Greenhouse gases

Automated greenhouse gas measuring system (SAGES)

Greenhouse gas emissions constitute a relatively well-known global issue. A number of gases, including carbon dioxide (CO_2) and methane (CH_4), contribute to atmospheric change. These gases are not only attributable to human activity, they are also part of normal ecosystem dynamics.

Hydroelectric reservoirs temporarily generate more greenhouse gases (GHGs) than the natural environments they replace. It is therefore important to measure GHGs in order to monitor the extent of the environmental impacts of hydroelectric power generation. With that in mind, a system that measures the GHG emissions of discharged reservoir water was developed. Even when taken in winter, the measurements are used to estimate the carbon footprint of our electricity, expressed in CO_2 equivalent per kWh produced.

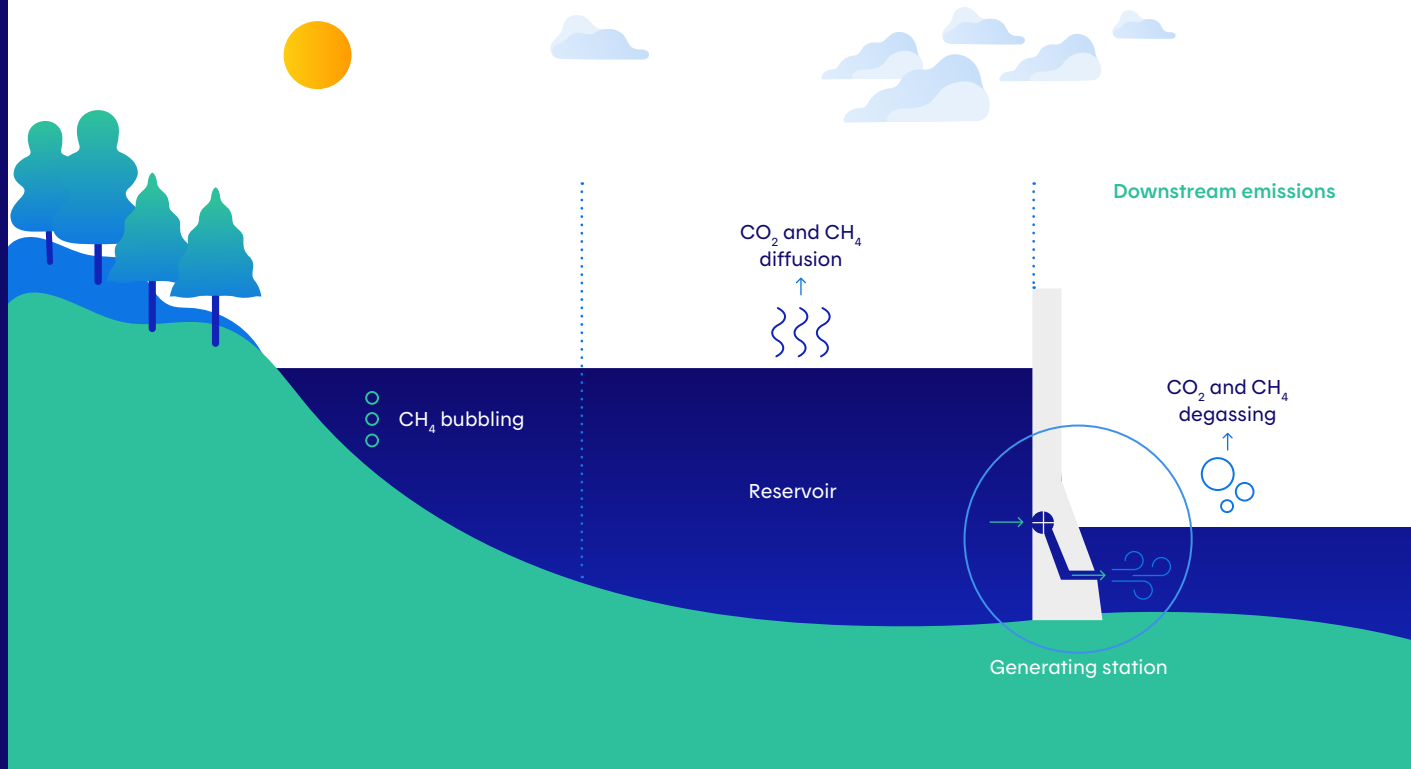
Hydroelectric reservoirs and their different GHG emissions

Like natural bodies of water, hydroelectric reservoirs may release GHG emissions by diffusion and bubbling. In the first years following impoundment, the emission rates may be higher as the decomposition of the vegetation that is flooded temporarily emits more GHGs. Degassing downstream of generating stations also adds to the emissions balance (Tremblay et al., 2005).

Diffusion at the surface of an aquatic ecosystem occurs when the concentration of gases is higher in the water than in the atmosphere: the water releases the gases to balance the concentration levels.

Bubbling is mainly due to methane accumulation in sediment as a result of the anaerobic degradation of organic matter (i.e., degradation without oxygen). It occurs most often in shallower water, where the relatively low hydrostatic pressure allows bubbles to surface.

Emissions from downstream degassing are caused by the difference in pressure at the turbine inlets and outlets and by the turbulence of downstream waters, which force the water and atmosphere to reach equilibrium, just as they do in rapids.

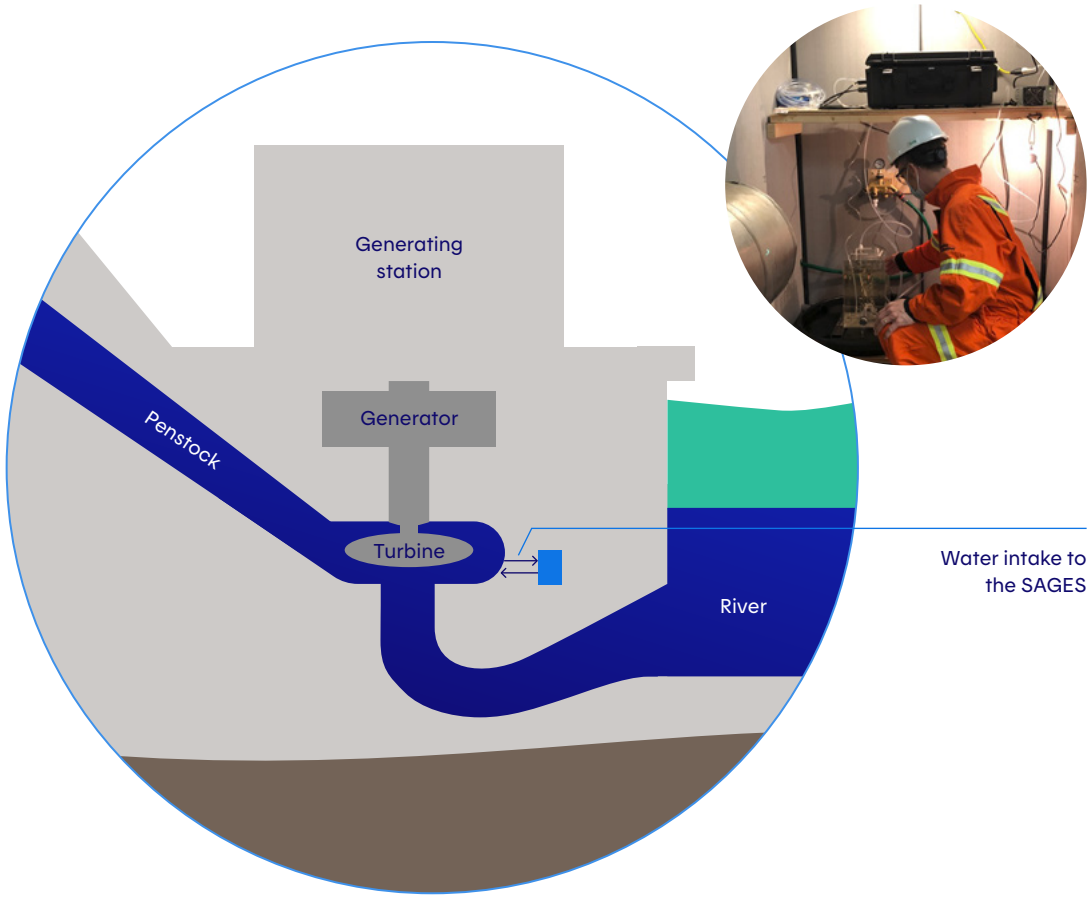


System installed in a generating station

The SAGES is installed in a dedicated cabinet and is powered at all times—even in the event of a major service interruption—by a battery that is continuously recharged. The bubbler is installed at the bottom of the device (gas extraction area) to extract the gases from the water, which are then sent to the analyzer, which is in a small black case at the top of the device (gas analysis area) (Deblois et al., 2021).

Better measurement

The data gathered by measuring the emissions at reservoir surfaces over several years revealed that, after a period of approximately 15 years, the GHG emissions from Québec's boreal reservoirs are generally comparable to those emitted by natural environments. To optimize and increase the accuracy of the field measurements, we use reliable and efficient SAGESs installed directly in generating stations (i.e., in the reservoir waters that flow through the turbines). Our data are for carbon dioxide and methane in particular.



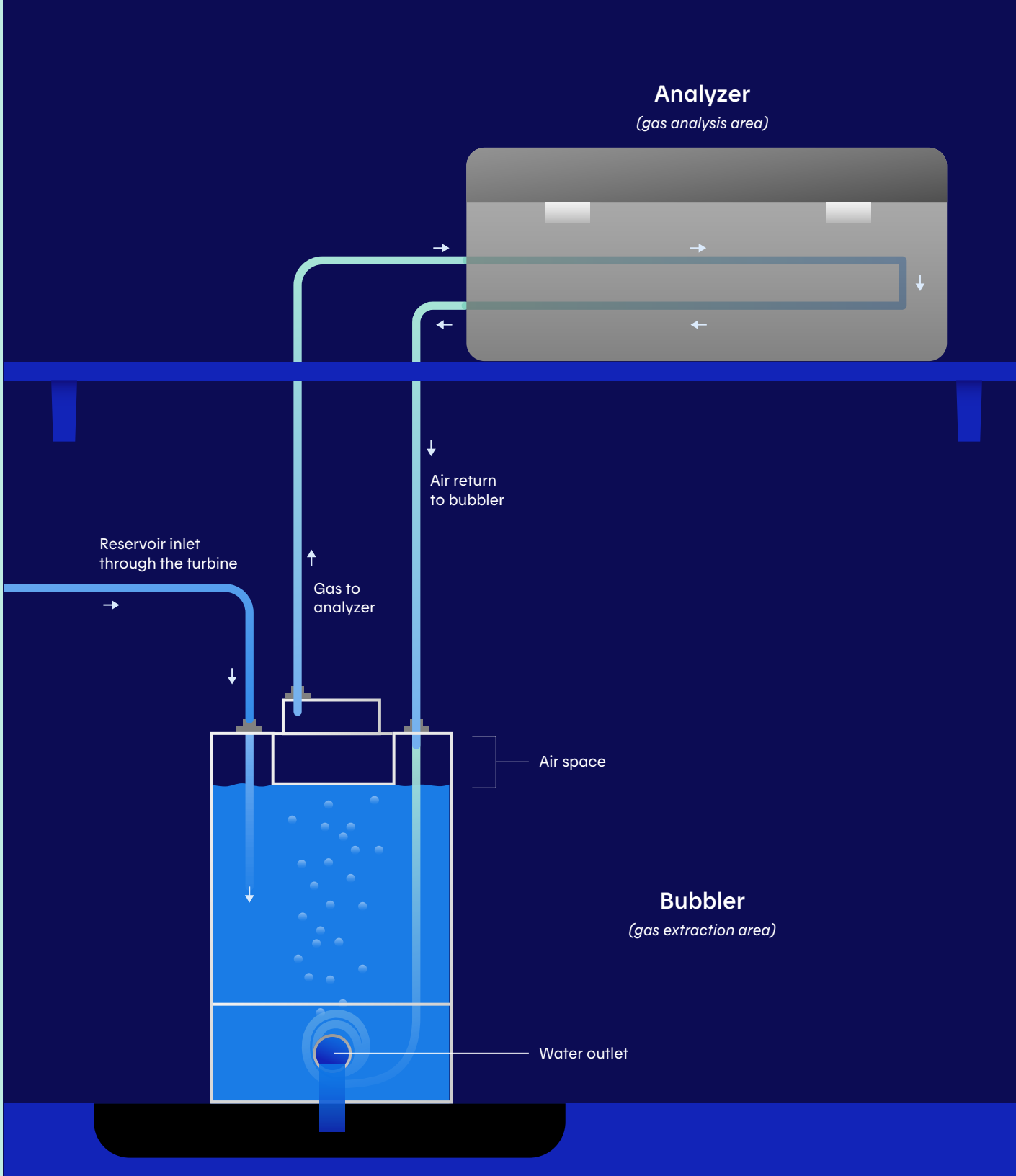
Operation of a SAGES in a generating station

Installed directly in a generating station, the SAGES is made up of two main components:

- the *bubbler*, which keeps the concentrations of CO_2 and CH_4 between the turbined water and the air space in its upper part at equilibrium by injecting air bubbles

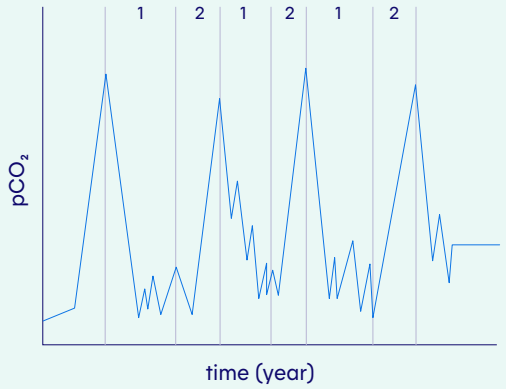
- the *analyzer*, which constantly measures gas concentrations contained in the bubbler's air space using the probes installed in its circuity.

The air flows in a closed circuit between the bubbler and the analyzer, where the temperatures and concentrations of CO_2, CH_4 and oxygen (O_2) are measured.



Benefits of the large-scale deployment of SAGESs

While the accuracy and robustness of GHG emissions measurement and modelling has improved substantially, there are obstacles to the development of an efficient measurement network that adequately covers the entire territory and has the capacity to report emissions for all Hydro-Québec facilities in a way that is representative (Demarty and Tremblay, 2019). SAGESs significantly contribute to the establishment of this type of network.



1 Ice-free season
2 Season with ice

Measurements throughout the year

Unlike standard devices, a SAGES installed in a generating station takes stable and consistent measurements throughout the year, even in winter, when the surfaces of the reservoir are covered in a layer of ice. It is also possible to consult the measurements in real time (Demarty et al., 2021).

Simple and minimal maintenance

Moving field measurement instruments to remote areas demands major logistics, but a SAGES may be installed quickly and require simpler and more cost-effective coordination and occupational health and safety rules.

Easy deployment

Thanks to their quick installation, SAGESs may be easily deployed in several generating stations.

Competitive cost

The materials required to operate a SAGES are more cost-effective that those used in current systems and may be paired with additional probes as needed.

Versatility

A SAGES may be modified for use in other field locations (e.g., by installing gas extractors or solar panels). It is also possible to integrate additional sensors.

Peer recognition

The technology is recognized in scientific literature, enabling large-scale comparisons of measurements for Québec and beyond (Demarty et al., 2009; Deblois et al., 2021).

Better definition of the carbon footprint

Temporal and spatial emissions tracking helps define the overall carbon footprint of hydropower and compare it with those of other generating options.

Current and future SAGES deployment

SAGESs are gradually being installed in Hydro-Québec generating stations. A number of installation projects are underway to create a robust system that is representative of Hydro-Québec's facilities for a more accurate estimation of the carbon footprint of the energy we generate (Tremblay et al., 2018; Demarty and Tremblay, 2019).

First steps

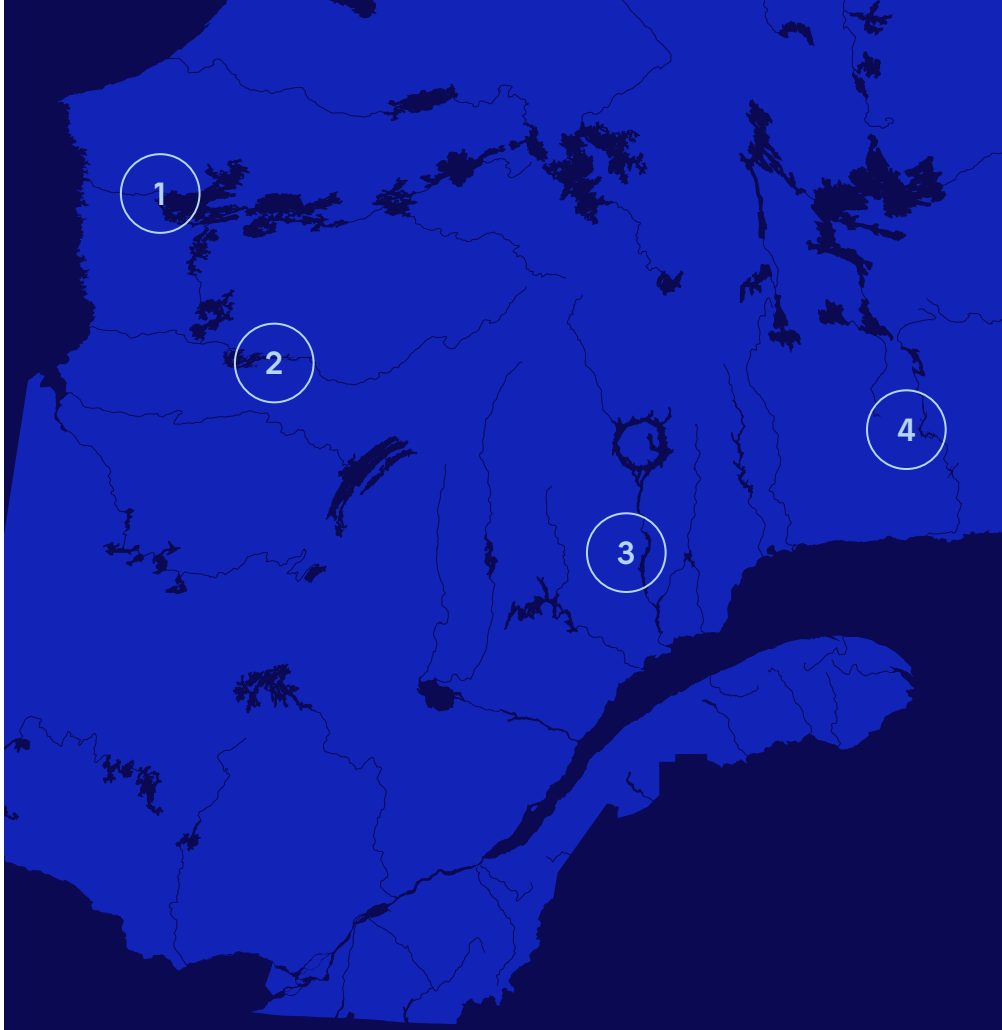
- Instrument calibration
- Validation of generating station measurements

Next steps

- Deployment of SAGESs in other facilities across the province to draw up a portrait of Québec
- Development of partnerships outside Québec

Long-term vision

- Combine flux measurements from the field with SAGES measurements for comparison purposes
- Establish links between the measurements to become less reliant on exorbitant field measurement campaigns while ensuring optimal emissions monitoring
- Make SAGES the reference measurement tool
- Rely on SAGES to calculate the emissions from Québec hydropower in real time and compare them with the emissions from other energy sectors to:
  - raise our customers' awareness of the carbon footprint of their consumption
  - promote the sale of our energy on external markets



Systems installed in Québec's hydropower facilities

1. La Grande-1
   La Grande-2
2. Paix des Braves
3. Manic-2
   Manic-5
4. Romaine-1
   Romaine-2
   Romaine-3
   Romaine-4

In perspective

Because SAGESs measure GHG concentrations in water, they constitute an excellent means to compare the GHG emissions from our reservoirs with flux measurements taken directly on their surface:

- They require simple and minimal maintenance.
- They enable the easy integration and secure positioning of precise sensors.
- They take GHG measurements on an ongoing basis and monitor emissions over time.
- They facilitate deployment in several facilities, thus enhancing the estimation of their carbon footprints.

Photos

Cover: Romaine-1 reservoir in the foreground with peatland and transmission lines in the background.

Page 2: Romaine-1 generating station and reservoir.

Page 4: Maintenance work on the system installed in Manic-2 generating station.

Page 8: Maintenance work on the measurement probes in the outlet of Des Bouleaux peatland north of Romaine-1 in collaboration with the Université du Québec à Montréal.

References

Deblois, C., M. Demarty and A. Tremblay. January 2021. *Système automatique de mesure de gaz à effet de serre (SAGES)*. Hydro-Québec, Centre de documentation Environnement et collectivités, HQ-2020-042.

Demarty, M., J. Bastien, A. Tremblay, R. H. Hesslein and R. Gill. 2009. "Greenhouse gas emissions from boreal reservoirs in Manitoba and Québec, Canada, measured with automated systems." *Environmental Science and Technology*, 43(23), p. 8908–8915.

Demarty, M. and A. Tremblay. 2019. "Long term follow-up of pCO_2, pCH_4 and emissions from Eastmain 1 boreal reservoir, and the Rupert diversion bays, Canada." *Ecohydrology & Hydrobiology*, vol. 19, p. 529-540.

Demarty, M., C. Deblois, F. Bilodeau and A. Tremblay. 2021. *Complexe Eastmain-Sarcelle-Rupert – Étude des émissions de gaz à effet de serre du réservoir de la Paix des Braves – Résultats de la campagne de l'été 2020*. Summary produced by Aqua-Consult, Englobe Corp. and Hydro-Québec, direction – Environnement, 13 p.

Tremblay, A., P. del Giorgio, M. Demarty, F. Bilodeau, F. Rust and S. Poliquin. 2018. *Greenhouse gas emissions from the newly created Romaine-1, Romaine-2 and Romaine-3 reservoirs in boreal Québec (Canada)*. Vienna, 20th Intern. Seminar on Hydropower Plants – Celebrating 40 Years of Industry-Academic Engagement.

Tremblay, A., L. Varfalvy, C. Roehm and M. Garneau, eds. 2005. *Greenhouse Gas Emissions: Fluxes and Processes, Hydroelectric Reservoirs and Natural Environments*. Berlin, Heidelberg and New York, Springer. 732 p.

Produced by:
Yann Chavaillaz, Climatologist, PhD
Alain Tremblay, Biologist, PhD
François Bilodeau, Chemist, MSc
Direction – Environnement – Expertise et soutien aux projets majeurs (2022G797A)

ISBN: 978-2-550-93556-8 PDF
Legal deposit – 4th quarter 2022
Bibliothèque et Archives nationales du Québec

Ce document est également publié en français.

Hydro Québec