments." *Marine and Petroleum Geology* 38(1):1-18.

Bureau of Economic Analysis (BEA). *Implicit Price Deflators for GDP.* June 2019. Accessed at: https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=3&isuri=1&1921=survey&1903=13#reqid=19&step=3&isuri=1&1921=survey&1903=13

31840001 BPA-2024-00643-F 0264

Capelle, D. W. and P. D. Tortell. 2016. "Factors Controlling Methane and Nitrous-Oxide Variability in the Southern British Columbia Coastal Upwelling System." *Marine Chemistry* 179:56-67.

De Angelis, M. and M. Lilley. 1987. "Methane in Surface Waters of Oregon Estuaries and Rivers." *Limnology and Oceanography* 32:716–722.

Descloux, S., Chanudet, V., Serça, D., & Guérin, F. 2017. Methane and nitrous oxide annual emissions from an old eutrophic temperate reservoir. *Science of the Total Environment,* 598, 959-972.DelSontro, T., D. F. McGinnis, S. Sobek, I. Ostrovsky, B. Wehrli. 2010. "Extreme methane emissions from a Swiss hydropower reservoir: Contribution from bubbling sediments." *Environmental Science and Technology* 44: 2419-2425.

Deemer B., J. A. Harrison, S. Li, J. J. Beaulieu, T. DelSontro, Barros, J. F. Besserra-Neto, S. M. Powers, M. A. Dos Santos, J. Arie Vonk. 2016. "Greenhouse Gas Emission from Reservoir Water Surfaces: A New Global Synthesis." *BioScience* 66 (11):949-964.

Demarty, M. and J. Bastien. 2011. "GHG Emissions from Hydroelectric Reservoirs in Tropical and Equatorial Regions: Review of 20 years of CH_4 Emission Measurements." *Energy Policy* 39(7):4197-4206.

Energy Information Administration. 2018. Energy-Related Carbon Dioxide Emissions by State, 2000-2015: Documentation. October 2018. https://www.eia.gov/environment/emissions/state/pdf/statemethod.pdf

Environmental Protection Agency. 2018. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. Report: EPA 430-P-18-001. Washington, D.C.

EPA. 2019a. "Regional Haze Program." https://www.epa.gov/visibility/regional-haze-program

_____. 2019b. Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Influenced by High Wind Dust Events Under the 2016 Exceptional Events Rule. EPA-457/B-19-001. https://www.epa.gov/sites/production/files/2019-04/documents/high_wind_dust_event_guidance.pdf

____. 1995. 1995. AP-42 Compilation of Air Emissions Factors Volume I Chapter 13: Miscellaneous Sources. January 1995. Accessible at: https://www3.epa.gov/ttn/chief/ap42/ch13/index.html

Falter, C. M. 2017. Greenhouse Gas Emissions from Lakes and Reservoirs: The Likely Contribution of Hydroelectric Project Reservoirs on the Mid-Columbia River. Prepared for Public Utility District No. 1 of Chelan County. University of Idaho Limnology and Aquatic Ecology. Moscow, ID.

Guerin, F., and G. Abril. 2007. "Significance of Pelagic Aerobic Methane Oxidation in the Methane and Carbon Budget of a Tropical Reservoir." *Journal of Geophysical Research-Biogeosciences* 112(G3):1-14.

Harrison, J. A., B. R. Deemer, M. K. Birchfield, M. T. O'Malley. 2016. "Reservoir Water-Level Drawdowns Accelerate and Amplify Methane Emission." *Environmental Science and Technology* 51(3):1267-1277.

Holgerson, M. A. and P. A. Raymond. 2016. "Large Contribution to Inland Water CO_2 and CH_4 Emissions from Very Small Ponds." *Nature Geoscience* 9(3):222-226.

Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. August 2016 Revision.

Intergovernmental Panel on Climate Change. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme [H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara and K. Tanabe (eds)], Institute for Global Environmental Strategies, Hayama, Japan.

International Rivers. 2008. Dirty Hydro: Dams and Greenhouse Gas Emissions. Berkeley, CA.

Johnson, B. D., B. P. Boudreau, B. S. Gardiner, R. Maass. 2002. "Mechanical Response of Sediments to Bubble Growth." *Marine Geology* 187(3-4):347-363.

Kemenes, A., F. R. Forsberg, J. M. Melack. 2007. "Methane Release Below a Tropical Hydroelectric Dam." *Geophysical Research Letters* 34(12):1-5.

Kumar, A., T. Schei, A. Ahenkorah, R. Caceres Rodriguez, J.-M. Devernay, M. Freitas, D. Hall, Å. Killingtveit, Z. Liu. 2012: Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Lilley, M. D., M. A. de Angelis, E. Olson. 1996. "Methane Concentrations and Estimated Fluxes from Pacific Northwest Rivers." *Mitteilungen des Internationalen Verein Limnologie* 25:187-196.

Lima, I. B. T. 2005. "Biogeochemical Distinction of Methane Releases from two Amazon Hydroreservoirs." *Chemosphere* 59(11):1697-1702.

Maeck, A., H. Hofmann, A. Lorke. 2014. "Pumping Methane Out of Aquatic Sediments: Ebullition Forcing Mechanisms in an Impounded River." *Biogeosciences* 11(1):2925-2938.

Marten, A. L., Kopits, E. A., Griffiths, C. W., Newbold, S. C., and Wolverton, A. 2015. Incremental CH4 and N20 mitigation benefits consistent with the U.S. Government's SC-CO2 estimates. Climate Policy 15:2 (272-298).

Middelburg, J., J. Nieuwenhuize, N. Iversen. 2002. "Methane Distribution in European Tidal Estuaries." *Biogeochemistry* 59:95–119.

Miller, B. L., Arntzen, E. V., Goldman, A. E., & Richmond, M. C. 2017. Methane ebullition in temperate hydropower reservoirs and implications for US policy on Greenhouse Gas emissions. *Environmental Management,* 60(4), 615-629.Morgan, J. J. 1967. Principles and Application in Water Chemistry. S. D. Faust and J. V. Hunter, eds. New York: J. Wiley and Sons.

MRCC (Midwestern Regional Climate Center). 2018. cli-MATE (cli-MRCC's Application Tools Environment): Hourly Average Wind Speed and Direction Data: 2000-2018. Accessed at: https://mrcc.illinois.edu/CLIMATE/

MT DEQ (Montana Department of Environmental Quality). 2007. Montana Climate Change Action Plan. Prepared by CCS (Center for Climate Strategies). Accessed at http://deq.mt.gov/Energy/climatechange/plan.

Nguyen, T. D., P. Crill, D. Bastviken. 2010. "Implications of Temperature and Sediment Characteristics on Methane Formation and Oxidation in Lake Sediments." *Biogeochemistry* 100(1-3):185-196.

Northwest Power and Conservation Council. 2017. Methane Emissions from Reservoirs. Portland, OR.

Nürnberg, G. 2004. "Quantified Hypoxia and Anoxia in Lakes and Reservoirs." *Freshwater Research* 4: 42-54

NW Council (Northwest Power and Conservation Council). 2016a. Seventh Northwest Conservation and Electric Power Plan. February 2016. Accessible at: https://www.nwcouncil.org/reports/seventh-power-plan

_____. 2016b. Regional Portfolio Model Scenario Analysis. Updated March 2016. Accessible at: https://www.nwcouncil.org/reports/technical-information-and-data

_____. 2018. "Power Supply: Existing and new/proposed power plants." May 2018. Accessed at: https://www.nwcouncil.org/energy/energy-topics/power-supply

_____. 2019. 7th Power Plan Midterm Assessment. February 2019. Accessible at: https://www.nwcouncil.org/reports/midterm-assessment-seventh-power-plan

Ocko, I. B., & Hamburg, S. P. 2019. Climate Impacts of Hydropower: Enormous Differences among Facilities and over Time. *Environmental Science & Technology,* 53(23), 14070-14082.

OR DEQ (Oregon Department of Environmental Quality). 20120. "Regional Haze." Accessed on January 15 2020. https://www.oregon.gov/deq/aq/Pages/Haze.aspx

Pfeiffer-Herbert, A. S., F. G. Prahl, B. Hales, J. A. Lerczak, S. D. Pierce, M. D. Levine. 2015. "High Resolution Sampling of Methane Transport in the Columbia River Near-Field Plume: Implications for Sources and Sinks in a River-Dominated Estuary." *Limnology and Oceanography* 61(S1):S204-S220.

Schlesinger, W. H. and E. S. Bernhardt. 2013. Biogeochemistry: An Analysis of Global Change. Academic Press, Elsevier.

Sobek, S., T. DelSontro, N. Wongfun, B. Wehrli. 2012. "Extreme Organic Carbon Burial Fuels Intense Methane Bubbling in a Temperate Reservoir." *Geophysical Research Letters* 39(1):1-4.

Soumis, N., E. Duchemin, R. Canuel, M. Lucotte. 2004. "Greenhouse gas emissions from reservoirs of the western United States." *Global Biogeochemical Cycles* 18:GB3022.

St. Louis, V.L., C.A. Kelly, E. Duchemin, J.W.M. Rudd, D.M. Rosenberg. 2000. "Reservoir Surfaces as Sources of Greenhouse Gases to the Atmosphere: A Global Estimate." *Bioscience* 50(9):766-775.

Stocker, T. F., D. Qin, G.K. Plattner, M. M. B. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. M. Midgley, eds. 2013. Climate change 2013: The Physical Science Basis. Cambridge University Press.

Tremblay, A., Lambert, M., Gagnon, L. 2004. "Do Hydroelectric Reservoirs Emit Greenhouse Gases?" *Environmental Management* 33:S509-S517.

Tremblay, A., L. Varfalvy, C. Roehm, M. Garneau, eds. 2005. Greenhouse Gas Emissions – Fluxes and Processes: Hydroelectric Reservoirs and Natural Environments. Germany: Springer-Verlag.

West, W. E., J. J. Coloso, S. E. Jones. 2012. "Effects of Algal and Terrestrial Carbon on Methane Production Rates and Methanogen Community Structure in a Temperate Lake Sediment: Methanogen Response to Trophic Change." Freshwater Biology 57(5):949-955.

Wetzel, R. G. 2001. Limnology: Lake and river ecosystems. Academic Press, San Diego, CA and London, United Kingdom.

Wilbraham, A. C, Staley, D. D., Matta, M. S. 2008. Prentice Hall Chemistry. Pearson Prentice Hall.

William Malm, National Park Service and Colorodo State Institute for Research on the Atmosphere. 1999. Introduction to Visibility. May 1999. https://www.epa.gov/sites/production/files/2016-07/documents/introvis.pdf

Wuebbles, D. and K. Hayhoe. 2002. "Atmospheric Methane and Global Change." Earth-Science Reviews 57:177-210.

USEPA (US Environmental Protection Agency). 2006. Air Quality Criteria for Lead. October 2006. Accessed at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=158823.

_____. 2008. Regulatory Impact Analysis of the Proposed Revisions to the National Ambient Air Quality Standards for Lead. October 2008. Accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/regulatory-impact-analyses-air-pollution.

_____. 2010a. Quantitative Risk and Exposure Assessment for Carbon Monoxide – Amended. July 2010. Accessed at https://www3.epa.gov/ttn/naaqs/standards/co/data/CO-REA-Amended-July2010.pdf.

_____. 2010b. Final Regulatory Impact Analysis (RIA) for the NO_2 National Ambient Air Quality Standards (NAAQS). January 2010. Accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/regulatory-impact-analyses-air-pollution.

_____. 2010c. Final Regulatory Impact Analysis (RIA) for the SO_2 National Ambient Air Quality Standards (NAAQS). June 2010. Accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/regulatory-impact-analyses-air-pollution.

_____. 2012. Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter. December 2012. Accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/regulatory-impact-analyses-air-pollution.

_____. 2015. Regulatory Impact Analysis of the Final Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone. September 2015. Accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/regulatory-impact-analyses-air-pollution.

_____. 2016. NAAQS Table. Last Updated December 20, 2016. Accessed at https://www.epa.gov/criteria-air-pollutants/naaqs-table.

_____. 2018. EPA Approved Air Quality Implementation Plans in Region 10 (Alaska, Idaho, Oregon, Washington and 271 Native Tribes). Accessed on October 24 2018: https://www.epa.gov/air-quality-implementation-plans/approved-air-quality-implementation-plans-region-10

_____. 2018. Emissions and Generation Resource Integrated Database (eGRID). Updated February 2018. Accessed from: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

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From: Petersen,Christine H (BPA) - EWP-4
Sent: Monday, January 9, 2023 9:53 AM
To: Calvert,Paula P (BPA) - E-4; Bettin,Scott W (BPA) - EWP-4; Norris,Tony (BPA) - PGPO-5; Hausmann,Benjamin J (BPA) - EWP-4
Subject: CH4 output

Hi,

After reading commentary about Columbia basin reservoirs producing methane, I looked up a few papers.
Perhaps this is already widely discussed in Paula's area, and I'd be interested in what the most updated issues are.

I had heard this raised with respect to the tropical reservoirs+ greenhouse gas review that came out a few years ago. Locally, we have pointed out that most Columbia reservoirs are in rocky terrain and not very much soil was inundated. However, I have seen reference to a specific estimate of the volume of methane released.

This non-peer reviewed assessment by John Twa, appears to be one source of this estimate. He is starting with the PNNL study done by Evan Arntzen and others, who of course, have done temperature monitoring for us at Ives Island. In this study, they talk about 3-4 different ways in which reservoirs can generate methane. Their study is publishable because they highlight ebullition measurements of methane, and are able to report high values at sites at Lower Monumental and Priest Rapids. They didn't have a variety of sample points throughout the reservoirs, but rather, sampled only in shallow locations in side embayments that they classified as "depositional littoral zones" where sediment and milfoil tend to collect. There is very likely higher bacterial activity in these spots, so the ebullition methane value could be a high or maximum level for the whole reservoir. (Paula??) (Also – how comparable are natural wetland marsh environments to the shallow depositional zones in the reservoirs?). A larger list of sampling sites was used for diffusive methane.

Arntzen et al. do not estimate the methane flux of the whole reservoir. What John Twa does in his estimate is take the description of the embayment sites sampled for ebullition methane as all areas shallower than 10 m, and he estimates what fraction of the whole reservoir is shallower than 10 m (about 1/3) and expands the value from the depositional littoral zone to the whole reservoir. He did not do adjustments with respect to how much of the shallow area is truly depositional with slow water movement and high bacterial growth. For that reason, I doubt that his total methane estimate is correct.

Twa does accurately say that Miller/Arntzen say that the highest ebullition is with depth <10m, water velocity near zero, near agriculture and temperatures above 17 C. But as far as correcting for areas with low water velocity, he says that velocities are below 1 ft/s after June 21st. What about the free-flowing river upstream of Lower Granite?

I do think that the literature review in the Miller/Arntzen paper has an interesting finding that ebullition values measured in lakes were lower than for reservoirs, averaged among multiple studies in other areas and it would be interesting to hear them talk about that? Lakes supposedly are slowly filling with sediment, while free flowing rivers keep moving sediment downstream, and this sediment is the source of the methane.
The Priest Rapids values were lower than for Lower Monumental, which has much slower velocities or longer water retention time. Agricultural runoff is also important. What does this mean for reservoir management, if we were to want to reduce the ebullitive flux? For example, would a deeper reservoir like Hells Canyon naturally have less ebullition methane because it has less <10 m shallow area? What about low volume tributary rivers and wetlands in late summer? In the study, they do say that something about the reservoir itself encourages the condition: "Mean daily ebullitive CH4 fluxes from temperate hydropower reservoirs were significantly higher than mean daily ebullitive CH4 fluxes from temperate rivers and lakes. This emphasizes that hydropower structures alter natural systems by creating environments

that can increase sediment and organic carbon deposition behind dams, which may foster CH_4 ebullition in certain conditions (Maeck et al. 2013; Thornton et al. 1990)."

(links to his earlier 2016 estimate here too)
https://damsense.org/the-lower-snake-river-reservoirs-generate-significant-amounts-of-methane-a-potent-greenhouse-gas/?utm_source=rss&utm_medium=rss&utm_campaign=the-lower-snake-river-reservoirs-generate-significant-amounts-of-methane-a-potent-greenhouse-gas#:~:text=About%20Us-,The%20Lower%20Snake%20River%20Reservoirs%20Generate%20Significant,Methane%2C%20a%20Potent%20Greenhouse%20Gas&text=The%20reservoirs%20formed%20by%20the,is%20not%20%E2%80%9Cclean%E2%80%9D%20energy.

PNNL Study
https://www.pnnl.gov/sites/default/files/media/file/Methane%20Ebullition%20in%20Temperate%20Hydropower%20Reservoirs%20and%20Implications%20for%20US%20Policy%20on%20Greenhouse%20Gas%20Emissions.pdf

From: Kaseweter,Alisa D (BPA) - AI-7
Sent: Wednesday, April 12, 2023 4:22 PM
To: Leary,Jill C (BPA) - LN-7
Cc: Godwin,Mary E (BPA) - LN-7
Subject: RE: DOE Methane Study
Attachments: LIHI_GHG Presentation_Final.pdf

I'll reach out to the DOE WPTO and find out the state of this and report back. In the meantime, here is the project overview from 2021.

From: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>
Sent: Wednesday, April 12, 2023 2:28 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Subject: DOE Methane Study

Confidential and privileged attorney client communication/FOIA-exempt

Hi Alisa,

(b)(5) [redacted]

Thanks,
Jill

From: Leary,Jill C (BPA) - LN-7
Sent: Thursday, April 13, 2023 2:55 PM
To: Pytlak,Erik S (BPA) - PGPW-5; Kaseweter,Alisa D (BPA) - AI-7; Godwin,Mary E (BPA) - LN-7
Cc: McManamon,Ann (BPA) - PGPW-5; Sullivan,Leah S (BPA) - PGB-5
Subject: RE: [EXTERNAL] RE: Question on DOE/ORNL Reservoir GHG Emission Study

Thanks, Alisa and Erik, and welcome, Ann and Leah.

(b)(5) [redacted]

Confidential and privileged attorney client communication/FOIA-exempt

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From: Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Sent: Thursday, April 13, 2023 2:18 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>
Cc: McManamon,Ann (BPA) - PGPW-5 <amcmanamon@bpa.gov>; Sullivan,Leah S (BPA) - PGB-5 <lssullivan@bpa.gov>
Subject: RE: [EXTERNAL] RE: Question on DOE/ORNL Reservoir GHG Emission Study

(b)(5) [redacted]

-Erik

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Thursday, April 13, 2023 1:10 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>
Subject: FW: [EXTERNAL] RE: Question on DOE/ORNL Reservoir GHG Emission Study

Jill,

(b)(5) [redacted]

Alisa

From: Scaife, Charles <charles.scaife@ee.doe.gov>
Sent: Thursday, April 13, 2023 12:24 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Battey, Hoyt <hoyt.battey@ee.doe.gov>
Cc: Wuestewald, Eric (CONTR) <Eric.Wuestewald@ee.doe.gov>
Subject: [EXTERNAL] RE: Question on DOE/ORNL Reservoir GHG Emission Study

Hi Alisa,

Thanks for writing!

The project is still ongoing. The team published a paper last year (Getting lost tracking the carbon footprint of hydropower - ScienceDirect) and is slated to publish several more this year.

WPTO also plans to publish an evergreen webpage, initially based on the paper above, that highlights the state of the science and that will be updated periodically as new science is available. It will link from here - Hydrologic Systems Science | Department of Energy, when it's complete. The draft text of the webpage is in internal review now, but I'd be happy to share the draft in the next day or so before it goes live.

I'd be curious to learn the specific questions you receive. It could help us inform how we structure our external communications. Perhaps we can have a quick chat to discuss. And depending on how often you'd like updates and the level of detail, we can think about one-page briefings, quarterly updates, or webinars periodically on the topic.

Thank you,
Charles

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Thursday, April 13, 2023 2:34 PM
To: Scaife, Charles <charles.scaife@ee.doe.gov>; Battey, Hoyt <hoyt.battey@ee.doe.gov>
Subject: Question on DOE/ORNL Reservoir GHG Emission Study

Hi Charles and Hoyt,

BPA is wondering what the status is of the attached study related to GHG emissions for reservoirs. Have there been any updates since 2021 that the WPTO could share? And how would we best stay apprised of the progress? This is a question that comes up in our region at times and we like to be able to point to the best available science. Any insight you can share is appreciated!

Thanks!
Alisa

Alisa Kaseweter
Climate Change Specialist | Intergovernmental Affairs
BONNEVILLE POWER ADMINISTRATION
alkaseweter@bpa.gov
503-230-4358 (office) | (b)(6) [redacted] (cell)

From:	Olive,Kelly J (BPA) - PSS-6
Sent:	Wednesday, April 26, 2023 3:14 PM
To:	Kaseweter,Alisa D (BPA) - AI-7; Leary,Jill C (BPA) - LN-7; Wilson,Scott K (BPA) - PSW-6; Chennell,Mildrid A (BPA) - PGPR-5
Cc:	Lichtenfels,Michelle E (BPA) - PS-6; Paustian,Jennavive F (BPA) - PGPL-5
Subject:	RE: Methane Emissions from FCRPS
Attachments:	20230420_Workshop_Portland_OR_Notes.docx

Scott Levy, Redfish Bluefish; Portland workshop last Thursday; notes attached. The notes condense the conversation down to a sentence or two, but cumulatively, he spoke for ~4-5 min by my best guess.

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Wednesday, April 26, 2023 2:46 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>; Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>
Cc: Lichtenfels,Michelle E (BPA) - PS-6 <melichtenfels@bpa.gov>; Olive,Kelly J (BPA) - PSS-6 <kjmason@bpa.gov>; Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>
Subject: RE: Methane Emissions from FCRPS

Scott,

Out of curiosity, which roadshows did it come up in and who raised it?

I've also attached the latest on the DOE/ORNL study on this. It reinforces statements from the CRSO EIS. You know where to find me if you want to chat about it.

Alisa

From: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>
Sent: Wednesday, April 26, 2023 2:08 PM
To: Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>; Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>
Cc: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Lichtenfels,Michelle E (BPA) - PS-6 <melichtenfels@bpa.gov>
Olive,Kelly J (BPA) - PSS-6 <kjmason@bpa.gov>; Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>
Subject: RE: Methane Emissions from FCRPS

Thanks, Milli.

Scott, for your awareness, this issue is popping up in multiple forums. I wanted you to have the information from the Final CRSO EIS for reference below and attached. Appendix G does an even deeper dive into methane (attached) starting on page G 5-1. Please reach out if there are specific questions:

Methane (Appendix T Response to Comments):
The EIS evaluates the research pertaining to methane emissions from hydropower reservoirs. Appendix G, Chapter 5 of the EIS details the assessment of reservoir methane emissions from the CRS projects. The findings are summarized in Section

3.8. This assessment finds that reservoir characteristics and management substantially influence methane emissions. A 2016 study developed by the Corps' Walla Walla District concluded that for the relatively clean reservoirs of the Federal Columbia River Power System, which include the lower Snake River dams, conditions for low dissolved oxygen concentrations are not prevalent; thus methane gas is generally not an issue. Additionally, in 2017, the Northwest Power and Conservation Council found that data on these sites were insufficient to estimate the reservoir methane emissions specifically for the Columbia River hydrosystem, but that methane emissions at high levels are not likely due to the lower organic and nutrient loads to the system, and higher dissolved oxygen content. The EIS describes that emerging technologies will allow forbettermeasuringandunderstandingtheeffectsofreservoirmethaneemissionsfrom CRS projects, including the four
lower Snake River dams.

Section 3.8 "Reservoir Methane Emissions from Hydropower Projects" pages 3-1022 to 3-1023

"While hydropower-based power generation does not itself emit GHGs, GHG emissions are associated with hydropower construction and maintenance activities (e.g., use of vehicles and equipment). A recent publication by Deemer et al. (2016), which evaluated global reservoir data, states that artificial reservoirs created by dams can create substantial GHG emissions. Deemer et. al. describe that reservoirs result in flooding of large areas with organic matter that decomposes, consume oxygen, and convert the organic biomass to CO_2, CH_4, and NOx. If sufficient biomass and nutrients are available, natural breakdown of these substances can create an anoxic condition favorable to methane production. Methane emissions from reservoirs take two dominant forms. During drawdown, emissions of methane can occur during degassing (diffusion) at turbines and spillways (Deemer et al. 2016). Drops in hydrostatic pressure during water level drawdowns can also enhance methane bubbling (ebullition) because decreased hydrostatic pressure enables bubbles to move upward easily and faster (Maeck, Hofmann, and Lorke 2014). In deeper water, less ebullition occurs because the bubbles are absorbed before reaching the air (Beaulieu, McManus, and Nietch 2016; Falter 2017). Across studies in temperate zones, recorded methane emissions from ebullition are generally greater than recorded methane emissions from diffusion (e.g., Arntzen et al 2013; Beaulieu et al. 2016, 2018). Across two eastern Washington reservoirs specifically, ebullition accounted for over 97 percent of methane emissions from the systems studied (Miller et al. 2017). Conditions that promote methane emissions have been studied across reservoir sites. In general, methanogenesis depends on the availability of organic matter, which is then reduced under anaerobic conditions. Recent studies have associated CH_4 production with shallow depth systems, shallow (littoral) areas of reservoir systems, marshlands, embayments (coves), and stream deltas, which provide concentration points for organic matter and can positively influence methanogenesis (Bastviken et al. 2004; Demarty and Bastien 2011; West, Coloso, and Jones 2012; Arntzen et al. 2013; Deemer et al. 2016; Falter 2017). Additionally, influx of organic and nutrient-rich material from urban and agricultural areas can cause additional decomposition and subsequent GHG emissions. Reservoir characteristics and management practices can also influence methane emissions. Among others, Deemer et al. (2016) notes the many characteristics of reservoirs that that have been linked to the amount of methane emissions. These include age of the system, surface area, shoreline development, hydraulic retention time, lake level fluctuation, water circulation, winter ice cover, stratification, water temperature and transparency, etc. (see Appendix G for more detail on this factors). A recent study by Harrison et al. (2016) reviewed data for six Pacific Northwest reservoirs, identifying that reservoir drawdown affects the amount and timing of methane emissions. A global study by Ocko and Hamburg (2019) finds that the ratio of reservoir surface area to electricity generation, maximum temperate of the reservoir, and erosion rate of the reservoir are among the three best proxies for greenhouse gas emission potential. Historically, estimating methane emissions at reservoirs has been challenging due to spatial and temporal heterogeneity. More recently, promising new measurement techniques provide more sophisticated options for capturing this variability (e.g., Beaulieu et al. 2016). However, limited application of these and other techniques to gather data to date hinders the ability to estimate methane emissions at each project site. The literature identifies substantial methane emissions from hydropower projects in tropical climates, where a variety of factors, such as temperature, organic matter, and geology, generate higher emissions (St. Louis et al. 2000; Demarty and Bastien 2011). Additionally, recent studies at temperate reservoir sites, including in the United States and Europe, have shown non-negligible methane emissions levels, particularly from ebullition (e.g., Arntzen et al. 2013, Beaulieu et al. 2016, 2018, Bevelhimer et al. 2016, Del Sontro et al. 2010, Descloux et al. 2017). In response to Deemer et al. (2016), the Corps' Walla Walla District evaluated the potential for methane generation specifically from dams and reservoirs in the lower Snake River (Corps 2016c). The evaluation concluded that "for the relatively clean reservoirs of the Federal Columbia River Power System, which include the lower Snake River dams, conditions for low dissolved oxygen concentrations are not prevalent; thus methane gas is generally not an issue" (Corps 2016a). The NW Council concluded that insufficient data was available to estimate reservoir methane emissions specifically for the Columbia River hydrosystem (NW Council 2017a). The NW Council also found that methane emissions at high levels are not likely due to the lower organic and nutrient loads to the system, and higher dissolved oxygen content (NW Council 2017a). Appendix G, *Air Quality and Greenhouse Gases*, of this EIS further discusses reservoir methane emissions and the relevant literature."

From: Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>
Sent: Wednesday, April 26, 2023 11:32 AM
To: Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>; Lichtenfels,Michelle E (BPA) - PS-6 <melichtenfels@bpa.gov>; Olive,Kelly J (BPA) - PSS-6 <kjmason@bpa.gov>; Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>
Subject: RE: Methane Emissions from FCRPS

Thanks you Milli
--Scott

From: Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>
Sent: Wednesday, April 26, 2023 11:10 AM
To: Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>; Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>
Cc: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Subject: RE: Methane Emissions from FCRPS

Hey Scott – Jill Leary would like to be included if you do need to put something together on this topic as she would like to coordinate making sure anything we say is consistent with the CRSO EIS. She also said Alisa also has some presentations from the national labs on recent studies on carbon emissions from reservoirs.

Thanks,
Milli

From: Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>
Sent: Wednesday, April 26, 2023 11:02 AM
To: Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>; Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>
Subject: RE: Methane Emissions from FCRPS

Appreciate that. If we need to delve further we will be sure to include Alisa. She is a great source for all things carbon, green and emissions related. Thanks for being available.
--Scott

From: Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>
Sent: Wednesday, April 26, 2023 8:51 AM

To: Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>; Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>
Subject: RE: Methane Emissions from FCRPS

Hi Scott, I did some work on the existing conditions section of the CRSO EIS several years ago before the contracting group took it over. My knowledge is probably a bit stale at this point. Have you looped in Alisa Kaseweter? I believe she's still the agency's climate change SME. I'm happy to help but want to make sure the most knowledgeable folks are involved.

Jen

Jen Paustian
Supervisor (acting) | PGPL, Regional Coordination
BONNEVILLE POWER ADMINISTRATION
bpa.gov | P 503-230-3151 | C [redacted]

From: Chennell,Mildrid A (BPA) - PGPR-5 <machennell@bpa.gov>
Sent: Tuesday, April 25, 2023 2:03 PM
To: Wilson,Scott K (BPA) - PSW-6 <skwilson@bpa.gov>
Cc: Paustian,Jennavive F (BPA) - PGPL-5 <jfpaustian@bpa.gov>
Subject: Methane Emissions from FCRPS

Hi Scott –

I know there were some questions about methane emissions from reservoirs at the recent Provider of Choice Roadshows. I wanted to let you know that Jen did the vast majority of the work on this topic for the CRSO and might be the best person to provide information on methane emissions.

Thanks,

Milli Chennell
Senior Hydro Resource Planner | PGPR
BONNEVILLE POWER ADMINISTRATION
machennell@bpa.gov | P 503-230-3042
she/her

PROVIDER OF CHOICE POST 2028

Provider of Choice Workshop Notes – Location Portland, OR
April 19, 2023 9am – 4pm

See Appendix for a list of participants.

Meeting Materials

https://pwrportal.bud.bpa.gov/orgs/PS-ReqMarketing/poc/2022PolicyWorkshops

Participants – See Appendix for Names and Affiliations

Category	Non-BPA Participants	BPA Participants
Total	144	74

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

(b)(5)

[redacted]

Appendix: Participants

Note: Participant type was estimated by BPA following the meeting; type designation is used for general informational purposes only. (Blend of in person versus on the phone participants)

Date	Name	Affiliation	Type
4/20/2023	2063****44		Other
4/20/2023	2067****43		Other
4/20/2023	2067****44		Other
4/20/2023	2069****42		Other
4/20/2023	2532****26		Other
4/20/2023	3609****08		Other
4/20/2023	4063****14		Other
4/20/2023	4065****01		Other
4/20/2023	4065****16		Other
4/20/2023	5033****36		Other
4/20/2023	5033****92		Other
4/20/2023	5036****47		Other
4/20/2023	5037****72		Other

4/20/2023	5038****47		Other
4/20/2023	5038****83		Other
4/20/2023	5039****19		Other
4/20/2023	5092****15		Other
4/20/2023	5094****26		Other
4/20/2023	5419****50		Other
4/20/2023	Aaron Bush	EWEB	Customer
4/20/2023	Aimee Robinson	bpa.gov	BPA
4/20/2023	Alex Swerzbin	pngcpower.com	customer
4/20/2023	Alisa Kaseweter, BPA	bpa.gov	BPA
4/20/2023	Alissa Jackson	pngcpower.com	customer
4/20/2023	Amber Whitaker	southsidepower.com	customer
4/20/2023	Amy Mai	bpa.gov	BPA
4/20/2023	Amy Schlusser	energy.oregon.gov	Other
4/20/2023	Andrew Miller	bpa.gov	BPA
4/20/2023	Andrew Munro	gcpud.org	customer
4/20/2023	Andy Fletcher	Columbia Basin	Customer
4/20/2023	Annamarie Weekley	bpa.gov	BPA
4/20/2023	Annie Terracciano	nli.coop	customer
4/20/2023	Bach, Alan	seattle.gov	customer
4/20/2023	Bear Prairie	ifpower.org	customer
4/20/2023	Bill Edmonds	nwcouncil.org	Industry
4/20/2023	Billi Kohler	westoregon.org	customer
4/20/2023	Blake Wheathers	UEC	Customer
4/20/2023	BPA Hearing Rates	gmail.com	BPA
4/20/2023	Branden	crpud.org	customer
4/20/2023	Brandon Hignite	Central Lincoln	Customer
4/20/2023	brenda brown	bpa.gov	BPA
4/20/2023	Brian Dombeck	bpa.gov	BPA
4/20/2023	Brooke Stegmeier	elmhurstmutual.org	Other
4/20/2023	Carol Obeng	bpa.gov	BPA
4/20/2023	Celeste Schwendiman	bpa.gov	BPA
4/20/2023	Chris Allen	NWCPUD	Customer
4/20/2023	Chris Johnson -Benton PUD	bentonpud.org	customer
4/20/2023	Chris Roden	Clatskanie	Customer
4/20/2023	Christina Wyatt	BBEC	Customer
4/20/2023	Christine Gillins	bpa.gov	BPA
4/20/2023	Clair Allen	bpa.gov	BPA
4/20/2023	Claire Hobson	BPA	BPA
4/20/2023	Clay Fitch	wrec.coop	customer
4/20/2023	Clint Whitney	Richmond	Customer

4/20/2023	Cody Augustine	bpa.gov	BPA
4/20/2023	Courtney Rose	bpa.gov	BPA
4/20/2023	Dale Dunckel-Okanogan	okpud.org	customer
4/20/2023	dan bedbury	clarkpud.com	customer
4/20/2023	Dan Boyes	skamaniapud.com	customer
4/20/2023	Dan Yokota	bpa.gov	BPA
4/20/2023	Daniel Fisher (BPA)	bpa.gov	BPA
4/20/2023	Daniel Moon he/him	bpa.gov	BPA
4/20/2023	Dave Churchman	gcpuld.org	customer
4/20/2023	David Moody	bpa.gov	BPA
4/20/2023	David Ochs	bpa.gov	BPA
4/20/2023	Deanna Carlson	Cowlitz	Customer
4/20/2023	Debra Smith	SCL	Customer
4/20/2023	Doll, Mitchell	seattle.gov	customer
4/20/2023	Doug Elliott	kec.com	customer
4/20/2023	Ed Mount/TEA	teainc.org	Industry
4/20/2023	Eden Faure	dwgp.com	Industry
4/20/2023	Elizabeth Osborne	nwcouncil.org	Industry
4/20/2023	Enoch Dahl	NRU	Trade Assn
4/20/2023	Erik Voice	salemelectric.com	customer
4/20/2023	Erika Doot	BPA	BPA
4/20/2023	Erin Erben	pngcpower.com	customer
4/20/2023	Erin Riley	bpa.gov	BPA
4/20/2023	Espenhorst, Eric	seattle.gov	customer
4/20/2023	Frank Brown	bpa.gov	BPA
4/20/2023	Fred Huette	NWEC	Industry
4/20/2023	Garrison Marr - Snohomish	snopud.com	customer
4/20/2023	Greg Huebner	bpa.gov	BPA
4/20/2023	Hanna Lee	bpa.gov	BPA
4/20/2023	Hannah Dondy-Kaplan	bpa.gov	BPA
4/20/2023	Heather Nicholson	yahoo.com	Industry
4/20/2023	Hope Ross, BPA	bpa.gov	BPA
4/20/2023	Ian Hunter - SnoPUD	snopud.com	customer
4/20/2023	Jaime Phillips	mc-power.com	Customer
4/20/2023	Jane Van Dyke	gmail.com	Other
4/20/2023	Jared Teeter	southsidepower.com	customer
4/20/2023	Jason Williams	flathead.coop	customer
4/20/2023	Jeff Fuller - TEA	teainc.org	Industry
4/20/2023	Jennifer Light (NWPCC)	nwcouncil.org	Industry
4/20/2023	Jessica Reichers	energy.oregon.gov	Other
4/20/2023	Jim Bennett - BPA	bpa.gov	BPA

4/20/2023	Jim Russell	cityoftacoma.org	customer
4/20/2023	JimWebb	lvenergy.com	customer
4/20/2023	Joel Jenck	bpa.gov	BPA
4/20/2023	John Goodman	skamaniapud.com	customer
4/20/2023	John Purvis	clallampud.net	customer
4/20/2023	John Shurts	nwcouncil.org	Industry
4/20/2023	Jolene Jonas	gmail.com	Other
4/20/2023	Jon Meyer	bentonpud.org	customer
4/20/2023	Jonathan Ramse	bpa.gov	BPA
4/20/2023	Josh Warner	BPA	BPA
4/20/2023	Joshua Weber	dvclaw.com	Industry
4/20/2023	Karlee Manary - BPA	hotmail.com	BPA
4/20/2023	Karma H	bpa.gov	BPA
4/20/2023	Karma Hara	bpa.gov	BPA
4/20/2023	Kathryn Patton - BPA	bpa.gov	BPA
4/20/2023	Kayla Cisco (She/Her)	bpa.gov	BPA
4/20/2023	Keith Mercer, Benton PUD	bentonpud.org	customer
4/20/2023	Kelly	snopud.com	customer
4/20/2023	Kelly Olive	BPA	BPA
4/20/2023	Kenn Backholm SNPD	snopud.com	customer
4/20/2023	Kevin Farleigh	bpa.gov	BPA
4/20/2023	Kevin Mozena BPA	bpa.gov	BPA
4/20/2023	Kevin Nordt	gcpud.org	customer
4/20/2023	Kim Thompson (BPA)	bpa.gov	BPA
4/20/2023	Korenna Colquitt	nwascopud.org	customer
4/20/2023	Kori Lintner	pngcpower.com	customer
4/20/2023	Kyna Alders	bpa.gov	BPA
4/20/2023	Laura Hein	westoregon.org	customer
4/20/2023	Lea Fisher	WPAG	Trade Assn
4/20/2023	Leann Bleakney	nwcouncil.org	Industry
4/20/2023	Lee Hall	bpa.gov	BPA
4/20/2023	Lena Wittler	clarkpud.com	customer
4/20/2023	Libby Calnon	hoodriver.coop	customer
4/20/2023	Lisa Moore	bpa.gov	BPA
4/20/2023	Liz Oberhausen	bpa.gov	BPA
4/20/2023	Lon Peters	nw-econ.com	customer
4/20/2023	Luke Canfield	Lewis PUD	Customer
4/20/2023	marc sullivan	hotmail.com	Other
4/20/2023	Marcus Perry	bpa.gov	BPA
4/20/2023	Marie Morrison - Snohomish	snopud.com	customer
4/20/2023	Mark	ravallielectric.com	customer

4/20/2023	Mark Bergan	bpa.gov	BPA
4/20/2023	Martin Wick	bpa.gov	BPA
4/20/2023	Mary Beth Evans	bpa.gov	BPA
4/20/2023	Mary Bodine	bpa.gov	BPA
4/20/2023	Matt Scroettnig	NRU	Trade Assn
4/20/2023	Megan Capper	EWEB	Customer
4/20/2023	Micah (PenLight)	penlight.org	customer
4/20/2023	Michael Corrigan	powerex.com	Industry
4/20/2023	Michael Darrington	uec.coop	customer
4/20/2023	Michael Deen	ppcpdx.org	Trade Assn
4/20/2023	Michael Hill	cityoftacoma.org	customer
4/20/2023	Michael Normandeau	bpa.gov	BPA
4/20/2023	Michael Sykes	Columbia River PUD	Customer
4/20/2023	Mike Deen	PPC	Trade Assn
4/20/2023	Mike DeMott-KPUD	klickpud.com	customer
4/20/2023	Mike Hill	cityoftacoma.org	customer
4/20/2023	Milli Chennell (she/her) - BPA	bpa.gov	BPA
4/20/2023	Mitch Green	bpa.gov	BPA
4/20/2023	Molly Childers	bpa.gov	BPA
4/20/2023	Nancy Becker	bpa.gov	BPA
4/20/2023	Nancy Schimmels	bpa.gov	BPA
4/20/2023	Nathan Anderson	cityofchewelah.org	customer
4/20/2023	Neal Gschwend	bpa.gov	BPA
4/20/2023	Niki Zumbrunnen	bpa.gov	BPA
4/20/2023	Norm Rummel FCPD	franklinpud.com	customer
4/20/2023	Paul Dockery	SCL	Customer
4/20/2023	Paul Garrett	bpa.gov	BPA
4/20/2023	Phillip Law	gcpud.org	customer
4/20/2023	Pontip Kruse, BPA	bpa.gov	BPA
4/20/2023	Randy Payne	Skamania	Customer
4/20/2023	Ray Johnson - Tacoma Power	cityoftacoma.org	customer
4/20/2023	Ray Wiseman	yakamapower.com	customer
4/20/2023	RC	kec.com	customer
4/20/2023	Rich Sargent	Franklin	Customer
4/20/2023	Rob Burr	bpa.gov	BPA
4/20/2023	rob currier, epud	epud.org	customer
4/20/2023	Robert Cromwell-UEC	uecoop.com	customer
4/20/2023	Robyn Miller	bpa.gov	BPA
4/20/2023	Rod Morris	bpa.gov	BPA
4/20/2023	Roger Gray	pngcpower.com	customer
4/20/2023	Ron Gadeberg-Okanogan PUD	okpud.org	customer

4/20/2023	Ruchi Sadhir - She/Her (OR Dept of Energy)	energy.oregon.gov	Other
4/20/2023	Ryan E	bpa.gov	BPA
4/20/2023	Ryan Neale	WPAG	Trade Assn
4/20/2023	Ryan Robertson PWX	powerex.com	Industry
4/20/2023	Sam Justice, MW&L	mc-power.com	customer
4/20/2023	Sami Babaidhan	bpa.gov	BPA
4/20/2023	Sara Cole	bpa.gov	BPA
4/20/2023	Sarah Burczak	BPA	BPA
4/20/2023	Schuyler Burkhart	ghpud.org	customer
4/20/2023	Scott Levy	gmail.com	Other
4/20/2023	Scott Simms	PPC	Trade Assn
4/20/2023	Scott Winner BPA	bpa.gov	BPA
4/20/2023	Sean Worthington	clallampud.net	customer
4/20/2023	Shailesh Shere, GHPUD	ghpud.org	customer
4/20/2023	Sharon Silver	penlight.org	customer
4/20/2023	Sidney Villanueva	Troutman	Customer
4/20/2023	Sommer Moser	dvclaw.com	Industry
4/20/2023	Stefan Brown	pgn.com	customer
4/20/2023	Steve Anderson	Clark	Customer
4/20/2023	Steve Bellcoff, BPA	bpa.gov	BPA
4/20/2023	steve kern	yahoo.com	other
4/20/2023	Steven Taylor - Okanogan PUD	okpud.org	customer
4/20/2023	Summer Goodwin	bpa.gov	BPA
4/20/2023	Suzanne Cooper	bpa.gov	BPA
4/20/2023	Suzanne Zoller	bpa.gov	BPA
4/20/2023	Tara Maynard, Grays Harbor PUD	ghpud.org	customer
4/20/2023	Tara Schaefer	bpa.gov	BPA
4/20/2023	Tashiana Wangler	NRU	Trade Assn
4/20/2023	Tim Johnson	bpa.gov	BPA
4/20/2023	Tim Nies	energy-northwest.com	Industry
4/20/2023	Toni Williams	bpa.gov	BPA
4/20/2023	Trena McManus, MW&L	mc-power.com	customer
4/20/2023	Ty Hillebrand	Central Lincoln	Customer
4/20/2023	Tyler King - CCPUD	clallampud.net	customer
4/20/2023	Watkins, Michael SCL	seattle.gov	customer
4/20/2023	Wendy Gerlitz	pse.com	IOU
4/20/2023	Will Mulhern	energy.oregon.gov	Other
4/20/2023	WOEC Board	westoregon.org	customer
4/20/2023	Wright, Cindy M	seattle.gov	customer
4/20/2023	Zabyn Towner - NRU	nru-nw.com	Trade Assn

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[redacted]

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[redacted]

From: Thompson,Kim T (BPA) - PS-6
Sent: Friday, April 28, 2023 1:57 PM
To: Warner,Joshua P (BPA) - AIR-7; Kaseweter,Alisa D (BPA) - AI-7
Cc: Burczak,Sarah E (BPA) - PS-6; Baskerville,Sonya L (BPA) - AIN-WASH
Subject: RE: [EXTERNAL] Methane Emissions from Reservoirs follow-up

Thanks Josh. I appreciate seeing the details from Jenn – and really appreciate the point that there is no baseline against which to assess.

Best Regards,
Kim Thompson (she/her/hers)
Vice President | Northwest Requirements Marketing
BONNEVILLE POWER ADMINISTRATION
bpa.gov | P 503-230-3408 | C(b)(6) [redacted]

From: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Sent: Friday, April 28, 2023 12:30 PM
To: Thompson,Kim T (BPA) - PS-6 <ktthompson@bpa.gov>; Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Cc: Burczak,Sarah E (BPA) - PS-6 <seburczak@bpa.gov>; Baskerville,Sonya L (BPA) - AIN-WASH <slbaskerville@bpa.gov>
Subject: FW: [EXTERNAL] Methane Emissions from Reservoirs follow-up

When Scott Levy raised the methane emissions topic at the POC workshop last week Jenn Light reached out just because Scott mentioned the Council. She did not want to be in the middle. See what she shared below. I wouldn't share it broadly, as I didn't suggest I would share it beyond myself.

Josh

From: Jennifer Light <JLight@NWCouncil.org>
Sent: Friday, April 28, 2023 12:21 PM
To: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Subject: [EXTERNAL] Methane Emissions from Reservoirs follow-up

Hi Josh,

I wanted to follow up with you on the methane emissions from reservoirs issue that came up from Scott Levy at the provider of choice workshop last week. For context, we did look into methane emissions from reservoirs for the 2021 Plan. Ultimately, after reviewing the studies available at the time, we determined that it wasn't a big factor in the Pacific NW. Studies were showing that this was a bigger issue as you get closer to the equator, and the temperatures up here were mitigating it.

Since the plan, new studies have come out that have called this into question a bit. More weeds than you probably care about, but the data to inform our initial assumption was from studies that focused on the transfer of methane from water to air (or surface flux). This was previously what received the most attention and what is low in our region. But studies since have shown that this is a very tiny part of the overall methane emissions. Bubbling (ebullition)/degassing makes up about 70% with another close to 30% coming from degassing and downstream emissions that haven't been accounted for. The emissions from bubbling varies throughout the reservoir (higher closer to shore) and throughout the seasons. There isn't great data on this. The degassing/downstream isn't known as well.

At this point, all we have done since the plan is to get our heads around why the impact might be different than what we assumed in the plan and identified a model that could be used to help us estimate if we want to go there. The lift is getting the data to put into the model. You need to understand the difference between the pre- and post-impoundment areas (there may have been emissions before depending on what was there, and to understand the actual impact of the existing dams this delta is important). Dor estimates this would be a summer intern (likely grad level) worth of time to just dig up the data. Given all of our other priorities, this is not one I plan to spend time on at this point. We will definitely continue to monitor the research, but us trying to model the impact doesn't seem as critical to our overall role as other work. I mean, knowing the total emissions from the system is useful, but since we don't consider new hydro and we don't/won't make recommendations about removing existing resources, I don't think the information would change the ultimate resource strategy (and might just provide ammunition to folks that we don't intend to provide). Dor pointed out that there are potential changes you can make in operations that might reduce emissions, and I could see something there potentially down the road as those changes would have impacts on F&W, but again, not on the critical path.

Let me know if you want to chat more. I will be seeing you Wednesday I think, and we could chat then if useful.
Thanks,
Jenn

Jennifer Light (she/her)
Director of Power Planning
Direct: 503-820-2315
Mobile (b)(6) [redacted]
www.nwcouncil.org | LinkedIn

Northwest **Power** and
Conservation Council

From: Kaseweter,Alisa D (BPA) - AI-7
Sent: Friday, June 23, 2023 11:33 AM
To: Marker,Doug R (BPA) - AIR-7
Subject: Reservoir Emissions

Doug,

You inquired about a comment from CEQ requesting BPA state in testimony that the emissions from the reservoirs "could be statistically significant." I did a quick review of the PNNL study, CRSO statements (which reviewed all previous literature) and latest DOE study. To conclude, the science at this time is inclusive and we should stick to factual findings and not speculate about whether emissions from reservoirs "could be statistically significant." Rather, studies to date indicate emissions are likely very low. And this is an active area that DOE is studying, and we look forward to better information on how the reservoirs in the basin act as both a sink and source of methane.

- I re-looked at the PNNL 2013 study and it does not state that emissions from the reservoirs "could be statistically significant." PNNL found that surface flux results indicated that the reservoirs sampled in the study **were CO2 sinks**, and that **CH4 surface effluxes were lower compared to other studies conducted in temperate regions**. However, PNNL found there were high methane emissions in littoral embayments, particularly during the summer.

- Our review of methane emissions from reservoirs for the CRSO included review of the PNNL study, among other literature. Excerpts from the FINAL CRSO EIS, Appendix G, section 5.3.3 Conclusions:

The available data and comparisons presented in this report support the likelihood that CH4 emissions are very low from pelagic waters within Columbia River basin hydroelectric project reservoirs. The sporadic distribution of moderately high CH4 emissions for some reservoirs results from 'hot spots' of littoral sediment accumulation and robust aquatic macrophyte beds. (Alisa's note: this last sentence addressed PNNL's findings that there were high methane emissions measured in littoral embayments).

CH4 emissions are specific to the local characteristics of the reservoir and its operation, and those in the western United States, particularly the Columbia River basin, have been shown to be a minor player in contributing to the global budgets of GHG and especially CH4 emissions compared to worldwide or even solely U.S. sources.

- There is also an ongoing DOE study on this issue, which is being done by ORNL. The DOE WPTO just put out a really good press release that points out significant gaps in current understanding. Tracking the Carbon Footprint of Hydropower | Department of Energy It is consistent with our CRSO findings, and I'm excited about this researching shedding more light on this challenging topic in the future. I note that DOE and ORNL also do not conclude at this time that methane emissions from the reservoirs "could be statistically significant" and rather points out lacking data such as how these reservoirs act as sinks for CO2, so net emissions may be more relevant than gross (which is how the measurements that exist today have been done).

I hope this helps respond to the feedback.

Thanks,

Alisa

From: Erich Hester <ehester@vt.edu>
Sent: Monday, November 6, 2023 7:30 AM
To: Calvert,Paula P (BPA) - E-4
Subject: Re: [EXTERNAL] R&D funding opportunities with DOE's Water Power Technologies Office

Hi Paula,

Just circling back on methane emissions. WPTO is currently funding ORNL to look more into emissions in the Southeast, as described here

https://www.ornl.gov/project/quantifying-greenhouse-gas-emissions-hydropower-reservoirs

with one publication already out (let me know if you can't access the full article and I can send it)

Diversity in reservoir surface morphology and climate limits ability to compare and upscale estimates of greenhouse gas emissions - ScienceDirect

More broadly, I know methane emissions with continue to be a topic of interest at WPTO as shown here

https://www.energy.gov/eere/water/tracking-carbon-footprint-hydropower

but I don't have information about whether they will be funding additional work in that area at this time. Regardless, I will include this topic in my internal report to WPTO about BPA research interests at the end of my detail (early in the new year).

Erich

On Thu, Nov 2, 2023 at 2:59 PM Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov> wrote:

> Hi Erich,
>
> Here is EPA's Cold Water Refuges Plan for the lower Columbia River:
>
> https://www.epa.gov/columbiariver/columbia-river-cold-water-refuges-plan
>
> It was great meeting you! I look forward to what you might uncover regarding methane production if that turns out to be good path for further investigation.
>
> Thanks,
>
> Paula

From: Erich Hester <ehester@vt.edu>
Sent: Wednesday, November 1, 2023 9:52 AM
To: Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Subject: Re: [EXTERNAL] R&D funding opportunities with DOE's Water Power Technologies Office

Sounds great! I just sent a Zoom invite, let me know of any issues. I set it for the default duration of an hour, but happy to keep it shorter if desired. I look forward to speaking with you.

On Wed, Nov 1, 2023 at 11:25 AM Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov> wrote:

> An 11:00 Zoom tomorrow works great. I look forward to our conversation. Thank you, Erich.
>
> Paula
>
> ---
>
> **From:** Erich Hester <ehester@vt.edu>
> **Sent:** Wednesday, November 1, 2023 7:15 AM
> **To:** Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
> **Subject:** Re: [EXTERNAL] R&D funding opportunities with DOE's Water Power Technologies Office
>
> Thanks for the quick reply. Of the times you mentioned, I can do any of the following. Perhaps this Thursday at 11? I can set up a Zoom meeting, or can do a phone call if you prefer.
>
> Thu Nov. 2, 10am-1pm
>
> Mon Nov. 6, 8-9:30am
>
> Wed Nov. 8, 8-11am
>
> Thu, Nov. 9, 8-9am
>
> Erich

On Tue, Oct 31, 2023 at 5:48 PM Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov> wrote:

Hello Erich,

I would be happy to talk with you about BPA's knowledge/research needs, from a water quality perspective, as it may relate to WPTO's funding portfolio. Here is my availability over the next couple weeks (PT):

Thu Nov. 2, 10am-2pm 10-1

Fri Nov. 3, 11am-2pm

Mon Nov. 6, 8-9:30am 8-9:30

Wed Nov. 8, 8-11am 8-11

Thu, Nov. 9, 8am-12pm 8-9

Thanks,

Paula

Paula Calvert
Clean Water Act Policy Advisor | Fish & Wildlife, E-4

BONNEVILLE POWER ADMINISTRATION
bpa.gov | P 503-230-5651| C (b)(6) [redacted] | ppcalvert@bpa.gov

---

From: Erich Hester <ehester@vt.edu>
Sent: Tuesday, October 31, 2023 9:27 AM
To: Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>
Cc: Hester, Erich (FELLOW) <erich.hester@ee.doe.gov>
Subject: [EXTERNAL] R&D funding opportunities with DOE's Water Power Technologies Office

Dear Paula Calvert,

I am a river engineer on the faculty at Virginia Tech, and I'm currently doing a sabbatical-type fellowship with the US DOE's Water Power Technologies Office (WPTO), including a detail/rotation with BPA. One aspect of the detail is to better learn how BPA's knowledge/research needs overlap the funding portfolios at WPTO, to potentially expand WPTO research opportunities that could benefit BPA. I recently spoke with Leah Sullivan about research needs related to topics such as fish passage at dams, and she recommended I speak with you about BPA's research needs related to water quality. WPTO has funded research in the past on thermal aspects of hydropower, as one example. Do you have availability in the next few weeks for a quick virtual meeting? I would appreciate any insight you might have.

Regards,
Erich Hester

--

Erich T. Hester, Ph.D., P.E.

AAAS Fellow, Water Power Technologies Office, U.S. Dept. of Energy

Associate Professor, Civil and Environmental Engineering, Virginia Tech

www.flow.cee.vt.edu

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Erich T. Hester, Ph.D., P.E.

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Associate Professor, Civil and Environmental Engineering, Virginia Tech

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Erich T. Hester, Ph.D., P.E.
AAAS Fellow, Water Power Technologies Office, U.S. Dept. of Energy
Associate Professor, Civil and Environmental Engineering, Virginia Tech
www.flow.cee.vt.edu

From: Egerdahl,Ryan J (BPA) - PGPR-5
Sent: Friday, December 1, 2023 4:26 PM
To: Moody,David F (BPA) - PEH-6; Maslow,Jeffrey J (BPA) - EC-4
Cc: Delorenzo,Thomas M (BPA) - ECF-4
Subject: RE: Question at RP Workshop - EPA GHG Inventory

Thank Jeff. I remember Julie Doumbia working on this a bit too leading up to or during the CRSO. That was my recollection too. Also, as long as the FCRPS (hydro and nuclear) output/emissions are carbon free, I think there is no connection here. Or, do other resources count as carbon emitting if their supply chain (inputs to production) emits carbon in some form? Ahhhh, all of them. ☺ Some want power producers to count the total value chain, but that is not the standard today. For good or bad.

That's been my pov at least. Thanks again.

From: Moody,David F (BPA) - PEH-6 <dfmoody@bpa.gov>
Sent: Friday, December 1, 2023 3:44 PM
To: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>; Egerdahl,Ryan J (BPA) - PGPR-5 <rjegerdahl@bpa.gov>
Cc: Delorenzo,Thomas M (BPA) - ECF-4 <tdelorenzo@bpa.gov>
Subject: RE: Question at RP Workshop - EPA GHG Inventory

Thanks Jeff, I really appreciate that! I would have given a blank look in response to that sort of question absent this info.

From: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Sent: Friday, December 1, 2023 3:38 PM
To: Egerdahl,Ryan J (BPA) - PGPR-5 <rjegerdahl@bpa.gov>; Moody,David F (BPA) - PEH-6 <dfmoody@bpa.gov>
Cc: Delorenzo,Thomas M (BPA) - ECF-4 <tdelorenzo@bpa.gov>
Subject: Question at RP Workshop - EPA GHG Inventory

Hi Ryan and Dave. I wanted to share one item that could tie in with your potential follow-up discussion through Josh Warner with Scott Levy. If I read it right, I recall Scott's question at the RP workshop citing a recent EPA GHG inventory and asking whether BPA would account for the GHG emissions attributable to FCRPS hydropower reservoirs. Specifically, in his question, it appears that Scott likely referenced this 2023 EPA US GHG Inventory: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 – Main Report (epa.gov).

This EPA report shows a very low methane factor for cool temperate climate regions found in the Pacific Northwest (see pp. 6-122 to 6-125; figure 6-11 on p. 6-123). In general, this is consistent with the science that the co-lead agencies surveyed in the CRSO EIS (see appendix G, section 5.3.1). Based on that CRSO EIS discussion, and citing studies by the Council and Corps, we recently provided the bolded response below to assist the Corps in responding to a draft Willamette EIS comment raising the issue:

> **Regarding methane, some research has shown that reservoirs can emit methane under certain conditions, particularly in tropical climates where there is a lot of plant growth and algae—conditions not found in the Federal Columbia River Power System. Regional entities, including the Northwest Power and Conservation Council and Walla Walla District of the Army Corps of Engineers, have evaluated these studies and generally have found that, in the context of the Federal Columbia River Power System, conditions for low dissolved oxygen concentrations are not prevalent, thus methane gas is generally not an issue.**

Just wanted to share these data points in case helpful for the follow-up discussion with Scott. Let me know if you have any questions. Thanks!

Jeff Maslow
Senior Environmental Protection Specialist
Environmental Planning and Analysis
BONNEVILLE POWER ADMINISTRATION
503-230-3928

From: Warner,Joshua P (BPA) - AIR-7
Sent: Tuesday, December 5, 2023 6:21 PM
To: Egerdahl,Ryan J (BPA) - PGPR-5
Cc: Moody,David F (BPA) - PEH-6; Hilliard Creecy,Jamae (BPA) - PE-6; Cathcart,Michelle M (BPA) - PG-5; Dombeck,Brian J (BPA) - PGPR-5; Mace,Allison R (BPA) - PTM-5; Dibble,Rachel L (BPA) - PT-5; Cooper,Suzanne B (BPA) - P-6; Baskerville,Sonya L (BPA) - AI-WASH
Subject: RE: Summary for John H. in prep for Dec. 5th PIQ mtg

Ryan-

Thank you again for this update. The Resource Program did not come up at the PIQ today.

However, EE related to the RDC did come up and John was well prepared to answer very effectively with the TPs that Jamae and Dave provided. Thank you!

Best,
Josh

From: Egerdahl,Ryan J (BPA) - PGPR-5 <rjegerdahl@bpa.gov>
Sent: Thursday, November 30, 2023 5:58 PM
To: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Cc: Moody,David F (BPA) - PEH-6 <dfmoody@bpa.gov>; Hilliard Creecy,Jamae (BPA) - PE-6 <jlhilliard@bpa.gov>; Cathcart,Michelle M (BPA) - PG-5 <mmcathcart@bpa.gov>; Dombeck,Brian J (BPA) - PGPR-5 <bjdombeck@bpa.gov>; Mace,Allison R (BPA) - PTM-5 <armace@bpa.gov>; Dibble,Rachel L (BPA) - PT-5 <rldibble@bpa.gov>; Cooper,Suzanne B (BPA) - P-6 <sbcooper@bpa.gov>; Baskerville,Sonya L (BPA) - AI-WASH <slbaskerville@bpa.gov>
Subject: Summary for John H. in prep for Dec. 5th PIQ mtg

Hi Josh. Here are some key takeaways from our November 28th Resource Program public workshop to share with John on Monday for Tuesday's Public Interest Quarterly meeting. Thanks

Others that attended, please modify this below if desired. I don't want to give John my diary version of notes, but want to paint a good picture. ☺ thx

---

- At the November 28th Resource Program public workshop, we presented our latest NW regional and BPA load forecasts, provided a summary of our analytical scope of work that's coming up next, and invited feedback from customers and other stakeholders on other studies they would like us to consider.

- NWEC was appreciative of our transparency and provided feedback that BPA should study, not only sensitivities that focus on more load being placed on BPA, but also major loss in FCRPS capability, especially in the form of a new Columbia River Treaty hydro operation that diminishes BPA's ability to meet its load service obligations.

- Both Jim Waddell and Scott Levy raised questions and made claims related to the lower snake river projects.

- They asked if we were going to study LSN dam removal in this process. We answered no, we just did this in the CRSO and had E3 conduct these studies recently. Several others in the region have studied this too. They requested that we study it in the Resource Program.

- Scott Levy brought up a few other issues related to a) methane emissions in the reservoirs behind the federal dams, and b) an observation about if BPA had achieved more EE in the past, then BPA would not need the LSN projects anymore.

- Scott did not think we answered his questions enough and we indicated we are happy to chat with him offline (with Josh) at a later date.

- If these issues come up at the Public Interest Quarterly meeting, a recommended response would be to acknowledge that BPA staff have received this feedback and will evaluate these suggestions as we prioritize our work.

Thanks
Ryan

From: Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Sent: Monday, November 27, 2023 8:21 AM
To: Egerdahl,Ryan J (BPA) - PGPR-5 <rjegerdahl@bpa.gov>; Dombeck,Brian J (BPA) - PGPR-5 <bjdombeck@bpa.gov>; Mantifel,Russell (BPA) - MTM-3 <rxmantifel@bpa.gov>; Hayes,Matthew C (BPA) - PGST-5 <mchayes@bpa.gov>
Subject: RP & Markets Prep for PIQ

All-

There is a Public Interest Quarterly meeting next Tuesday, December 5th, with John. I know both the Resource Program and Markets teams have public meetings this week. Unfortunately, I will miss both of them. If there are any high level takeaways out of the meetings that John should be aware of before the meeting let me know and I can forward it on to him. This meeting is the RNs, NWEC, and the like of our interested parties.

I will be OOO Tuesday – Friday, but will share with John, along with other materials, next Monday. If you have a sentence or two that you would like me to share before then feel free to get it to me today.

Thanks Russ and Matt for making yourselves available for the meeting on the 5th. The invite is on your calendar. You can be in-person or on WebEx.

Thanks,
Josh

Josh Warner (he/him/his)
Liaison | Public Interest Organizations
BONNEVILLE POWER ADMINISTRATION
jpwarner@bpa.gov | O: 503-230-5857| C: (b)(6) [redacted]

From: Baskerville,Sonya L (BPA) - AI-WASH
Sent: Monday, December 11, 2023 1:02 PM
To: Warner,Joshua P (BPA) - AIR-7; Pytlak,Erik S (BPA) - PGPW-5; Kaseweter,Alisa D (BPA) - AI-7; Godwin,Mary E (BPA) - LN-7; Leary,Jill C (BPA) - LN-7; Petersen,Christine H (BPA) - EWP-4; Olive,J Courtney (BPA) - LP-7; Calvert,Paula P (BPA) - E-4
Subject: RE: [EXTERNAL] GHG Resource

WAPA's and SWPA's government affairs folks have been watching that issue. They would be interested in keeping up with this. I can make sure to share info with them that comes up from your discussions. Thanks.

Sonya Baskerville
BPA Intergovernmental Affairs and National Relations
(b)(6) [redacted]m

On Dec 11, 2023 3:54 PM, "Leary,Jill C (BPA) - LN-7" <jcleary@bpa.gov> wrote:
Thank you, Alisa!

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Monday, December 11, 2023 12:24 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>; Petersen,Christine H (BPA) - EWP-4 <chpetersen@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Cc: Baskerville,Sonya L (BPA) - AI-WASH <slbaskerville@bpa.gov>
Subject: FW: [EXTERNAL] GHG Resource

Hi all,

I'm passing along this ORNL website on reservoir emissions. It explains the current study (southern US) and makes digestible some pretty technical information on reservoir emissions. I'm also working with Charles on setting up a meeting with DOE WPTO and ORNL where we can swap some information. My vision is they can speak to us about that study and we can share what we hear about reservoir emissions and what might be useful (or not useful) to us in terms of future reservoir studies. Charles is really great and willing to share information, but didn't really know this was something BPA was hearing about. One thing I've flagged for him is that given they are studying a reservoir with expected greater amounts of methane emissions, it would be useful to then look at a reservoir where they would expect to find less substantial emissions.

This topic came up in a workshop on 9505 back in October. It appears that out of the PMAs just BPA plus TVA hear about reservoir emissions. WAPA, SWAPA and SEPA by and large didn't even know it was a thing.

Alisa

From: Scaife, Charles <charles.scaife@ee.doe.gov>
Sent: Wednesday, December 6, 2023 12:19 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Subject: [EXTERNAL] GHG Resource

Hi Alisa,

Hope you're well! I can't remember if I shared this with you, but here's something ORNL put together as part of the work we're funding with them. Let me know how we can make things like this more helpful.

Improving understanding of greenhouse gas emissions from reservoirs | ORNL

Thanks,
Charles

Charles I. Scaife, Ph.D. (*he/him/his*)
Physical Scientist/Technology Manager
Water Power Technologies Office
U.S. Department of Energy
charles.scaife@ee.doe.gov | (b)(6) [redacted] (m)

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energy.gov/water

From: Egerdahl,Ryan J (BPA) - PGPR-5
Sent: Tuesday, December 12, 2023 11:07 AM
To: Kaseweter,Alisa D (BPA) - AI-7
Subject: RE: [EXTERNAL] GHG Resource

Thanks. Scott Levy brought it up again. Glad Josh let you know.

I worked with Charles a bit the other week as he was helping Kieran at NWPPA set up a CC panel for a power conference last week. Erin was on leave so I joined the panel to talk about CC hydro generation forecast method mostly. Ronda from Seattle and Todd White(?) from ACES power were on the panel too. Kieran moderated since Charles got stuck in DC. Or something....

thx

From: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Sent: Monday, December 11, 2023 2:12 PM
To: Egerdahl,Ryan J (BPA) - PGPR-5 <rjegerdahl@bpa.gov>
Subject: FW: [EXTERNAL] GHG Resource

Heard this came up for you recently so thought I would pass it along.

From: Kaseweter,Alisa D (BPA) - AI-7
Sent: Monday, December 11, 2023 12:24 PM
To: Leary,Jill C (BPA) - LN-7 <jcleary@bpa.gov>; Godwin,Mary E (BPA) - LN-7 <megodwin@bpa.gov>; Olive,J Courtney (BPA) - LP-7 <jcolive@bpa.gov>; Calvert,Paula P (BPA) - E-4 <ppcalvert@bpa.gov>; Petersen,Christine H (BPA) - EWP-4 <chpetersen@bpa.gov>; Pytlak,Erik S (BPA) - PGPW-5 <espytlak@bpa.gov>; Warner,Joshua P (BPA) - AIR-7 <jpwarner@bpa.gov>
Cc: Baskerville,Sonya L (BPA) - AI-WASH <slbaskerville@bpa.gov>
Subject: FW: [EXTERNAL] GHG Resource

Hi all,

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This topic came up in a workshop on 9505 back in October. It appears that out of the PMAs just BPA plus TVA hear about reservoir emissions. WAPA, SWAPA and SEPA by and large didn't even know it was a thing.

Alisa

From: Scaife, Charles <charles.scaife@ee.doe.gov>
Sent: Wednesday, December 6, 2023 12:19 PM
To: Kaseweter,Alisa D (BPA) - AI-7 <alkaseweter@bpa.gov>
Subject: [EXTERNAL] GHG Resource

Hi Alisa,

Hope you're well! I can't remember if I shared this with you, but here's something ORNL put together as part of the work we're funding with them. Let me know how we can make things like this more helpful.

Improving understanding of greenhouse gas emissions from reservoirs | ORNL

Thanks,
Charles

Charles I. Scaife, Ph.D. (*he/him/his*)
Physical Scientist/Technology Manager
Water Power Technologies Office
U.S. Department of Energy
charles.scaife@ee.doe.gov | (b)(6) [redacted] (m)

Stay current with the Water Power Technologies Office! Sign up for the monthly Water Wire and our bi-monthly Marine Energy and Hydropower newsletters.

energy.gov/water

From: Mai,Amy E (BPA) - EC-4
Sent: Monday, March 18, 2024 2:44 PM
To: Maslow,Jeffrey J (BPA) - EC-4; Eraut,Michelle L (BPA) - EC-4; Delorenzo,Thomas M (BPA) - EC-4
Subject: RE: FYI

Thanks for sharing Jeff. That is an interesting article. They cite this study: Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis | BioScience | Oxford Academic (oup.com) which provides more background and details.

From: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Sent: Monday, March 18, 2024 2:26 PM
To: Eraut,Michelle L (BPA) - EC-4 <mleraut@bpa.gov>; Delorenzo,Thomas M (BPA) - EC-4 <tdelorenzo@bpa.gov>; Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Subject: FYI

E&E News | Article | Study: Lower Snake River dams match emissions of 1M tons of coal (politicopro.com)

From:	Perry,Marcus I (BPA) - PSW-6
To:	Mai,Amy E (BPA) - EC-4
Cc:	Maslow,Jeffrey J (BPA) - EC-4
Subject:	RE: Reservoirs/methane
Date:	Friday, August 11, 2023 8:01:51 AM

Thank you for the information, Amy and Jeff. This is very helpful.

-Marcus

From: Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Sent: Thursday, August 10, 2023 3:45 PM
To: Perry,Marcus I (BPA) - PSW-6 <miperry@bpa.gov>
Cc: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Subject: RE: Reservoirs/methane

One more piece of info- here is the formal comment response we are using for the Willamette EIS:

> Bonneville Power Administration's analysis in the Draft EIS determined that no replacement resources would need to be procured as part of the generation losses under the EIS alternatives. Regarding methane, some research has shown that reservoirs can emit methane under certain conditions, particularly in tropical climates where there is a lot of plant growth and algae—conditions not found in the Federal Columbia River Power System. Regional entities, including the Northwest Power and Conservation Council and Walla Walla District of the Army Corps of Engineers, have evaluated these studies and generally have found that, in the context of the Federal Columbia River Power System, conditions for low dissolved oxygen concentrations are not prevalent, thus methane gas is generally not an issue.

(Thanks Jeff for providing this!)

From: Mai,Amy E (BPA) - EC-4
Sent: Thursday, August 10, 2023 3:36 PM
To: Perry,Marcus I (BPA) - PSW-6 <miperry@bpa.gov>
Cc: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Subject: RE: Reservoirs/methane

Hi Marcus,

I have a couple of links below that provide helpful background on the info of potential methane production in reservoirs. I'm copying Jeff Maslow here, as he might have additional suggestions (he provided these links for our Willamette process). I'm happy to discuss further if you'd like. Generally, the study from WSU looked at reservoirs in places like Ohio, with greater volumes of plants in the reservoirs than we have in the northwest, and thus more decaying vegetation. The Council reviewed the study and noted that the federal hydropower system is less likely to produce the kind of conditions that would result in increased methane.

> Columbia and Snake River Reservoirs Not Associated with High Greenhouse Gas Emissions (nwcouncil.org)
>
> Columbia River System Operations Final Environmental Impact Statement: Appendix G (Air Quality and Greenhouse Gases) [Please see Appendix G pages G-5-13 to G-5-20 for a survey of the relevant literature including the same study cited in the WVS EIS: Beaulieu et al. 2018, which relies on data collected at a lake in Ohio.]

Thanks-
Amy

From: Perry,Marcus I (BPA) - PSW-6 <miperry@bpa.gov>
Sent: Thursday, August 10, 2023 11:36 AM
To: Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Subject: RE: Reservoirs/methane

Hi Amy. Thank you for the follow up. That would be very helpful. I keep hearing this used as an argument from anti-dam folks and haven't had a real great understanding of what the magnitude of that might be.

-Marcus

From: Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Sent: Thursday, August 10, 2023 11:34 AM

To: Perry,Marcus I (BPA) - PSW-6 <miperry@bpa.gov>
Subject: Reservoirs/methane

Hi Marcus,

Would you like me to send you some language we pulled from the CRSO EIS regarding methane? We addressed it in CRSO, and didn't consider it a significant impact. It came up again recently on the Willamette EIS, so we had pulled it out. I can see what I can find if that's helpful.

Thanks-
Amy

Amy Mai
Environmental Protection Specialist | Environmental Planning & Analysis (EC-4)
BONNEVILLE POWER ADMINISTRATION
aemai@bpa.gov | O: 503-230-7349 |

From: Maslow,Jeffrey J (BPA) - EC-4
To: Mai,Amy E (BPA) - EC-4
Subject: RE: Reservoirs/methane
Date: Thursday, August 10, 2023 3:42:37 PM

Excellent answer—thanks Amy. If I were to add anything, it'd be the team-vetted suggested comment response to the Willamette EIS comment raising the issue:

> Bonneville Power Administration's analysis in the Draft EIS determined that no replacement resources would need to be procured as part of the generation losses under the EIS alternatives. Regarding methane, some research has shown that reservoirs can emit methane under certain conditions, particularly in tropical climates where there is a lot of plant growth and algae—conditions not found in the Federal Columbia River Power System. Regional entities, including the Northwest Power and Conservation Council and Walla Walla District of the Army Corps of Engineers, have evaluated these studies and generally have found that, in the context of the Federal Columbia River Power System, conditions for low dissolved oxygen concentrations are not prevalent, thus methane gas is generally not an issue.

From: Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Sent: Thursday, August 10, 2023 3:36 PM
To: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Subject: FW: Reservoirs/methane

Marcus asked about this in the AECAT meeting today, and I remembered we had just discussed this, so I offered to send more info.

From: Mai,Amy E (BPA) - EC-4
Sent: Thursday, August 10, 2023 3:36 PM
To: Perry,Marcus I (BPA) - PSW-6 <miperry@bpa.gov>
Cc: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Subject: RE: Reservoirs/methane

Hi Marcus,

I have a couple of links below that provide helpful background on the info of potential methane production in reservoirs. I'm copying Jeff Maslow here, as he might have additional suggestions (he provided these links for our Willamette process). I'm happy to discuss further if you'd like. Generally, the study from WSU looked at reservoirs in places like Ohio, with greater volumes of plants in the reservoirs than we have in the northwest, and thus more decaying vegetation. The Council reviewed the study and noted that the federal hydropower system is less likely to produce the kind of conditions that would result in increased methane.

Columbia and Snake River Reservoirs Not Associated with High Greenhouse Gas Emissions (nwcouncil.org)

Columbia River System Operations Final Environmental Impact Statement: Appendix G (Air Quality and Greenhouse Gases) [Please see Appendix G pages G-5-13 to G-5-20 for a survey of the relevant literature including the same study cited in the WVS EIS: Beaulieu et al. 2018, which relies on data collected at a lake in Ohio.]

Thanks-
Amy

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Sent: Thursday, August 10, 2023 11:36 AM
To: Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Subject: RE: Reservoirs/methane

Hi Amy. Thank you for the follow up. That would be very helpful. I keep hearing this used as an argument from anti-dam folks and haven't had a real great understanding of what the magnitude of that might be.

-Marcus

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Sent: Thursday, August 10, 2023 11:34 AM
To: Perry,Marcus I (BPA) - PSW-6 <miperry@bpa.gov>
Subject: Reservoirs/methane

Hi Marcus,

Would you like me to send you some language we pulled from the CRSO EIS regarding methane? We addressed it in CRSO, and didn't consider it a significant impact. It came up again recently on the Willamette EIS, so we had pulled it out. I can see what I can find if that's helpful.

Thanks-
Amy

Amy Mai
Environmental Protection Specialist | Environmental Planning & Analysis (EC-4)
BONNEVILLE POWER ADMINISTRATION
aemai@bpa.gov | O: 503-230-7349 |

From:	Maslow,Jeffrey J (BPA) - EC-4
To:	Mai,Amy E (BPA) - EC-4; Biegel,Sarah T (BPA) - EC-4; Marker,Doug R (BPA) - AIR-7; Kintz,Jesse H (BPA) - PG-5; Spear,Daniel J (BPA) - PGB-5
Subject:	RE: DRAFT BPA Suggestions for Power & Transmission Responses to Draft EIS Comments - Request for Review of First Draft (Before Sending to OGC)
Date:	Tuesday, April 25, 2023 3:34:22 PM
Attachments:	fs-201901-The-carbon-free-footprint-of-BPA-hydropower-supply.PDF

Thanks Amy. I'm also of the mind that we should point out the best available information on the methane issue. I've attached a BPA fact sheet, for example, that provides a good basis for a suggested response, which mentions relevant studies: "**Some research has shown that reservoirs can emit methane under certain conditions, particularly in tropical climates where there is a lot of plant growth and algae—conditions not found in the Federal Columbia River Power System.**"

The Corps has made clear that it's their sole discretion what goes into the final responses. So I think providing this is well within our purview and would advocate for providing this suggested answer and making the Corps aware of their own studies on this issue, especially where they might be apt to only say "comment noted." I'll plan to suggest some of this language in the next iteration of the comments to allow OGC to weigh in on whether we include it in our suggested responses. Thanks.

From: Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>
Sent: Tuesday, April 25, 2023 7:41 AM
To: Biegel,Sarah T (BPA) - EC-4 <stbiegel@bpa.gov>; Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>; Marker,Doug R (BPA) - AIR-7 <drmarker@bpa.gov>; Kintz,Jesse H (BPA) - PG-5 <jhkintz@bpa.gov>; Spear,Daniel J (BPA) - PGB-5 <djspear@bpa.gov>
Subject: RE: DRAFT BPA Suggestions for Power & Transmission Responses to Draft EIS Comments - Request for Review of First Draft (Before Sending to OGC)

Hi All,

Thanks for putting this together Jeff. Overall I think this is looking really good. I agree with Sarah's edits, and I share your concern that the response to Eric Strickler should likely be around islanding rather than dam removal. For one of Sarah's edits on the potential for methane production at reservoirs, I would just note that I thought it might be helpful to reiterate the information that reservoirs in the northwest are generally not thought to have the same issues (not as much algal production, etc.). It's not necessarily BPA's issue, as the Corps is operating the dams, but I suggested it in the meeting Jeff and I had with Margaret Ryan, who is coordinating the Corps edits. We're hearing this point made in several forums (including Provider of Choice last week), and I think it doesn't hurt to include the science-based references in the record. I don't feel strongly about it, but I think it doesn't hurt to add that in.

Thanks-
Amy

From: Biegel,Sarah T (BPA) - EC-4 <stbiegel@bpa.gov>
Sent: Monday, April 24, 2023 7:38 PM

To: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>; Marker,Doug R (BPA) - AIR-7 <drmarker@bpa.gov>; Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>; Kintz,Jesse H (BPA) - PG-5 <jhkintz@bpa.gov>; Spear,Daniel J (BPA) - PGB-5 <djspear@bpa.gov>
Subject: RE: DRAFT BPA Suggestions for Power & Transmission Responses to Draft EIS Comments - Request for Review of First Draft (Before Sending to OGC)

Hi all,

Attached are comments from me. Thank you, Jeff, for taking a first crack at these responses. I do think that there are some opportunities here for Bonneville to state the power production is a residual benefit for the Willamette Valley System – i.e., other purposes are optimized first and then power is addressed. Please let me know if you have any questions or concerns with my comments.

Thanks,
Sarah

Sarah Thompson Biegel
NEPA Compliance Officer

Bonneville Power Administration
905 NE 11th Avenue
Portland, OR 97232
(503) 230-3920

From: Maslow,Jeffrey J (BPA) - EC-4 <jjmaslow@bpa.gov>
Sent: Monday, April 24, 2023 5:54 PM
To: Marker,Doug R (BPA) - AIR-7 <drmarker@bpa.gov>; Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>; Kintz,Jesse H (BPA) - PG-5 <jhkintz@bpa.gov>; Biegel,Sarah T (BPA) - EC-4 <stbiegel@bpa.gov>; Spear,Daniel J (BPA) - PGB-5 <djspear@bpa.gov>
Subject: RE: DRAFT BPA Suggestions for Power & Transmission Responses to Draft EIS Comments - Request for Review of First Draft (Before Sending to OGC)

With my apologies to Dan, I forgot to add him moments ago when I first hit send, and have now attached the subject document to include him in this first round of review, thanks!

From: Maslow,Jeffrey J (BPA) - EC-4
Sent: Monday, April 24, 2023 5:51 PM
To: Marker,Doug R (BPA) - AIR-7 <drmarker@bpa.gov>; Mai,Amy E (BPA) - EC-4 <aemai@bpa.gov>; Kintz,Jesse H (BPA) - PG-5 <jhkintz@bpa.gov>; Biegel,Sarah T (BPA) - EC-4 <stbiegel@bpa.gov>
Subject: DRAFT BPA Suggestions for Power & Transmission Responses to Draft EIS Comments - Request for Review of First Draft (Before Sending to OGC)

Hi Doug, Amy, Jesse, and Sarah. Requesting a lightning-round review of our draft recommended responses to the hydropower- and transmission-related comments on the draft WV PEIS.

I've received revised responses from the Corps that I've incorporated into the attached word doc. I've discovered that Doug's suggested language citing the disposition study could be plugged in to respond to other comments, too. (Thanks Doug for crafting it and sending along!)

And please take a close look at the last comment row in this bunch regarding reservoir methane because it's a bit squirrely and could use a close look from this team. I'm not sure how far we want to wade into that issue. Minimally, I think we should ensure that the Final EIS cites to and relies on the best available scientific information, which the proposed comment response outlines.

Please share your thoughts/wordsmithing by **2PM tomorrow, April 25th,** if you can get to these by then. Jesse and I will be reviewing together tomorrow afternoon, and then we'll loop OGC on the more polished product from there. The plan is to try to send this to the Corps, after OGC reviews, before the end of the week. There will be another opportunity to review this before it goes out.

Thanks,
Jeff

Jeff Maslow
Senior Environmental Protection Specialist
Environmental Planning and Analysis
BONNEVILLE POWER ADMINISTRATION
503-230-3928

Fact Sheet

January 2019

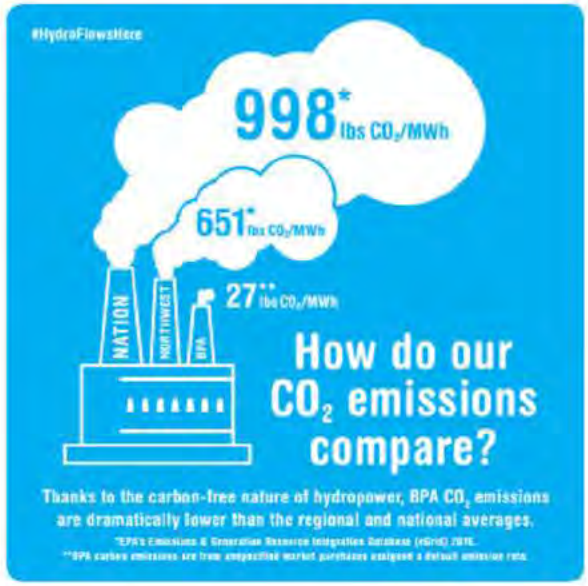
The carbon-free footprint of BPA's hydropower supply

The Columbia River produces more hydropower than any other river in North America. BPA plays a unique role in the sale and distribution of this renewable resource, giving its customers access to 22,000 MW of flexible, reliable, carbon-free hydropower across 15,000 miles of transmission lines.

As a nonprofit wholesale power marketer and transmission provider, BPA sells its products and services to Northwest utilities at the cost of production. The power BPA sells is produced by 31 federally-owned hydroelectric dams that are operated by the U.S. Army Corps of Engineers and Bureau of Reclamation. BPA also markets the output of the 1,200 MW Columbia Generating Station, a nuclear plant in Washington that is owned and operated by Energy Northwest.

The federal dams in the Columbia River Basin and the Columbia Generating Station produce enough carbon-free power to meet nearly 30 percent of the Northwest's electricity needs.

While the federal dams and Columbia Generating Station produce carbon-free power, a small amount of carbon emissions is associated with the federal system. This is because BPA sometimes purchases power on the open market, and that power has a certain amount of carbon emissions attributed to it. BPA uses these purchases to balance resources and meet its customers' demands beyond what the federal system can provide. But even with these market purchases, the emissions associated with BPA's system are significantly lower than the regional average.



Where does the carbon in BPA's resource mix come from?

The power BPA purchases on the wholesale market cannot be attributed to a specific resource. These unspecified market purchases, which are assigned a default emissions factor, make up about 3 to 12 percent of BPA's total annual power supply. The difference from year to year is largely due to the significant streamflow variability in the Columbia River Basin.

BPA typically purchases more power in the market during years when there is less water. Other factors that

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BPA-2024-00643-F 0330

contribute to BPA's market purchases include the availability of the Columbia Generating Station and whether it experiences an extended outage, and fish operations that are designed to help endangered fish migrate to the ocean. These operations call for spilling water past dams instead of sending it through turbines, which reduces generation.

The power BPA sells is not attributed to individual resources. The entire federal system, including market purchases, is treated as a single source. Therefore, the federal system is collectively assigned an annual emissions factor, which is measured as pounds or metric tons of carbon dioxide per megawatt-hour.

BPA RESOURCE MIX

Between 3 and 12 percent of BPA's annual fuel mix comes from market purchases, depending on the water year and other factors. 2010 was a low water year, while 2016 was a higher-than-average water year.

Maximizing the value of the region's carbon-free assets

BPA is taking steps to ensure its long-term commercial success by addressing industry challenges that could affect its ability to remain a cost-effective power supplier. BPA's strategy includes improving its competitive position by reducing costs, while also maximizing revenues from sales of surplus federal power. To do this, BPA is focused on new market opportunities for clean capacity resources.

The West Coast states are setting ambitious carbon reduction goals and aggressively pursuing energy policies that put a price on carbon. The Northwest's existing hydropower resources can play an essential role in meeting these goals most cost-effectively while maintaining safe, reliable service. Policies that put a price on carbon could increase the value of BPA's surplus sales because of an increased premium for low-carbon power.

For example, California's existing cap-and-trade program has created value for low-carbon generation. Demand for BPA's low-carbon power has resulted in surplus sales to California at a premium over other wholesale market prices. The premium BPA earns from these surplus sales is used to offset its costs, thereby lowering power rates for the agency's principal customer base, which is made up primarily of Northwest public utilities.

WHAT ABOUT OTHER GREENHOUSE GASES ASSOCIATED WITH THE FEDERAL SYSTEM?

Sulfur hexafluoride: SF_6 is a greenhouse gas commonly used as an insulator in high-voltage electrical equipment, including in BPA's transmission system. Since 1999, BPA has led the nation as a charter partner in the Environmental Protection Agency's SF_6 Emission Reduction Partnership for Electric Power Systems. BPA's 2017 emissions rate — the ratio of SF_6 emissions relative to total amount of SF_6 contained in electrical equipment — was 0.53 percent. That is well below even the EPA partnership's latest reported average of 1.9 percent.

Methane: The conversion of water into power does not produce methane, but some research has shown that reservoirs can emit methane under certain conditions, particularly in tropical climates where there is a lot of plant growth and algae — conditions not found in the Federal Columbia River Power System. Both the U.S Army Corps of Engineers and the Northwest Power and Conservation Council concluded that the reservoirs in the Columbia and Snake rivers do not emit a measurable level of methane.

CARBON PRICING PROGRAMS AND BPA

Carbon pricing programs, such as California's cap-and-trade program, require participants to purchase carbon allowances for power that they either generate in California or import into California. If BPA were to import power into California, the requirement to purchase allowances would apply due to the emissions factor that is assigned to the federal system as a whole (arising from the small amount of market purchases BPA makes). However, carbon allowances are considered a state tax by the U.S. Department of Energy, BPA and other federal agencies. Federal agencies cannot pay state taxes unless Congress specifically authorizes it. Therefore, BPA currently cannot purchase these carbon allowances. As an alternative, BPA uses third-party arrangements to sell to entities who take BPA's power into the California market and who pay for the carbon allowances. But these arrangements are costly, inefficient and raise complications. BPA is exploring options for future participation in markets that put a price on carbon.

BONNEVILLE POWER ADMINISTRATION
DOE/BP-4899 • January 2019

From:	Maslow,Jeffrey J (BPA) - EC-4
To:	Marker,Doug R (BPA) - AIR-7; Mai,Amy E (BPA) - EC-4; Kintz,Jesse H (BPA) - PG-5; Biegel,Sarah T (BPA) - EC-4
Subject:	DRAFT BPA Suggestions for Power & Transmission Responses to Draft EIS Comments - Request for Review of First Draft (Before Sending to OGC)
Date:	Monday, April 24, 2023 5:52:13 PM
Attachments:	WVS_PEIS_Power_and_Transmission_Comment_Responses_BPA_4-24-23.docx

Hi Doug, Amy, Jesse, and Sarah. Requesting a lightning-round review of our draft recommended responses to the hydropower- and transmission-related comments on the draft WV PEIS.

I've received revised responses from the Corps that I've incorporated into the attached word doc. I've discovered that Doug's suggested language citing the disposition study could be plugged in to respond to other comments, too. (Thanks Doug for crafting it and sending along!)

And please take a close look at the last comment row in this bunch regarding reservoir methane because it's a bit squirrely and could use a close look from this team. I'm not sure how far we want to wade into that issue. Minimally, I think we should ensure that the Final EIS cites to and relies on the best available scientific information, which the proposed comment response outlines.

Please share your thoughts/wordsmithing by **2PM tomorrow, April 25th,** if you can get to these by then. Jesse and I will be reviewing together tomorrow afternoon, and then we'll loop OGC on the more polished product from there. The plan is to try to send this to the Corps, after OGC reviews, before the end of the week. There will be another opportunity to review this before it goes out.

Thanks,
Jeff

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Senior Environmental Protection Specialist
Environmental Planning and Analysis
BONNEVILLE POWER ADMINISTRATION
503-230-3928

Commenter	Main Comment	Corps DRAFT Response	BPA DRAFT Response
John Cissel	It is imperative that USACE do everything it can to maximize hydropower. It is widely recognized that we are in a climate emergency and that we need to decarbonize our economy. According to state of Oregon official reports over 70% of total energy consumed in Oregon comes from fossil fuels. To convert all or most of that to non-fossil electricity requires a four- or five-fold increase in noncarbon electricity generation. That is a monumental challenge and we can not afford to lose any hydropower. Please maximize hydropower.	The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation.	**The Corps acknowledges comments on the future role of hydropower production in the Willamette Valley System. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate the value of the power that they generate.**
Jim Walsh	The loss of the hydro-electric production that powers 14,333 homes is ridiculous to say the least…. Also reducing hydropower generation will I'm confident cause rates to rise.	Comment noted. The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation.	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in**

			the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.
Ronald Edwards	On 15 August 2006 I was involved in "FOS/GPR ISLAND EVENT", which further identifies the need for all generators running when something happens. There is no excuse to put the citizens power in jeopardy because of ill thought out programs or policies. The operating Generators prevented an outage. I have submitted the three documents I have mentioned to the Corps of Engineers.	The Corp analyzes potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation. When making its decision based on analyses in an EIS, CEQ regulations state, "An agency may discuss preferences among alternatives based on relevant factors including economic and technical considerations and agency statutory missions…An agency shall identify and discuss all such factors…which were balanced by the agency in making its decision…" (40 CFR 1505.2)b)). The Corps is required under Congressional mandate to manage the Willamette Valley System for eight authorized purposes as described in Chapter 1 and Chapter 2 of the EIS. The analyses demonstrate the level of	**Integration with the overall transmission system provides reliable local service without relying on the hydropower generation at Green Peter and Foster Dams for reliability. Bonneville Power Administration would continue to meet the applicable power and transmission reliability requirements under EIS alternatives that limit the availability of generation at those dams. In addition, as directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate all potential impacts to power and transmission reliability. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**

		effect that would occur to each authorized purpose anticipated under each alternative. Corps leadership will assess these effects analyses to make an informed decision about a selected alternative, which will necessarily involve consideration of effects to, and a balance of those effects on, all authorized purposes.	
Ronald Edwards	I think much thought needs to be expended in figuring this out. People need to consider these projects were funded for important reason and everyone can see much industrial growth and population growth because of reliable power has occurred.	Comment noted.	**As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate all potential impacts to power and transmission reliability. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Hal Smith	Unless and until alternate energy supplies are actually on line it is foolish to select any alternative that would diminish current hydro-electric sources.	The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation.	**The Corps acknowledges comments on the future role of hydropower production in the Willamette Valley System. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate the value of the power that they generate.**
Eric Strickler	requires the additional of diesel generators to be used where hydropower generation is stopped,	The Corp analyzed potential impacts to hydropower production under each of the alternatives including	*[Corps comment doesn't appear to address the core concern. This could be interpreted as raising an issue with islanding service*

		the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation.	*evaluated in the draft EIS and not dam removal, as the Corps response appears to assume.]*
Ronald Edwards	My concerns are based on the potential harm that will be caused with voltage control issues and the potential harms which will occur on the operations of the electrical systems undervoltage protection systems. I also provided a document written to prevent a "blackout" or "voltage emergency'' and my question is, have these questions and concerns been addressed? I am willing to discuss my concerns so as to prevent a low voltage high reactive current trip causing a power outage and potential harm to the equipment being used to support life.	The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation. When making its decision based on analyses in an EIS, CEQ regulations state, "An agency may discuss preferences among alternatives based on relevant factors including economic and technical considerations and agency statutory missions…An agency shall identify and discuss all such factors…which were balanced by the agency in making its decision…" (40 CFR 1505.2)b)). The Corps is required under Congressional mandate to manage the Willamette Valley System for eight authorized purposes as described in Chapter 1 and Chapter 2 of the EIS. The analyses demonstrate the level of effect that would occur to each	**Integration with the overall transmission system provides reliable local service without relying on the hydropower generation at Green Peter and Foster Dams for reliability. Bonneville Power Administration would continue to meet the applicable power and transmission reliability requirements under EIS alternatives that limit the availability of generation at those dams. In addition, as directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate all potential impacts to power and transmission reliability. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**

		authorized purpose anticipated under each alternative. Corps leadership will assess these effects analyses to make an informed decision about a selected alternative, which will necessarily involve consideration of effects to, and a balance of those effects on, all authorized purposes.	
Ronald Edwards	I am concerned because as a care giver and understanding what some people need that are fragile (health issues) and needing electrical equipment to support life.	The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation. When making its decision based on analyses in an EIS, CEQ regulations state, "An agency may discuss preferences among alternatives based on relevant factors including economic and technical considerations and agency statutory missions...An agency shall identify and discuss all such factors...which were balanced by the agency in making its decision..." (40 CFR 1505.2)b)). The Corps is required under Congressional mandate to manage the Willamette Valley System for eight authorized	**Integration with the overall transmission system provides reliable local service without relying on the hydropower generation at Green Peter and Foster Dams for reliability. Bonneville Power Administration would continue to meet the applicable power and transmission reliability requirements under EIS alternatives that limit the availability of generation at those dams. In addition, as directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate all potential impacts to power and transmission reliability. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**

		purposes as described in Chapter 1 and Chapter 2 of the EIS. The analyses demonstrate the level of effect that would occur to each authorized purpose anticipated under each alternative. Corps leadership will assess these effects analyses to make an informed decision about a selected alternative, which will necessarily involve consideration of effects to, and a balance of those effects on, all authorized purposes.	
Eric Rosso	Given the growing need for clean sources of energy, (and that hydro is the least invasive, least damaging, and least toxic form of renewable energy), I would think projects that incorporated improved (natural) passages, as well as hydro-electric generating facility would get greater consideration than they do.	The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and will be considered prior to a final decision when balancing all impacts associated with alternative implementation.	*[Corps response sufficient?]*
Jody Marshall	1.7.2 Hydropower - I suggest adding that BPA is evaluating4 the viability of economical power generation at these WVS dams. The dams in the WVS generate a small amount of power relative to their operating costs. Bonneville Power Administration is evaluating the viability of economical power generation from these dams as it also seeks biologically effective and technologically feasible solutions for protecting, mitigating and enhancing fish and wildlife in the basin.	Comment noted. BPA was heavily involved and developed most of the primary analysis for this effort, so this consideration is part of the overall analysis. Under the no action condition, hydropower still has viability.	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the**

			incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.
Jennfier Fairbrother, Native Fish Society	The hydropower cost is likely to increase as additional fish protection is implemented. Does the Corps contend that Congress wanted to impose an undue burden on taxpayers by disallowing the Corps to make rational decisions about the economic viability of hydropower production? Does the Corps also contend that Congress would not have allowed the Corps to incorporate new information in planning a 30-year operations plan that is intended to improve fish populations? By refusing to consider the removal of hydropower at some (not all) dams, the Corps has not evaluated the full suite of measures to effectively provide fish passage.	The Corp does not propose, address, or analyze the disposal of the hydropower purpose in its EIS because this action is not within the scope of the proposed action. The possibility of the disposal of the hydropower purpose is being considered in other on-going studies. However, impacts to all of the Corps' Congressionally mandated purposes have been analyzed in the EIS including effects from the proposed action and alternatives on fish, hydropower, water supply, flood risk management, etc.	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Chris Mercier, Confederated Tribes of Grand Ronde	It is impossible to tell from the DEIS how the Corps weighed hydropower production when developing the alternatives. The final EIS should clearly spell out the maximum drawdown possible in depth, duration, and seasonality that would benefit the species. The final EIS should include a discussion of how much hydropower the Corps aims to produce under each alternative and how that production impacts salmonids.	Please see Appendix A, Alternatives Development, section 1.1.1 for information on how hydropower influenced the development of the alterantives. The Corp analyzed potential impacts to hydropower production under each of the alternatives including the proposed action. Impacts to hydropower production have been identified and	*[Corps response sufficient?]*

		will be considered prior to a final decision when balancing all impacts associated with alternative implementation.	
Chris Mercier, Confederated Tribes of Grand Ronde	Because hydropower production drives many of the Corps' operating decisions, the final EIS should provide an honest assessment of the value of hydropower. The description of hydropower in the DEIS leaves out the punchline: Upper Willamette River Basin hydropower does not make economic sense. Under the preferred alternative, the dams would lose a stunning $714 million over 30 years because the cost of generation far outweighs the revenue.13 The DEIS stated there "would be a $939 million reduction in Net Present Value to -$714 million." Killing salmon to lose money deserves a deeper analysis. The final EIS should fully describe the impact on ratepayers and spell out alternatives for a more logical approach... The final EIS should contain a detailed evaluation of the cost of the hydropower and the impact on ratepayers, considering a range of additional fish mitigation measures proposed in the DEIS and the upcoming BiOp. The Corps fails to disclose the low economic value of hydropower, which prevents a fair assessment of hydropower's benefits versus the tremendous harm to fish and wildlife.	The primary drivers for the loss to hydropower identified under the Preferred Alterantive is due to the cost associated with implementing the Preferred Alternative. The costs and benefits associated with hydropower under pre-injunction operations are identified in the No Action system, which does not indicate operating at a loss.	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, dispositions studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Lauren	Results of power disposition studies	Needs to be reassigned	**The Corps acknowledges comments**

Henderson, ODFW	directed by WRDA may influence the feasibility of potential WVS fish passage solutions and related water management. The USACE should coordinate with Regional WATER partners to share power disposition study results once they are available and to collaboratively determine how those results might expand options for providing fish passage, including opportunities to eliminate the need for re-regulating facilities in the basin. For example, the Preferred Alternative includes a deep drawdown of Cougar Reservoir to the diversion tunnel to provide fish passage. A large amount of sediment will be mobilized with this operation, resulting in economic and ecological impacts, including impacts to fisheries and the recently restored areas downstream of the dam. Robust evaluations of passage using the regulating outlet, and a turbine-less penstock if power is deauthorized, should be conducted to determine whether these options could provide similar passage survival to that of the diversion tunnel, but with fewer impacts. If a drawdown to the diversion tunnel remains the preferred passage solution, it will be critical to implement "lessons learned" from earlier sediment mobilization events resulting from drawing down Cougar Reservoir to the tunnel.		**suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, dispositions studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Michael Deen,	As PPC has urged in previous comments,	This comment requests information	**The Corps acknowledges comments**

Public Power Council	the final EIS must include consideration for potential deauthorization of power or significant cost reallocations between project functions. Failure to do so would frustrate the clear intent of Congress in the recent 2022 WRDA legislation and have the potential to make this entire EIS effort for the Willamette Valley System functionally moot. Completing the disposition studies on time and considering their results in the final EIS will have multiple benefits, including the potential for more cost-effective juvenile salmon passage options, reasonable basis for the reallocation of costs between flood control and power where appropriate, and allow for BPA to make informed investment decisions for the projects.	that is out of scope for the EIS analyses. See Final EIS Chapter 1 and Chapter 2 for descriptions of the scope of analyses, purpose and need statement, proposed action, range of alternatives, and resources analyzed because of a potential for impacts under any of the alternatives. Agencies are not required to analyze or address topics that are not within its scope of review as determined through internal and public scoping processes and documented in the project record. The commenters concerns are being considered in the on-going disposition study.	**suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, dispositions studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Lindsey Hutchison, Willamette Riverkeeper	As required by Congress, the Corps must study deauthorizing hydropower at some or all of the Willamette System dams.40 The draft PEIS does not analyze this possibility. The Corps must include its plans and timelines for studying hydropower deauthorization of the Willamette Valley System dams and, specifically, how the agency will incorporate the findings from these studies into the Operations and Maintenance Plan. The Corps may find that deauthorizing hydropower at the Willamette Valley Systems dams is the most practical option given that all of the alternatives the Corps is considering would create "long-term, major, adverse effects	This comment requests information that is out of scope for the EIS analyses. See Final EIS Chapter 1 and Chapter 2 for descriptions of the scope of analyses, purpose and need statement, proposed action, range of alternatives, and resources analyzed because of a potential for impacts under any of the alternatives. Agencies are not required to analyze or address topics that are not within its scope of review as determined through internal and public scoping processes and documented in the project record. The commenters	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, dispositions studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the**

	on economic viability of WVS power generation."41 If true, the Corps must put in place a plan to begin decommissioning hydropower at all or some of the dams and include its plan in the updated Operations and Maintenance Plan to ensure there is not a multi-decade delay in implementing these necessary actions. If the Corps determines that deauthorizing hydropower at some or all of the dams is the practical choice, the Corps must also consider removing hydropower-specific dams, including Big Cliff, Dexter, and Foster dams. The Corps should also consider placing dams into caretaker status.	concerns are being considered in the on-going disposition study.	**final PEIS and will inform the preferred alternative.**
Ronald Edwards	The point of all this is to introduce what is not spoken of thus far. First on the discussion is the letter from the NORTHWEST POWER POOL (WILLAMETTE VALLEY/SOUTHWEST WASHINGTON AREA VOLTAGE STABILITY OPERATINGPROCEDURE). This talks about the drop in voltage in this area with voltage instability from cold weather loads with reduced local area generation, the primary concern is to prevent a blackout or voltage emergency. This simply means with the electrical loads being inductive in nature driving the voltage down as loads increase beyond 7,000 megawatts the risk of a UVLS (Under Voltage Load Shedding Relays) operation which will cause a black out. I could spend hours going into the weeds but I believe this document has been	[Corps: NEED TO ADDRESS THIS LETTER. RESPOND WITH - Familiar with this letter? If so, does the Corps consider it to have merit? - KATE]	**Integration with the overall transmission system provides reliable local service without relying on the hydropower generation at Green Peter and Foster Dams for reliability. Bonneville Power Administration would continue to meet the applicable power and transmission reliability requirements under EIS alternatives that limit the availability of generation at those dams. In addition, as directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, disposition studies for the power purpose of the Willamette dams that will evaluate all potential impacts to power and transmission reliability. The Corps' schedule for the disposition studies coincides with**

	distributed. The other document is (WILSSWA VOLTAGE STABILITY 1998-1999), I had not seen an amended document or documents before I retired in 2013. In summary the voltage in the Foster area will drop to levels that will require action to prevent a trip during a cold weather event and high loads, period. I have seen this already which I will discuss in the next paragraph.During the 1990's there was a cold weather event and the voltage was getting quite low so the voltage control was increased on the generating units that were condensed but that was not enough. The only course of action left was to take the generating units from condense to generate and to add positive reactivity and the voltage was restored to a safe level. I was the operator on duty and I had two Green Peter units running. I later discussed this operation with two BPA engineers at Foster project and they agreed.		**the schedule for the final PEIS and will inform the preferred alternative.**
Michael Deen, PPC	PPC is fundamentally concerned that among the analyzed alternatives, there is no path for maintaining economic hydropower production in the Willamette Valley System. The Draft EIS analysis shows massive costs to regional ratepayers, but as described further in these comments, even these costs are likely to be drastically understated. This concern highlights the importance of the Corps' fulfilling in a timely manner its Congressional mandate from the 2022 Washington Resources	This comment requests information that is out of scope for the EIS analyses. See Final EIS Chapter 1 and Chapter 2 for descriptions of the scope of analyses, purpose and need statement, proposed action, range of alternatives, and resources analyzed because of a potential for impacts under any of the alternatives. Agencies are not required to analyze or address topics that are not within its scope	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, dispositions studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the**

	Development Act (WRDA) that directs the Corps to conduct disposition studies for power deauthorization of the Willamette Valley System.	of review as determined through internal and public scoping processes and documented in the project record. The commenters concerns are being considered in the on-going disposition study.	**incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Brian Posewitz, WaterWatch of Oregon	Given the potential benefits to fish from both drawdowns and stored water, storage for power production should be de-emphasized, particularly since power production appears to provide limited economic benefit.	Comment noted	**The Corps acknowledges comments suggesting that commercial hydropower may be of limited economic viability under alternatives examined in the Draft PEIS. As directed by Congress in the Water Resources Development Act of 2022, the Corps is undertaking, in consultation with the Bonneville Power Administration, dispositions studies for the power purpose of the Willamette dams. These studies will take into account the measures proposed in the preferred alternative, including the incorporation of the near term operations as described in the preferred alternative. The Corps' schedule for the disposition studies coincides with the schedule for the final PEIS and will inform the preferred alternative.**
Lindsay Hutchison, Willamette Riverkeeper	Alternative 2A would contribute to an overall increase in annual hydropower generation by 4 aMW, which could power 3,185 households annually. In contrast, Alternative 5 would decrease annual hydropower production by 18 aMW, enough to power 14,334 households annually. This equates to Alternative 2A providing 22 aMW more power than Alternative 5. Nevertheless, both	Comment noted	**The EIS cites a study (Beaulieu et al. 2018) with relatively high reported rates of methane that are among the highest ever reported at a reservoir; however, this reporting is based on samples taken at a site (Harsha Lake in Ohio) with different characteristics than the reservoirs of the Willamette River System. In addition, the Corps has previously acknowledged the data and knowledge gaps that need to be**

	alternatives would stress the long-term viability of Willamette System power generation; however, there are viable, cost-effective options for power replacement services, such as properly-sited wind and distributed solar, in addition to demand reduction efforts through energy efficiency and conservation. Further, hydropower is neither a carbon-neutral nor zero-emission energy source. Decomposing organic material built up in dam-created reservoirs produces the potent greenhouse gas methane, more so than natural lakes.46 Water level drawdowns lower pressure in reservoirs and can lead to greater methane release.47		**pursued to fully assess and verify methane emissions from hydroelectric reservoirs (*See* Columbia River System Environmental Impact Statement, Appendix G, pp. G-5-13 to G-5-20). Regional entities, including the Northwest Power and Conservation Council and Walla Walla District of the Army Corps of Engineers, have evaluated the studies that suggest a potential global underreporting of reservoir methane emissions and generally find that, in the context of the Federal Columbia River Power System, conditions for low dissolved oxygen concentrations are not prevalent, thus methane gas is generally not an issue** (https://www.nwcouncil.org/news/columbia-and-snake-river-reservoirs-not-associated-high-greenhouse-gas-emissions/).