Greenhouse gases

Why are reservoir GHG emissions lower in Québec?

Greenhouse gas (GHG) 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. For instance, GHG emissions are released by forest fires, by natural aquatic environments such as lakes and rivers, and when reservoirs are impounded. However, reservoirs of the hydroelectric developments located in northern regions such as Québec release far fewer GHG emissions than those in tropical regions. Why is that?

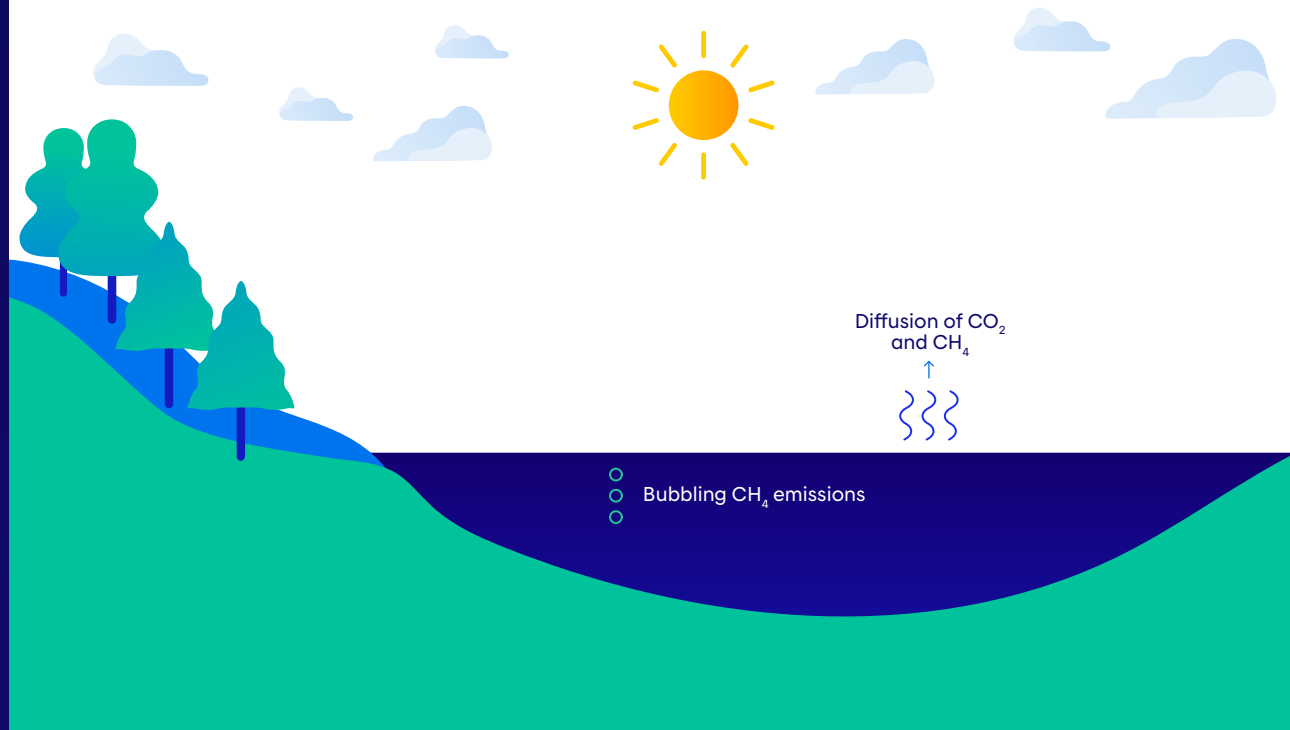
GHG emissions from hydropower reservoirs

When hydroelectric reservoirs are impounded, the decomposition of the vegetation that is flooded temporarily generates more CO_2 and CH_4 emissions. This is a well-known phenomenon (Tremblay et al., 2005). However, several factors contribute to the release of these GHG emissions into the atmosphere, such as water temperature and dissolved oxygen levels, organic matter inputs, the biological productivity in the aquatic environment, the age of the reservoir, the type of vegetation flooded, and the reservoir surface area and configuration (Tremblay et al., 2005; Deemer et al., 2016).

Reservoirs and methane

Deemer et al. (2016) reviewed the global scientific literature regarding GHG emissions based on data from 267 reservoirs on all continents and in several climate zones, including reservoirs located in Québec.

The authors state that particular attention should be paid to CH_4. According to the most recent studies, its global warming potential over 100 years is 34 times higher than CO_2.



Reservoir water temperature

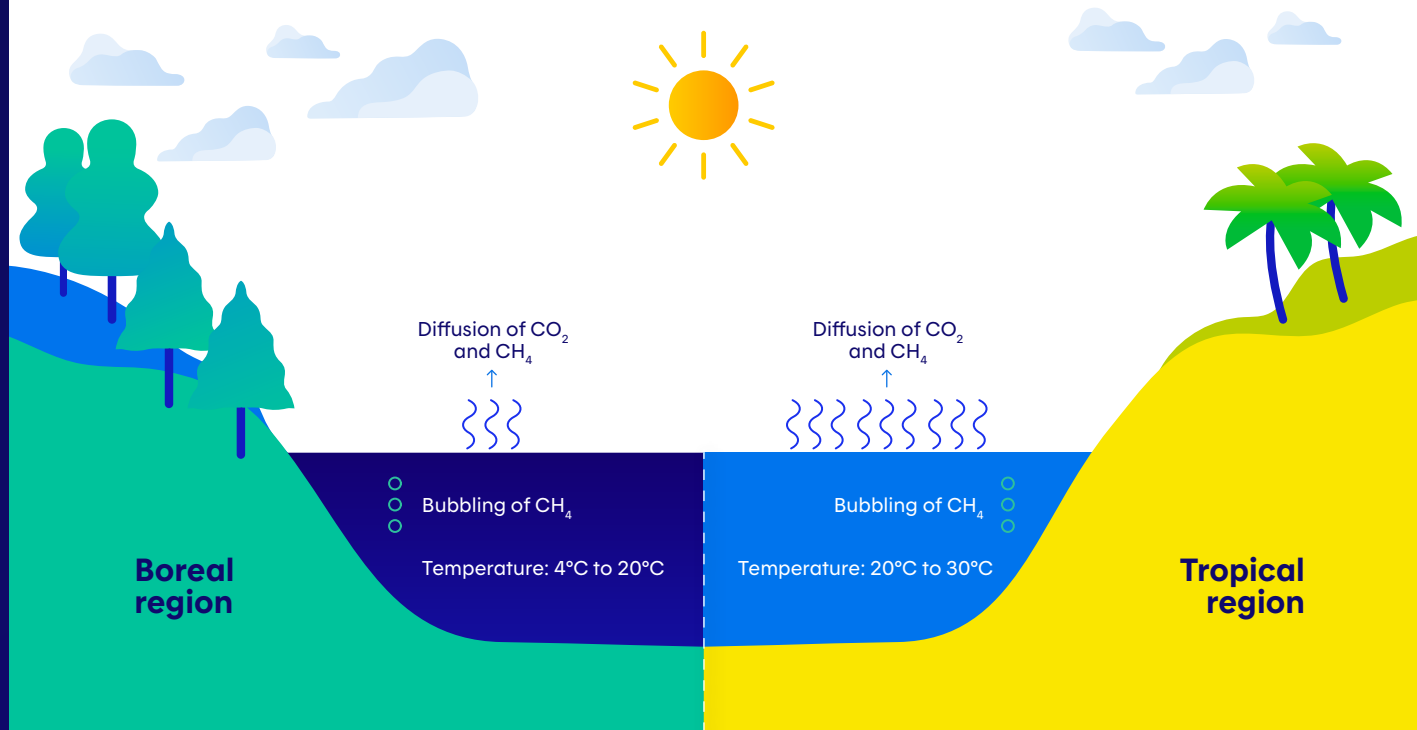
The decomposition rate of flooded vegetation varies significantly according to the geographic location of the reservoir. In fact, GHG emissions from reservoirs are influenced by water temperature and vary according to the climate zone where they are located (boreal, tropical, temperate, etc.). In other words, the colder the water, the more time it takes for the bacteria to break down the organic matter, resulting in lower GHG emissions. Consequently, Québec's reservoirs release far fewer GHG emissions than those located in warm regions given that the average annual temperature of most bodies of water in Québec varies between 4°C and 6°C.

Dissolved oxygen levels in water

The amount of oxygen that can be dissolved is also influenced by temperature, namely, the colder the water, the higher the dissolved oxygen levels. The breakdown of organic matter when oxygen is present promotes the production of CO_2 rather than CH_4.

When the dissolved oxygen in the water is depleted due to bacterial activity, this leads to anoxic conditions, which promotes the production of CH_4 rather than CO_2. When concentrations of CH_4 are high enough, the gas can be released by diffusion, bubbling or degassing downstream of generating stations.

Anoxic conditions and the absence of dissolved oxygen are more often present in reservoirs located in warm, tropical regions and consequently, those reservoirs generate more CH_4. In addition, the processes involved in CH_4 production can persist over time because the anoxic conditions are maintained by the organic matter inputs from upstream of the watershed. This results in GHG emissions that are generally higher in the long term in reservoirs located in warm or tropical regions (Tremblay et al., 2005).



Organic matter and nutrients

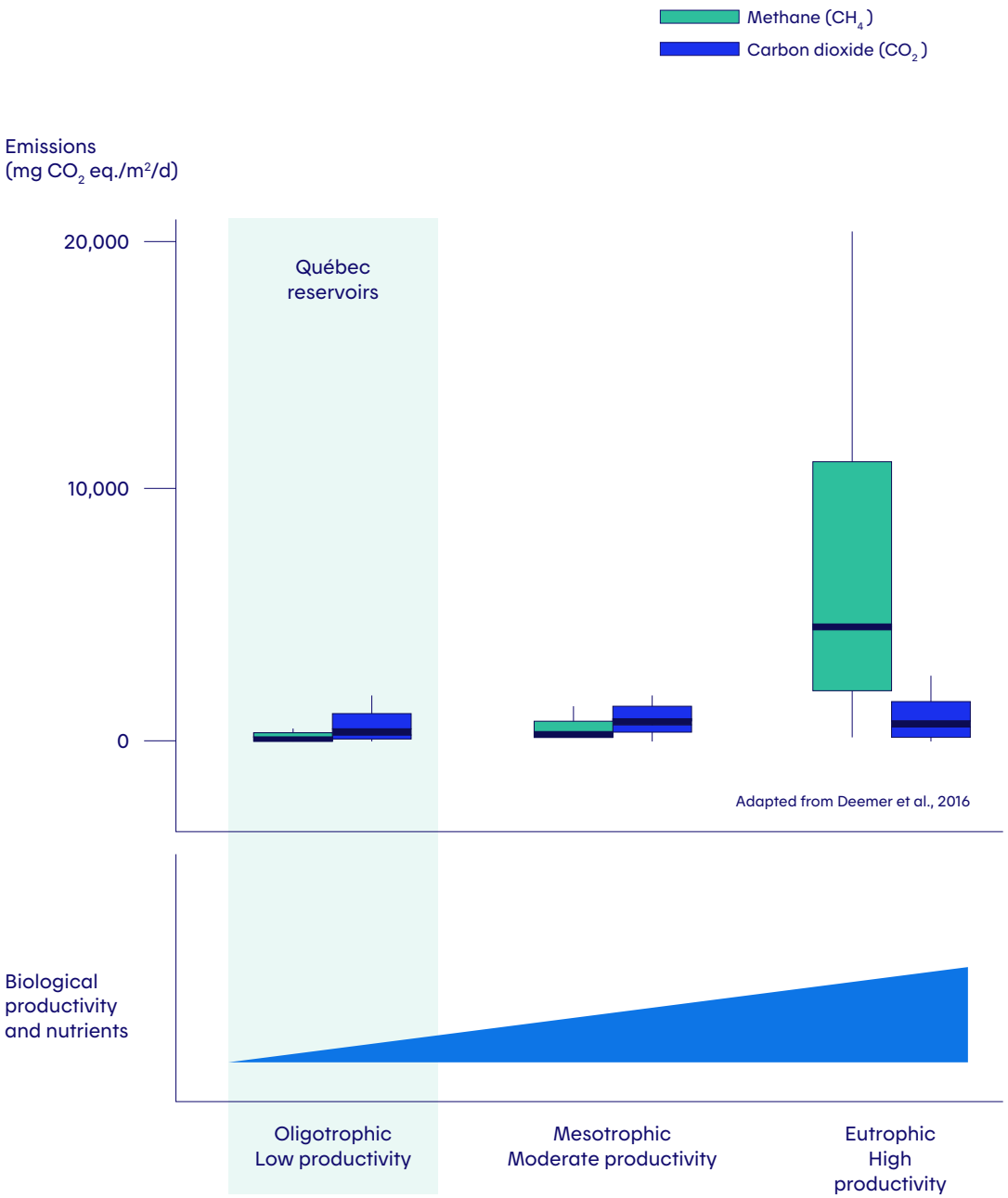
According to Deemer et al. (2016), reservoirs rich in nutrients (eutrophic reservoirs) release more GHG emissions, in particular CH_4, than those with fewer nutrients (oligotrophic reservoirs).

The generally higher CO_2 and CH_4 emissions in reservoirs located in tropical regions are due to higher water temperatures and higher biological productivity and, in several cases, greater amounts of flooded organic material (Soued and Prairie, 2020).

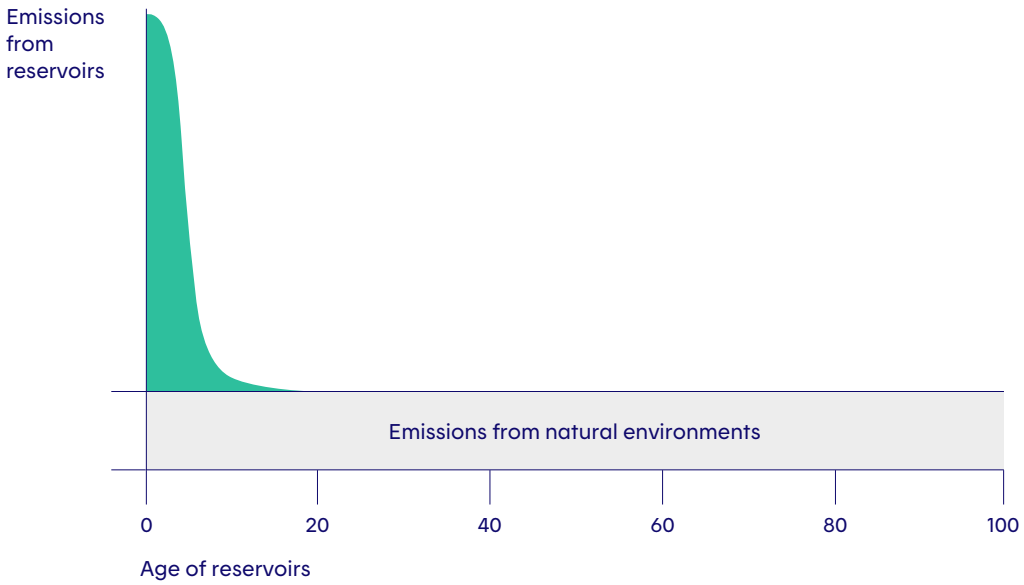
No eutrophication has ever been observed in Québec's hydroelectric reservoirs. Instead, low levels of nutrients, such as phosphorus, are observed. Moreover, pollution resulting from human activity (intensive farming, effluent releases, etc.) is a potential source of a large quantity of nutrients and organic matter. However, since Québec's reservoirs are mainly in northern regions far from intensive human activities, their watersheds are relatively unaffected.

Consequently, the small quantity of flooded organic matter and the low biological productivity in Québec's reservoirs, compared with those in warm regions, explain in part why they release lower GHG emissions.

GHG emissions from reservoirs by trophic status



GHG emissions from reservoirs



Age of réservoirs

When a hydropower reservoir is impounded, the flooded vegetation that breaks down temporarily releases more GHG emissions than the natural environments it replaces (Tremblay et al., 2005; Teodoru et al., 2012). The data collected over the years reveal that the GHG emissions from reservoirs located in cold areas of Québec are higher in the years following impoundment and then rapidly decrease. After a period of about 15 years, they are generally comparable to the emissions of natural environments (Tremblay et al., 2005).

GHG emissions pathways

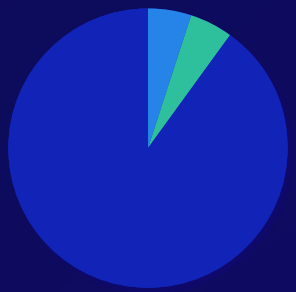
When it comes to hydropower reservoirs, GHG emissions pathways are similar throughout the world—they mainly include diffusion, degassing and bubbling (for more information, consult the document entitled *Greenhouse gas emissions from hydroelectric reservoirs*). However, the intensity level varies depending on many characteristics, including where the reservoir is located in the world.

For instance, in warmer tropical regions, degassing occurs more frequently compared with reservoirs in colder boreal regions, such as those located in Québec (Soued and Prairie, 2020).

Emissions pathways for reservoirs:

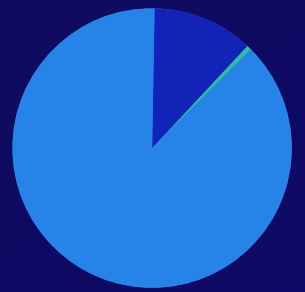
In Québec

- Diffusion
- Degassing
- Bubbling



In Malaysia

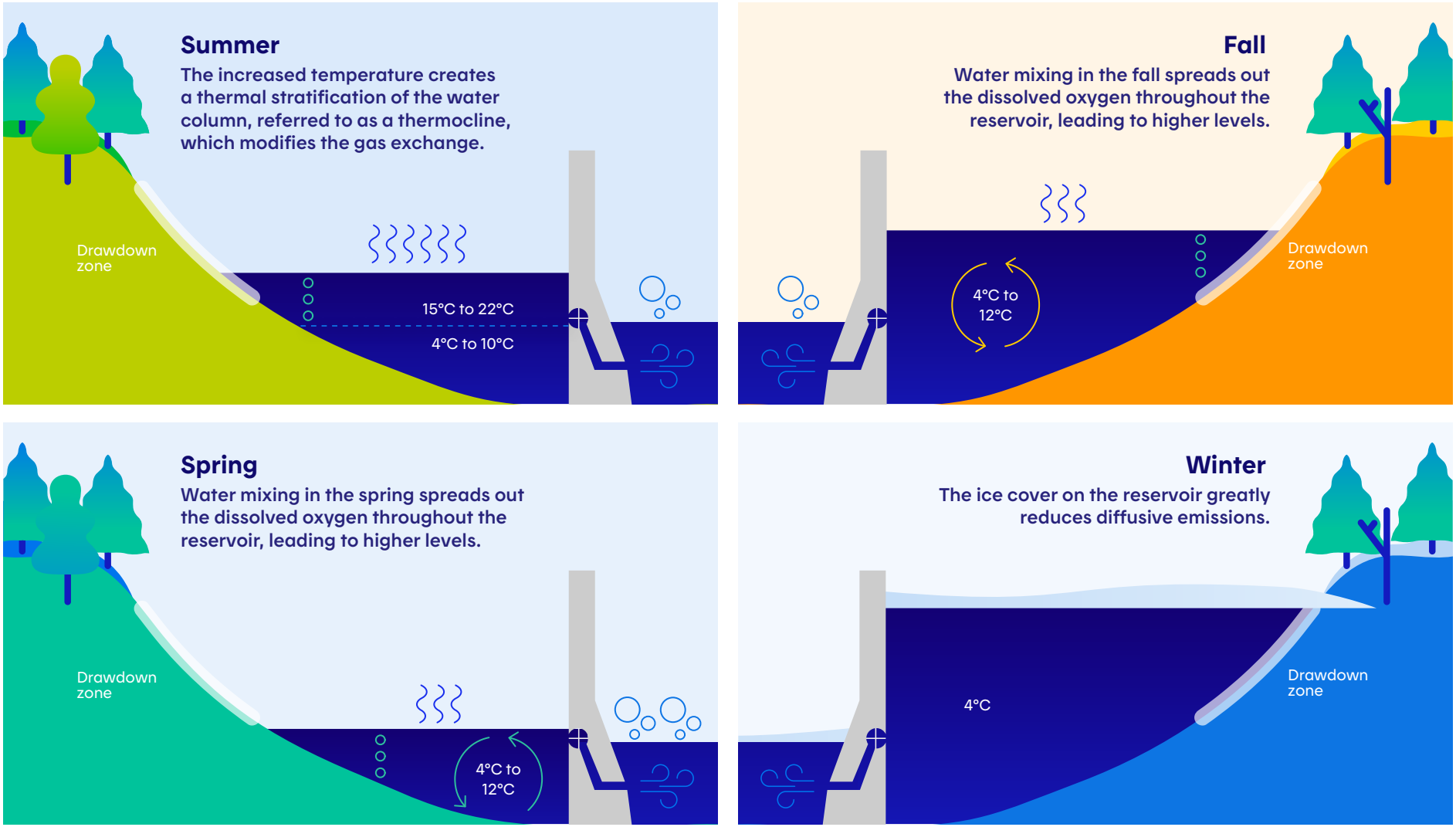
- Diffusion
- Degassing
- Bubbling



Québec's hydropower reservoirs

In addition to the factors already mentioned, some characteristics of Québec's reservoirs also contribute to the lower quantities of GHGs (e.g., CH_4) that they release compared with reservoirs in warmer climates.

The drawdown zones are affected by changes in the reservoir's water level. There is no vegetation or soil in the drawdown zones for a few years following impoundment, which reduces the amount of organic matter in shallow areas where CH_4 is likely to be produced.



What role does Québec's cold weather play?

The lower bacterial decomposition rate of organic matter, oxygen levels that promote the production of CO_2 rather than CH_4, the absence of significant anthropogenic pollution, and the presence of ice cover, which reduces diffusive GHG emissions, are all factors that explain why GHG emissions from Québec's hydropower reservoirs are lower than those released by reservoirs in warmer climates. In short, Québec's cold climate is a clear advantage!

Photos

Cover: Spillway and reservoir of the Robert-Bourassa development

Page 7: Paix des Braves reservoir and Bernard-Landry structures and facilities (left) and those of Eastmain-1 (right).

References

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