



The Climate Registry

**State of the Science: GHG Emissions from Hydro Reservoirs
A Dialogue with Experts**

EXECUTIVE SUMMARY

**17 September 2009
Montreal, QC**

The Climate Registry is a nonprofit organization governed by 41 U.S. states, the District of Columbia, 13 Canadian provinces and territories, six Mexican states and four Native Sovereign Nations and is dedicated to consistent, transparent and public reporting of high quality greenhouse gas (GHG) emissions data in one unified North American registry. More than 350 companies and organizations have joined The Registry to quantify, publicly report, and manage their emissions using our robust and transparent protocols and reporting methods.

In June 2009, The Climate Registry completed a lengthy process of developing a greenhouse gas accounting protocol for the electric power sector (EPS Protocol), which included guidance for reporting emissions associated with hydro reservoirs. This EPS Protocol is available at <http://www.theclimateresistry.org/resources/protocols/electric-power-sector-protocol/>. Given the evolving understanding of emissions from these sources, The Registry's Board of Directors requested that staff convene a workshop to provide an overview of the current state of the science with respect to measuring emissions from hydro reservoirs, and demonstrate the complexity and range of issues associated with them. This Executive Summary summarizes the presentations made in the course of a one-day workshop.

The day began with welcoming remarks and background on the workshop and its objectives presented by Registry staff, Alex Carr, Robyn Camp and Sam Hitz, and Board member, Robert Noël de Tilly. The purpose of the workshop, staff explained, was to introduce a wide range of Registry stakeholders to the current state of the science regarding emissions from hydro reservoirs and the complexities associated with measuring or empirically estimating emissions from them.

Joel Goldenfum, of the **International Hydropower Association**, provided an overview of the UNESCO/IHA workshop held earlier in the week. The workshop had focused on the development of two new documents to be incorporated as annexes to an update version of the available *Measurement Specification Guidance for Evaluating the GHG Status of Man-Made Reservoirs: the Field Manual for Measuring GHG Emissions from Reservoirs* and the *Calculation Manual for Evaluating the GHG Status of Reservoirs*. The purpose of the *Measurement Specification Guidance* is to establish an international standard for objective measurement of freshwater reservoir emissions. Such a standard will promote transparent and comparable emissions data for evaluating the impacts associated with the creation of these

reservoirs. The *Field Manual*, of which a draft version has been released, will provide clear instructions regarding field methods and necessary equipment for estimating GHG emissions under pre- and post-impoundment conditions. The *Calculation Manual* will provide standard procedures for calculating net GHG emissions based on field measurements. The larger UNESCO/IHA project, *Status of Freshwater Reservoirs*, of which the *Field Manual* and the *Calculation Manual* are components, will also involve the development of both empirical- and process-based predictive models. For more information see: http://www.hydropower.org/climate_initiatives.html

Alain Tremblay, of **Hydro-Québec**, presented an overview of sampling and analytical techniques used in measuring GHG emission fluxes from reservoirs. Techniques include those that measure fluxes directly, which are typically limited to use over a relatively small footprint as well as those that estimate flux indirectly by measuring gas concentrations in water or air. The former include use of floating chambers or funnels. The latter include techniques that are applicable over both large and small areas, including vertical eddy covariance, long path Fourier Transform infrared, trace metal addition and stable isotope techniques. Different techniques naturally involve trade-offs related to spatial and temporal resolution, expense, mobility, and conditions under which they may be used, among others.

Dr. Tremblay also presented an overview of the types of emissions generated by freshwater reservoirs and the processes leading to those emissions. Emissions in freshwater reservoirs follow three different possible pathways: diffusive (surface diffusion), ebullitive (bubbling), and downstream emissions (degassing and diffusive). Emissions are created by the incorporation of organic matter into the reservoir, either through initial flooding or via the draw-down zone. Existing data indicates that for most boreal reservoirs, flooding leads to the release of nutrients and a corresponding increase in biological production that is typically constrained to a period of 10 years following impoundment. After 10 years, it is primarily dynamics in the water column that control emissions, in a fashion that is analogous to natural bodies of water. Tropical reservoirs exhibit some differences in terms of processes, often with enhanced bacterial activity in sediments and with anoxic zones in the water column. In some instances this leads to larger methane emissions relative to boreal reservoirs and net emissions that are sustained longer than 10 years. In all instances, magnitude and duration can vary from location to location.

Stéphane Descloux, of **EDF, France**, presented recent results of emissions monitoring efforts in French Guiana and Laos. Results from the Petit Saut site in French Guiana indicate relatively high emissions within the first three years of flooding that decrease substantially during the remainder of the 10 year period following impoundment. The Nam Theun site in Laos is a newer reservoir, and as a consequence less data is available at this stage. Measurements indicate high methane emissions prior to impoundment. Initial data indicate large spatial variability in both CO₂ and CH₄ over the reservoir. Data were also presented for two older reservoirs in Laos, Nam Ngum and Nam Leuk, 38 and 10 years old, respectively. Preliminary results for the former suggest that the reservoir could act as a net carbon sink, while data for the latter suggest it continues to be a net CO₂ emitter.

Atle Harby, of **SINTEF, Norway**, presented results from reservoirs in Norway. Variability in yearly CO₂ and CH₄ results suggest the importance of multi-year measurement campaigns. Unlike results from other northern latitude reservoirs, methane was released, but only in some years. Methane release generally took place during a brief period of time following break up of ice, but in some instances took place in fairly large quantities (on par with that of some tropical reservoirs). Net emissions were calculated by taking estimates of pre-impoundment flux from the literature.

Julie Bastien, of **Environnement Illimité**, presented results from several reservoirs in Canada. Results from young reservoirs in Québec show that peak fluxes of CO₂ and CH₄ occur during the first five years following inundation with a return to reference levels by 10 years. Nonetheless these vary from site to site. In some instances, methane emissions took only a short period of time (on the order of one year) to return to reference levels. Peak CO₂ emissions can be on the order of five times those of the reference state. Again, this trend is site specific. Reservoirs in areas of high agricultural productivity (e.g. southern Manitoba and Ontario) tended to exhibit higher diffusive emissions relative to those reservoirs in lower productivity regions.

Mark Andersen, of the **California Department of Water Resources (DWR)**, presented preliminary findings for DWR's Oroville Facilities. Preliminary data reflect gross emissions (i.e. include natural fluvial system emissions) that are on par with published data for natural aquatic systems in Canada and the U.S. This suggests net emissions from the Oroville Facilities may be near zero, although, more data will be needed to effectively estimate net emissions. DWR is currently testing a prototype automated emissions sampler at Oroville. Lake Oroville is a multi-purpose reservoir (e.g. flood control, fish and wildlife habitat, water supply, recreation), which raises important questions about potential emissions allocation based on these statutorily defined purposes.

Joel Goldenfum, of the **International Hydropower Association**, returned to present an overview of the UNESCO/IHA GHG Research Project. The project is designed to meet several objectives including: 1) develop measurement guidance for net GHG measurements in freshwater reservoirs, 2) promote rigorous measurements and calculate net emissions from a representative set of reservoirs, 3) develop predictive modeling tools to assess the GHG status of unmonitored reservoirs and potential new reservoir sites, and 4) develop guidance and assessment tools for mitigation of GHG emissions for vulnerable sites. Key deliverables will include a measurement specification to be applied to a representative set of reservoirs as well as field and calculations manuals, a database of results, empirical and process based predictive models, and identification of possible mitigation measures for vulnerable sites. The first edition of the Measurement Specification Guidance, as well as a Scoping Paper and the Summaries of all Project Workshops, are currently available at the IHA and at the UNESCO websites. A first draft of the Field Manual and a framework for the Calculation Manual had been established. Interested parties are invited to participate in the remainder of the process (see http://www.hydropower.org/climate_initiatives.html for more information).

Brennan Smith, of **Oak Ridge National Laboratory**, presented on U.S. perspectives on hydropower emissions and prospects for new research. A U.S. Department of Energy effort, which includes Oak Ridge and Pacific Northwest National Labs as well as the Electric Power Research Institute and other organizations, will commence in October. It will generate, analyze and publish site-specific data for U.S. reservoirs. The study will examine seasonal and regional variability, look at factors such as reservoir age, influence of management policies on emissions, and allow for comparison of this data to existing tropical and boreal assessments. The project is scheduled to deliver a final report and recommendation for long term monitoring by 2012.

Bill Hamlin, of **Manitoba Hydro**, provided an overview of IPCC methodologies and highlighted several problematic issues related to their potential application to annual corporate inventories. For instance, methodologies do not account for annual variability and do not recognize that many hydro reservoirs are beyond an age where net emissions would be expected. Furthermore, these types of land use change emissions, when compared to estimates of

emissions associated with other generation sources, may be insignificant. It was suggested that existing IPCC methodologies may be better suited to more high level assessment of emissions potential (e.g. for permitting processes) rather than annual accounting.

Sam Hitz, of **The Climate Registry**, provided wrap up comments thanking presenters and participants, synthesizing the day's presentations and indicating that The Registry looked forward to providing an avenue for its Members and stakeholders to participate in or follow the UNESCO/IHA process. The Registry also plans to post presentations from the workshop on its website.