Greenhouse gases

Techniques for measuring reservoir greenhouse gas emissions

Greenhouse gases (GHGs) have a major impact on the climate. 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.

Reservoirs temporarily generate more GHGs than the natural environments they replace. It is therefore important to measure GHG emissions to assess the impact of hydroelectric power generation on the environment. With that in mind, several techniques are used to measure GHGs at the surface of reservoirs, at generating stations, and downstream of hydroelectric facilities. Used together, these techniques allow us to better estimate overall reservoir emissions and the carbon footprint of our electricity production.

Different measurement techniques for each type of emission

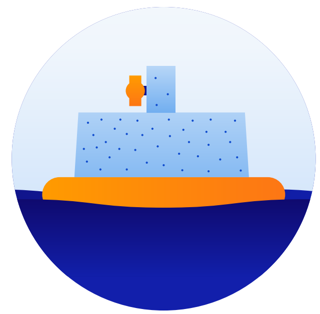
Hydroelectric reservoirs, like natural bodies of water, may emit GHGs by diffusion and bubbling. GHG production results from the decomposition of impounded vegetation, which temporarily generates more emissions than a natural environment. Degassing downstream of generating stations also adds to the emissions balance. Each measurement method has its advantages. When combined, these methods provide a representative picture of reservoir emissions (Tremblay et al., 2005).

Diffusion

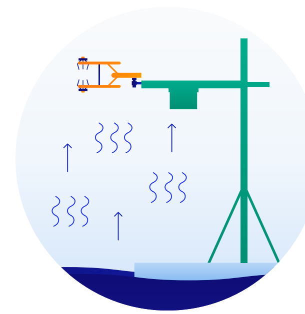
Surface diffusion in an aquatic ecosystem is a process by which gases in the water are released into the atmosphere. This balances the higher gas concentrations in the water with the lower concentrations in the atmosphere.

Diffusion can be measured in three different ways:

Indirect measurement by extracting dissolved gases using the headspace technique or an automated system



Direct measurement using a floating chamber placed on the water surface

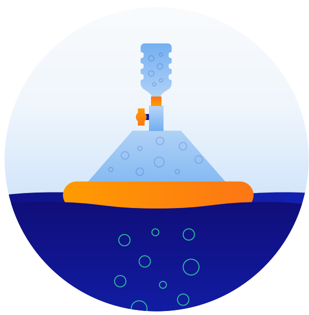


Direct measurement using equipment installed on a floating dock

Bubbling

Bubbling is mainly due to CH_4 accumulation in sediments as a result of anaerobic degradation of organic matter (i.e., degradation without oxygen). This occurs most often in shallower water bodies, where the relatively low hydrostatic pressure allows bubbles to surface.

Bubbling is hard to measure because it is quite unpredictable. It is mainly monitored using the following method:

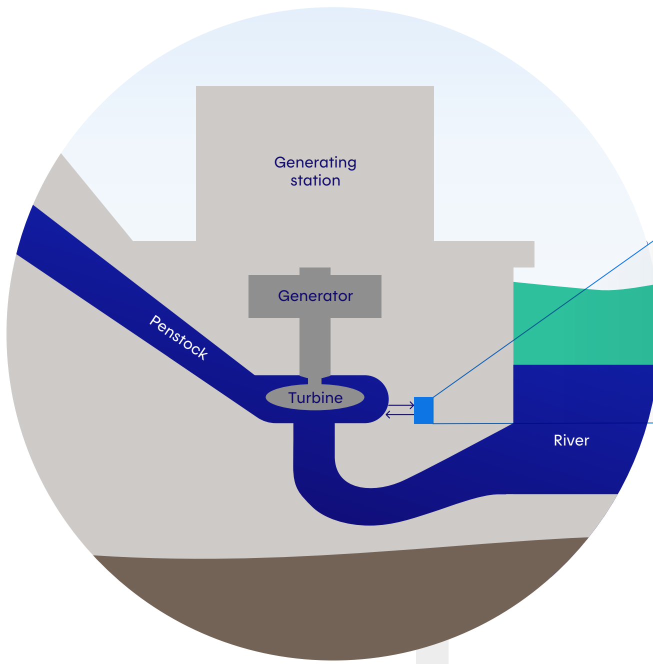


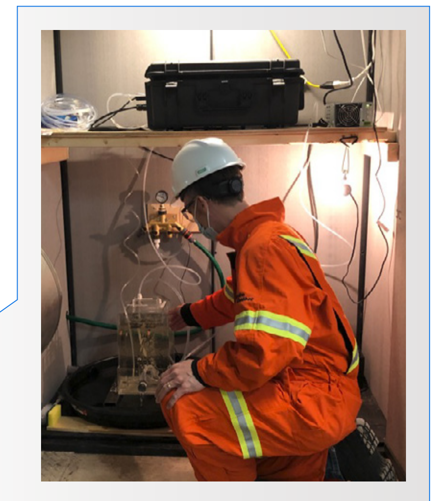
Bubble capture with inverted funnels

Degassing emissions downstream

Degassing emissions downstream of a generating station 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.

They can be estimated on a continuous basis using:





Automated measurement systems directly installed at generating stations

Indirect measurement of diffusive emissions

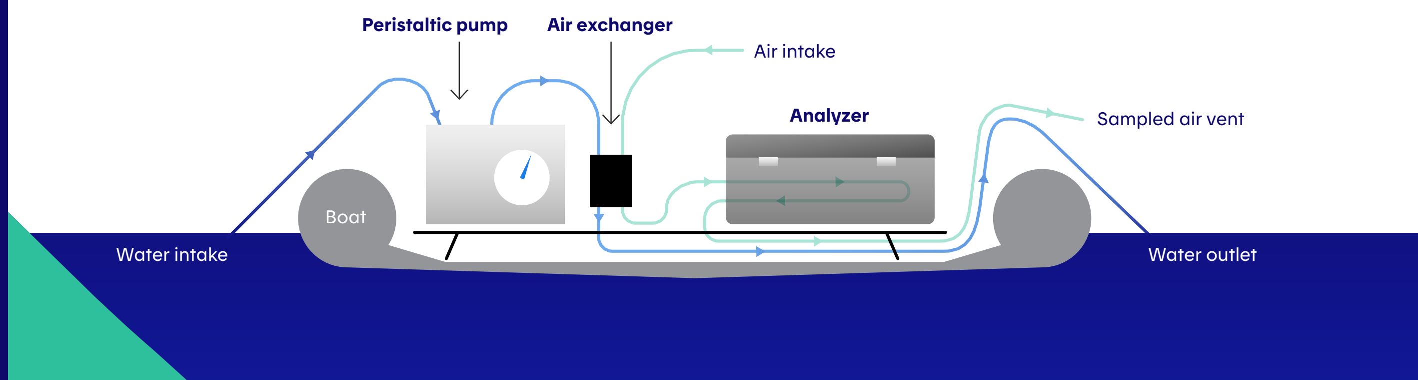
To estimate the quantity of GHGs that reservoirs emit by diffusion, we can measure the concentration of these gases in the water.
It can be hard to measure this directly in the water, so we use indirect methods. With the information obtained, emissions can then be estimated using equations based on physical and chemical principles.

Headspace sampling

A water sample is collected in a syringe, to which a certain amount of inert gas is added. This creates a gap between the top of the syringe and the water. The syringe is then shaken for a few minutes to more quickly equilibrate the concentrations of gas in the water and the inert gas. Once phase equilibrium is reached, the concentration of GHGs in the inert gas portion is measured. This corresponds to the concentration in the water sample (Kolb and Ettre 2006).

Automated system

Sampled water is pumped to an extractor at the surface that separates the gases dissolved in the water. These gases are then analyzed by an automated system that constantly measures the gas concentrations (CO_2, CH_4 and oxygen) using the probes installed on the sampling loop. It takes about 10 minutes to measure the gas concentration with this type of system (Demarty and Tremblay, 2017; Deblois et al., 2023; Demarty et al., 2024).

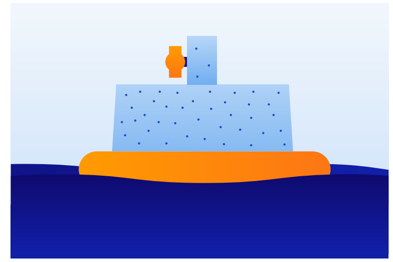


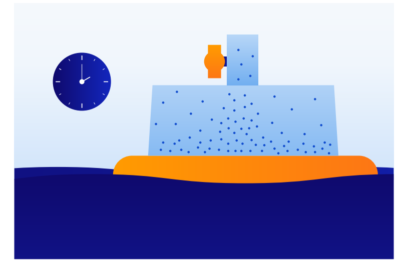
Direct measurement of diffusive emissions

The second category of methods for measuring diffusive GHG emissions involves direct measurement of gas fluxes at the reservoir surface.

Direct flux measurement using floating chambers

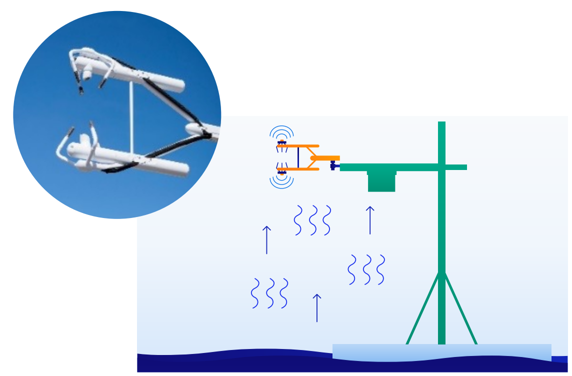
The first of these methods uses a floating chamber temporarily deployed on the surface of the reservoir. Since gas concentrations in reservoir water are greater than those in the air, an increase in the gas concentration inside the chamber is observed within 10 to 20 minutes. Emissions can be analyzed in the field in real time using the GHG analyzer connected to the chamber (Duc et al., 2013).





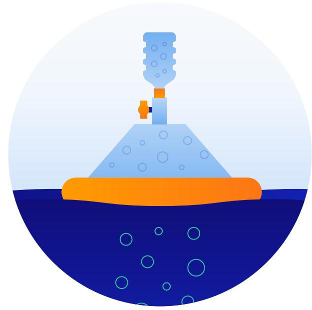
Direct flux measurement by turbulence using high frequency instruments

The turbulence method measures air movements that transport GHGs from the reservoir surface into the atmosphere. High frequency instruments are used to measure the movement and concentration of GHGs 10 times per second. The instruments are installed on towers along the edge of the Hydro-Québec reservoirs or on floating docks (Burba et al., 2013). Note that this method also measures bubbling fluxes, but it does not distinguish them from diffusive emissions.



Direct measurement of bubbling emissions

To estimate the quantity of reservoir GHG emissions from bubbling, inverted funnels are used to capture bubbles generated by sediments (Peifer Bezarra et al., 2020).



Inverted funnels

The latest generation of inverted funnels are directly connected to an analyzer. The analyzer calculates the volume of bubbles accumulated over a given period as well as the concentrations of gas they contain. Bubbles are mainly composed of CH_4 due to anaerobic degradation of organic matter. With the funnel-analyzer system, measurements that were previously possible only in the laboratory can now also be made directly in the field.

Given the difficulty of predicting exactly where bubbles will form, several experimental protocols have been developed to help obtain reliable estimates. Proper funnel distribution on the reservoir surface is essential, considering the presence of bays and the type of impounded vegetation. By deploying a series of funnels perpendicular to the shore, it is also possible to estimate the intensity of bubbling emissions at different water depths.

Bubbling measurement is an important area of research due to its complexity and the volume of these emissions. This is especially true for reservoirs, whose levels vary constantly with use.

Direct measurement of emissions from degassing

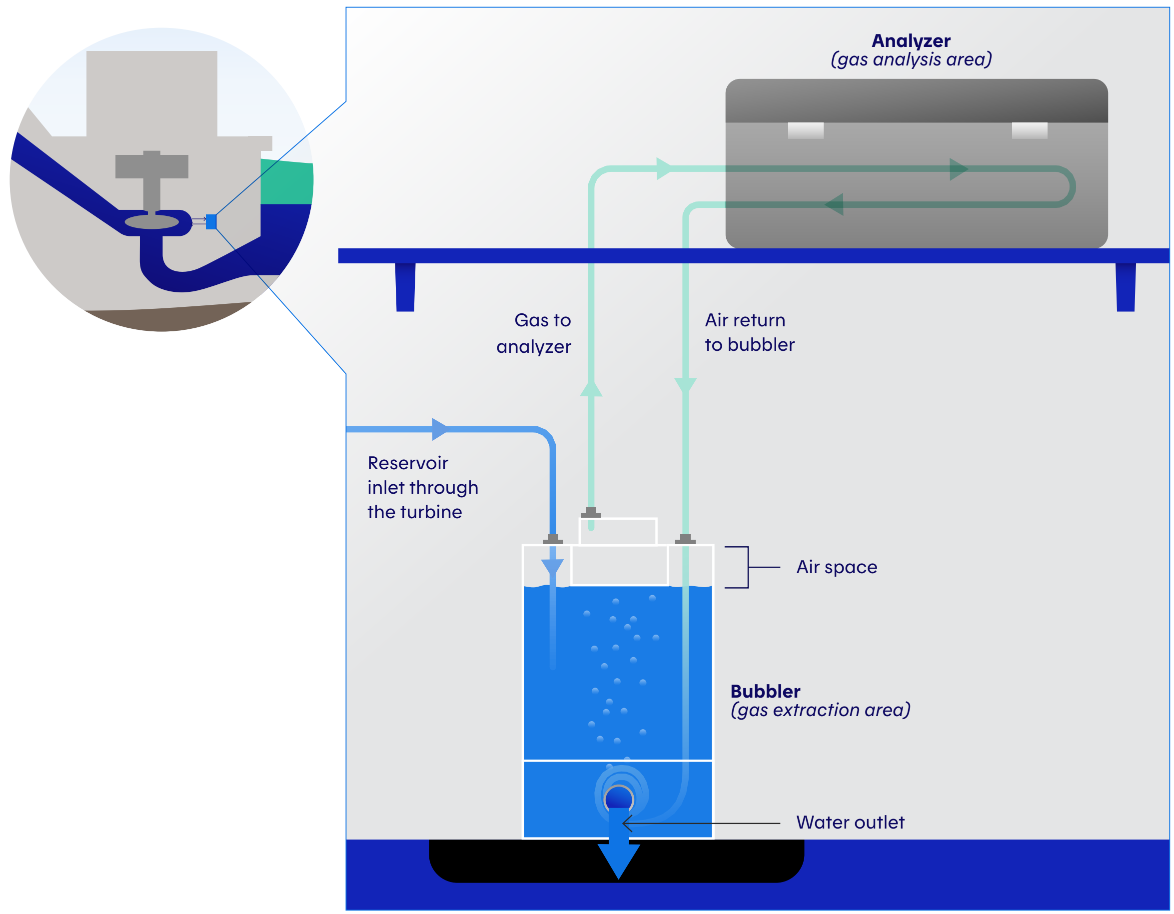
Some Hydro-Québec facilities are also equipped with an automated system that measures the concentration of CO_2 and CH_4 in turbinated water.

Automated measuring system

At generating stations, the system 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 housed in a small black case at the top of the device (gas analysis area) (Deblois et al., 2021).

Knowing the concentration of gases in the air downstream from the generating station and the total annual flow rate for each station allows us to estimate the quantity of GHG emissions generated by degassing.

Field measurements can be difficult to make in winter, but these systems provide second-by-second measurements throughout the year and add to our knowledge.



A range of measurement methods in support of our hydroelectricity

By boat or by seaplane, on shore or on floating docks, and directly at generating stations, Hydro-Québec does everything it can to systematically track and document reservoir GHG emissions.

The range of techniques we use help provide a complete and accurate picture of the environmental impacts of our facilities.

Thanks to the various measurements obtained, we can confidently state—and demonstrate—that Québec's hydroelectricity is a low-carbon source of energy.

Photos

Cover : Environmental monitoring of the Romaine project : Eddy tower on floating dock on the Romaine-2 reservoir

Page 2 : Aerial view of the dam and the spillway of the Romaine-2 power station

Page 9 : Aerial view of the Daniel-Johnson dam and the Manic-5 and Manic-5-PA power stations

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