

**ANTHROPOGENIC DISTURBANCE:**

# Cumulative Effects

Industrial expansion in the western boreal forest has led to a growing footprint from oil and gas, mining, peat harvesting, hydroelectricity, and other sectors. The footprints of these industries intersect with wetlands in a variety of ways with potential for temporary or permanent effects to wetlands. This includes effects to adjacent wetlands (e.g., forest harvest, *Factsheet #14*), potential temporary wetland loss or disturbance (e.g., resource road, seismic line), permanent wetland loss (e.g., hydroelectricity facility, mine site), other changes in wetland structure and function.



While wetland avoidance occurs for many activities (e.g., routing roads, delineating harvest blocks), it is not feasible or prioritized for all. For example, peat harvest necessarily occurs in organic wetlands, seismic lines will cross all ecosystems in their path, and valuable minerals can be overlain by wetlands.

With expected growth in many of these industries in the western boreal, considering their cumulative effects on wetlands and other ecosystems is necessary to effectively practice ecosystem-based management. This factsheet provides an overview of the effects of oil and gas infrastructure, hydroelectricity, mining, and peat harvesting on wetlands in the western boreal.

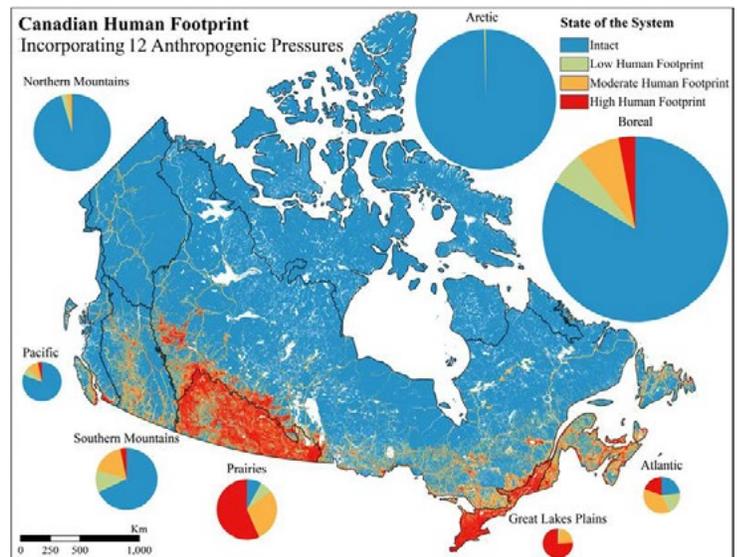
## Oil and Gas Infrastructure

Oil and gas facilities, including mines and well sites, directly impact an estimated 338,000 hectares of land.<sup>3</sup> There is an estimated 600,000 km of linear disturbances.<sup>1,2</sup> Of these, **353,000 km are composed of seismic lines and pipelines, the remainder being access roads.**<sup>1,2,3</sup>

Linear infrastructure and the extraction of oil and gas affect water resources and wetlands throughout all developmental stages. Each extraction method, whether it's from conventional oil fields, oil sands, or hydraulic fracturing, requires extensive infrastructure, that has varying degrees of environmental impact, depending on the specific requirements and techniques used.<sup>4</sup> These extraction activities pose contamination risks such as at well sites, excavated sites, tailing ponds, pipelines, and groundwater.<sup>4,5,6,7</sup>

## Seismic Lines

Seismic lines are linear, anthropogenically-modified corridors that use explosive charges to locate underground reservoirs of oil and natural gas by analyzing sub-surface sound wave reflections.<sup>9,10,11</sup> These lines are the most common linear disturbances associated with the energy sector, covering approximately **4,022 km<sup>2</sup> in the western boreal forest.**<sup>10,11,12</sup>



**Figure 1.** Map of human footprints across Canada, showing a concentration of boreal human impacts being in the western boreal forest.<sup>8</sup>

Seismic line construction techniques have shifted from wider exploration practices (up to 10 meters wide) to narrower methods (1.75 to 3 meters wide) in recent decades.<sup>10</sup> Technological advancements, regulatory incentives, and environmental awareness have driven the adoption of **low-impact seismic (LIS) lines as narrow as 1.5 meters and specialized management practices like winter operations.**<sup>10</sup> However, seismic lines typically do not prioritize wetland avoidance and even with efforts to reduce the overall disturbance footprint, seismic lines effect wetlands in a number of ways, including:

- Vegetation community composition
- Nutrient cycling, such as increased nutrient availability and increased decomposition
- Soil compaction
- Surface and subsurface water flow
- Species composition and predator-prey dynamics
- Greenhouse gas emissions, such as increased carbon losses.<sup>13</sup>

Wetlands, particularly treed organic wetlands, are some of the least likely ecosystems to regenerate naturally following the initial disturbance. Significant effort has gone into testing and applying new restoration techniques (e.g., mounding to re-establish local microtopography using mechanical site preparation<sup>13</sup>) to improve restoration outcomes in wetlands. Even with new techniques, wetlands continue to be challenging and costly ecosystems to restore.

### **Pipelines**

Pipelines, including construction, operation/ presence, and leaks or ruptures, can effect wetland hydrophysical properties and hydrologic regimes.<sup>14,15</sup> **While marshes and shallow open water wetlands are typically avoided in pipeline routing, organic wetlands and swamps are often crossed.** Beyond the immediate ecological impacts, pipeline construction introduces operational risks. When wetlands with subsurface water movement (e.g., fens) have been aligned perpendicular to the wetland's flow, there are examples of increased fluctuations in the rise and fall of the water table.<sup>14</sup>

Without regular maintenance or monitoring, **pipelines may corrode due to factors such as high water content, low pH, and the presence of microbial communities in wetland soils, particularly in organic wetlands like bogs and fens.** Due to the low shear strength and high compressibility of peat soils, there is potential for pipeline instability and movement. Peat soils may also exhibit negative buoyancy, placing upward pressure on buried pipes, resulting in pipeline stress and risks to pipeline integrity. Furthermore, increased movement is expected in soils with higher moisture content, and frost heave and permafrost melt can result in soil movement, thus exerting pressure on the pipeline. Lastly, pipeline leaks and ruptures can significantly impact wetland environments, including waterfowl habitat, water quality, and soil health. As wetlands are highly connected, spilled material can be transported, exacerbating the environmental implications.



## Well Pads

Well pads are used to extract bitumen from deposits situated more than 75 meters below the surface.<sup>16</sup> Typically, these well pads occupy an area of less than 4 hectares.<sup>16</sup> However, **well pads require supporting infrastructure, including access roads, pipelines, and storage facilities.**<sup>16</sup>

The average operational lifespan of a well pad is approximately 20 years.<sup>16</sup> **Nevertheless, the impact on vegetation species may persist for up to 50 years following the initial disturbance.**<sup>17</sup> Well pad construction starts with removing woody vegetation (trees and shrubs), then the remaining ground vegetation is covered with geotextile, and a mineral fill composed of clay, gravel, sand, and loam—ranging from 1.5 to 4 meters thick—is layered on top.<sup>16</sup> These construction methods may lead to ground surface compaction beneath the well pad, resulting in alterations to the peatlands' chemistry, hydrology, and soil properties.<sup>16</sup> Re-establishing wetlands, particularly organic wetlands, as part of well pad decommissioning and restoration is challenging due to soil compaction, changes in hydrologic regime, and the presence of mineral fill (which may not be economical to remove).



## Electric Power Development

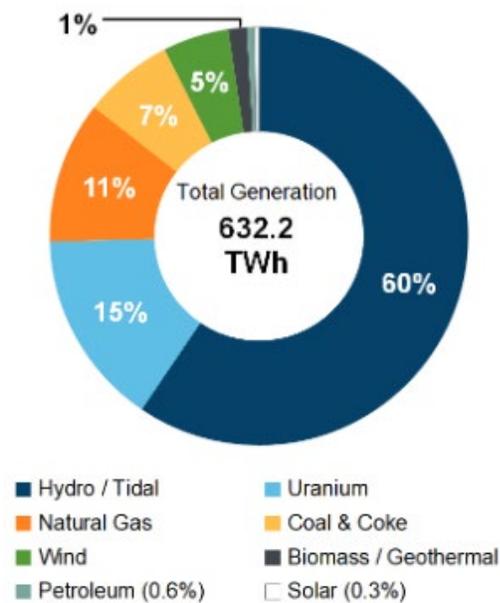
The electric power development sector consists of various industries that contribute to electricity generation, transmission, and distribution. This sector includes industries that are involved in producing electricity from sources, such as hydroelectric power, fossil fuels, nuclear power, and renewable sources like solar, wind, and geothermal energy.

In 2019, **60% of Canada's energy came from hydroelectric sources**, and the remaining was generated from a combination of natural gas, nuclear, wind, coal, biomass, solar, and petroleum.<sup>18</sup>

### Hydroelectric Production

Canada holds the fourth position globally in hydroelectricity production.<sup>18</sup> The environmental impacts of hydroelectric power generation, including effects on wetlands, vary depending on the method employed.<sup>4,19</sup> The three main methods of hydroelectric generation utilized in Canada are:

- **Conventional hydroelectric power:** the most common type of power generation in the boreal zone, it involves constructing dams to impound water for electricity generation.<sup>4</sup>
- **Thermal power generation:** Relies on fossil fuels or uranium heat energy to power steam turbines.<sup>4</sup>
- **Run-of-the-river installations:** Utilize minimal water retention within reservoirs, relying on the natural flow of rivers.<sup>4</sup>



**Figure 2.** Electricity generation by source in Canada.<sup>3</sup>

Although these hydroelectric production methods differ in their process and the land base needed, all methods require additional clearing for infrastructure, such as transmission lines and substations, to route power across the landscape. As conventional hydroelectric power is predominant in the boreal zone, this fact sheet will concentrate on the impacts of conventional hydroelectric power on wetlands. Hydroelectric dams can impact both upstream and downstream ecosystems of the dam.<sup>4</sup>



Upstream Impacts	Flooding of Riparian, Wetlands, and Upland Habitats	Conventional hydroelectric dams often result in the inundation of riparian zones, wetlands, and adjacent upland habitats due to reservoir creation, profoundly altering these ecosystems.
	Conversion of Lotic to Lentic Environments	The transformation from flowing water (lotic) to stagnant water (lentic) environments is a common consequence of hydroelectric dam construction, disrupting the natural flow in wetland ecosystems.
	Alteration of Groundwater Recharge	The construction of dams and subsequent reservoir formation can significantly modify groundwater recharge patterns, affecting the hydrological balance of wetlands and surrounding areas.
	Sedimentation and Nutrient Enrichment	Hydroelectric dams can induce sedimentation and nutrient enrichment in upstream areas due to flood material leaching into the water, leading to changes in the ecological dynamics and vegetation composition of wetlands.
	Mercury Methylation in Wetlands	The high density of organic matter deposits found in wetlands and riparian areas, coupled with natural and anthropogenic mercury deposits and induced anoxic conditions from flooding, can result in mercury methylation, posing risks to aquatic organisms. Flooding of wetlands is particularly detrimental due to the higher concentration of organic matter, leading to the production of methylmercury for longer periods, thus amplifying the ecological impact.
Downstream Impacts	Decreased Groundwater Recharge	Hydroelectric dams can lead to a reduction in groundwater recharge downstream, impacting the hydrological balance and water availability in wetland ecosystems.
	Streambank Erosion	The construction and operation of dams can exacerbate stream bank erosion downstream.
	Changes in Stream Morphology	Hydroelectric dams can induce changes in the morphology of downstream streams, affecting flow patterns and sediment and nutrient transport dynamics.
	Altered Timing of Water Flow	Dams often regulate water flow to meet electricity demands, resulting in significant alterations to the timing and magnitude of downstream flows, which can disrupt natural wetland hydrology and ecological processes.

**Table 5.** Impacts of hydroelectric dams, upstream and downstream of dams.<sup>4</sup>

## Mining

Globally, Canada is a , with 80% of Canada's mining activities concentrated in the boreal.<sup>4</sup> Various metals, including ferrous, precious, and base metals, oil sands, as well as coal and gems, are extracted within this region. The effects of mining on wetlands depends on the type of mining, location (e.g., in or adjacent to wetlands), and the stage in the mining cycle. However, consistent findings include the potential to **disrupt surface and groundwater quantity and quality**. Impacts to wetlands during mining phases include<sup>4</sup>:

### 1. Exploration Phase

**Disrupting surface water flow:** Seismic lines, roads, and camps established during initial stage prospecting can disrupt surface water flow patterns.

**Disrupting groundwater flow:** Sampling and drilling activities may interfere with groundwater flow, especially if they come into contact with subsurface aquifers.

### 2. Extraction Phase

**Surface Water Alteration:** Surface mining operations can alter surface water flow pathways, diverting rivers and lakes to access underlying materials.

**Removal of peat:** Open-pit mining involves large-scale removal of overburden (i.e. soil and peat) leading to changes in hydraulic gradients and a rise in the water table.<sup>3</sup>

**Altered biodiversity:** Discharge or seepage of mine effluents and acid mine draining can alter aquatic biodiversity.

**Dewatering:** To manage rising water tables, excess water is pumped away, increasing the surrounding land's vertical recharge, decreasing groundwater levels near the excavation, and reducing surface water levels which can lead to peatland drying.

**Wetland loss:** Wetlands are often drained, and peat is removed during mining operations in these areas.

### 3. Processing Phase

**Reduced water quantity:** Extraction and diversion of water for processing, cooling, diluting, or treating mined materials can affect overall water quantity.

**Reduced water quality:** Mine-related effluents, seepages, and emissions contribute to water contamination, impacting water quality.

### 4. Closure Phase

**Leaching and tailings:** persist even after mine closure, potentially leading to acid drainage and increased metal concentrations in receiving waters. Historical operations in older and abandoned mines show evidence of long-term water quality impacts, indicating the lasting consequences of mining activities.



## Peat Harvesting

Peat harvesting occurs in organic wetlands (peatlands) and is the process of removing peat (soil formed from decayed wetland plant material) for commercial uses e.g., as a horticultural growing medium. Peat harvesting affects a relatively small area but significantly impacts wetland hydrology.<sup>4</sup>

There are two methods for peat harvesting:

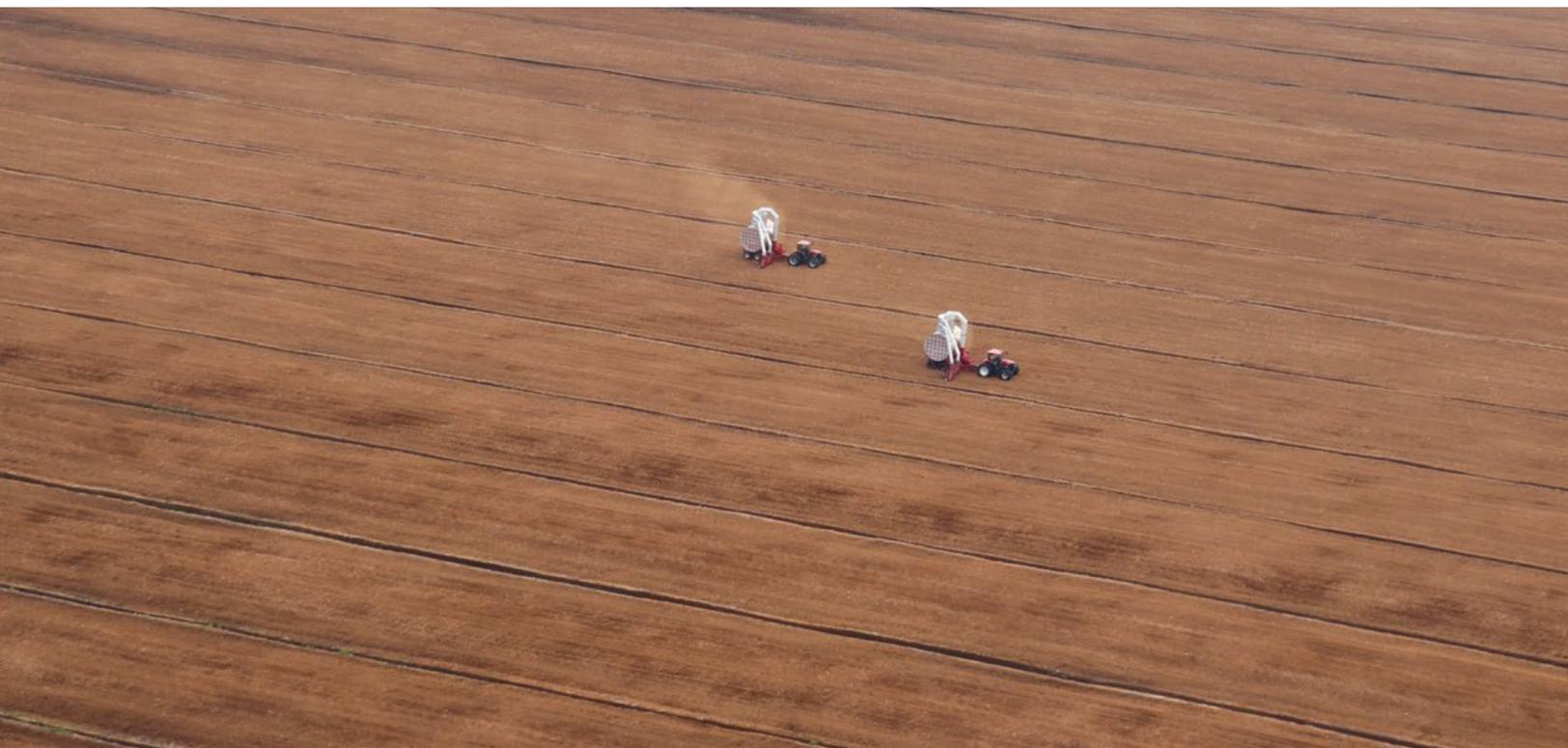
- **Dry Harvesting:** Requires draining the peatland, facilitating the extraction of dried peat through sod peat production, milled peat production, or vacuum peat production. Subsequently, the extracted peat undergoes further dewatering processes to create briquettes or pellets.
- **Wet Harvesting:** Extracting peat without solar drying or transportation for dewatering and thermal drying, utilized particularly when drainage is challenging, extending the peat production season with lower costs, although it is not currently widely adopted on a large scale in Canada.



*Canada is one of the leading global exporters of horticultural peat.*

Annually, Canada produces 11.8 million cubic meters of horticultural peat, approximately 0.03% of Canadian peatlands equivalent to 34,000 hectares, are harvested.<sup>4</sup> The majority of production areas, approximately 70%, are situated in eastern provinces such as New Brunswick and Quebec, while the central and western regions contribute to the remaining 30%.<sup>4</sup>

Impacts on water quality and quantity vary depending on extraction method. However, both methods result in significant peat material removal, leading to **permanent losses in water storage capacity**.<sup>4</sup> Peat harvesting results in a loss of stored carbon from the harvested wetland and can affect green house gas emissions.



## Resources:

- [Strategy for Responsible Peatland Management 6th Edition \(International Peatland Society\)](#)
- [Treatment Process Flowchart: Landscape \(NAIT\)](#)
- [Reclamation Decision Support System \(DSS\) - NAIT](#)
- Elmes, M. C., Petrone, R. M., Volik, O., & Price, J. S. (2022). Changes to the hydrology of a boreal fen following the placement of an access road and below ground pipeline. *Journal of Hydrology: Regional Studies*, 40. <https://doi.org/10.1016/j.ejrh.2022.101031>
- Webster, K. L., Beall, F. D., Creed, I. F., & Kreutzweiser, D. P. (2015). Impacts and prognosis of natural resource development on water and wetlands in Canada's boreal zone. In *Environmental Reviews* (Vol. 23, Issue 1, pp. 78–131). National Research Council of Canada. <https://doi.org/10.1139/er-2014-0063>
- Rooney, R. C., Bayley, S. E., & Schindler, D. W. (2012). Oil sands mining and reclamation cause massive loss of peatland and stored carbon. *Proceedings of the National Academy of Sciences of the United States of America*, 109(13), 4933–4937. <https://doi.org/10.1073/pnas.1117693108>



1. Pasher, J., Seed, E., & Duffe, J. (2013). Development of boreal ecosystem anthropogenic disturbance layers for Canada based on 2008 to 2010 Landsat imagery. *Canadian Journal of Remote Sensing*, 39(1). <https://doi.org/10.5589/m13-007>
2. Elmes, M. C., Kessel, E., Wells, C. M., Sutherland, G., Price, J. S., Macrae, M. L., & Petrone, R. M. (2021). Evaluating the hydrological response of a boreal fen following the removal of a temporary access road. *Journal of Hydrology*, 594. <https://doi.org/10.1016/j.jhydrol.2020.125928>
3. Pickell, P. D., Gergel, S. E., Coops, N. C., & Anderson, D. W. (2014). Monitoring forest change in landscapes under-going rapid energy development: Challenges and new perspectives. In *Land* (Vol. 3, Issue 3, pp. 617–638). MDPI AG. <https://doi.org/10.3390/land3030617>
4. Webster, K. L., Beall, F. D., Creed, I. F. & Kreutzweiser, D. P. (2015). Impacts and prognosis of natural resource development on water and wetlands in Canada's boreal zone. *Environmental Reviews*, 78-131, 23(1).
5. National Energy Board. 2009. A Primer for Understanding Canadian Shale Gas. *Energy Brief*. <https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/natural-gas/report/archive/primer-understanding-shale-gas-2009/a-primer-understanding-canadian-shale-gas-energy-briefing-note.pdf>
6. Canadian Association of Petroleum Producers (CAPP). 2010. Responsible water management in Canada's oil and gas industry. Available from <http://www.capp.ca/getdoc.aspx?DocID=173950> [accessed November 2011].
7. Environment Canada — Oil Sands Advisory Panel. 2010. A foundation for the future: Building and environmental monitoring system for the oil sands.
8. Hirsch-Pearson, K., Johnson, C. J., Schuster, R., Wheate, R. D., & Venter, O. (2022). Canada's human footprint reveals large intact areas juxtaposed against areas under immense anthropogenic pressure. *FACETS* 7398–419. <https://doi.org/10.1139/facets-2021-0063>
9. Energy, Mines, and Resources (EMR). 2006. Best management practices – oil and gas; seismic exploration. Yukon Government, Energy Mines and Resources, Oil and Gas Management Branch, Whitehorse, Y.T.
10. Dabros, A., Pyper, M., & Castilla, G. (2018). Seismic lines in the boreal and arctic ecosystems of North America: Environmental impacts, challenges, and opportunities. In *Environmental Reviews* (Vol. 26, Issue 2). <https://doi.org/10.1139/er-2017-0080>
11. Abib, T. H., Chasmer, L., Hopkinson, C., Mahoney, C., & Rodriguez, L. C. E. (2019). Seismic line impacts on proximal boreal forest and wetland environments in Alberta. *Science of the Total Environment*, 658. <https://doi.org/10.1016/j.scitotenv.2018.12.244>
12. Chen, S., McDermid, G. J., Castilla, G., & Linke, J. (2017). Measuring vegetation height in linear disturbances in the boreal forest with UAV photogrammetry. *Remote Sensing*, 9(12). <https://doi.org/10.3390/rs9121257>
13. Davidson, S. J., Goud, E. M., Franklin, C., Nielsen, S. E., & Strack, M. (2020). Seismic Line Disturbance Alters Soil Physical and Chemical Properties Across Boreal Forest and Peatland Soils. *Frontiers in Earth Science*, 8. <https://doi.org/10.3389/feart.2020.00281>
14. Elmes, M. C., Petrone, R. M., Volik, O., & Price, J. S. (2022). Changes to the hydrology of a boreal fen following the placement of an access road and below ground pipeline. *Journal of Hydrology: Regional Studies*, 40. <https://doi.org/10.1016/j.ejrh.2022.101031>
15. Volik, O., Elmes, M., Petrone, R., Kessel, E., Green, A., Cobbaert, D., & Price, J. (2020). Wetlands in the athabasca oil sands region: The nexus between wetland hydrological function and resource extraction. *Environmental Reviews*, 28(3). <https://doi.org/10.1139/er-2019-0040>
16. Lemmer, M., Xu, B., Strack, M., & Rochefort, L. (2023). Reestablishment of peatland vegetation following surface leveling of decommissioned in situ oil mining infrastructures. *Restoration Ecology*, 31(3). <https://doi.org/10.1111/rec.13714>
17. Chasmer, L., Lima, E. M., Mahoney, C., Hopkinson, C., Montgomery, J., & Cobbaert, D. (2021). Shrub changes with proximity to anthropogenic disturbance in boreal wetlands determined using bi-temporal airborne lidar in the Oil Sands Region, Alberta Canada. *Science of the Total Environment*, 780. <https://doi.org/10.1016/j.scitotenv.2021.146638>
18. (<https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html>)
19. Baxter, R. M. (1977). Environmental Effects of Dams and Impoundments. *Annual Review of Ecology and Systematics*, 8(1), 255-283.