Electricity import and export in Alberta and Ontario

In 2012, Ontario imported electricity from the US (0.9% of its power generation) and other Canadian provinces (3.2% of its power generation) (Statistics Canada, 2012). However, Ontario also exported more electricity (mostly to the US) over the same period, making it a net exporter of electricity in 2012. Electricity imported by Ontario from Canadian provinces (Québec and Manitoba) is assumed to be hydroelectricity since hydro dams generate almost 100% of the electricity in these provinces. Therefore, the consequence of electrical imports on GHG emissions may be reduced for Ontario. In 2012, Alberta imported electricity from the US (1.3% of its power generation, mostly from Washington State (Government of Canada, 2012)) and other Canadian provinces (5.5% of its power generation, mostly from British Columbia (Statistics Canada, 2012)). Hydroelectricity was the main source of electricity in Washington State and British Columbia in 2012 (70% (Washington State Department of Commerce, 2012) and 99% (BC Hydro, 2013), respectively) and hydro is expected to be the marginal source of electricity in these regions. Therefore, electricity imports in Alberta should result in an improvement in the environmental profile of the marginal kWh.

Identification of the marginal sources of electricity (example)

The identification of the marginal sources of electricity between two times (t1 and t2 in the example below) is made in two steps:

1. Calculation of the power generation variation by technology between t1 and t2:
   Power generation variation = Power generation at t2 – Power generation at t1
   Example (Nuclear):
   Power generation variation between t1 and t2 for nuclear = 11386 – 11382 = 4 MW.
2. Calculation of the marginal mix between t1 and t2:
   Marginal share = Power generation variation ÷ Total of power generation variation
   Example (Nuclear):
   Nuclear marginal share between t1 and t2 = 4 ÷ 386 = 1.0 %.

Data (example)	Nuclear	Coal	Gas	Hydro	Other	Wind	Total
Power Generation at t1 (MW)	11382	221	1747	5487	690	141	19668
Power Generation at t2 (MW)	11386	321	1990	5495	719	143	20054
Power generation variation between t1 and t2 (MW)	4	100	243	8	29	2	386
Marginal mix between t1 and t2 (%)	1.0	26.0	63.3	2.1	7.6	0.5	100.0

Calculation of the marginal emissions factor (example)

The marginal emissions factors between two times (t1 and t2 in the example below) are obtained by multiplying and summing the marginal share of each technology to the corresponding emissions factor between these times:

Marginal emissions factor between t1 and t2 = 1.0 × 23 + 26.0 × 1065 + 63.3 × 559 + 2.1 × 16 + 7.6 × 310 + 0.5 × 39 = 655 $gCO_2eq./kWh$.

Data (example)	Nuclear	Coal	Gas	Hydro	Other	Wind	Total
Marginal mix between t1 and t2 (%)	1.0	26.0	63.3	2.1	7.6	0.5	100.0
Emission factors ($gCO_2eq./kWh$)	23	1065	559	16	310	39	655

Minimization of real-time marginal GHG emissions (example)

The marginal GHG emissions are minimized by choosing the region where the marginal emissions factor is the lowest over a given period. Considering the three periods P1, P2 and P3 (in the table below): Ontario is chosen for P1, Alberta is chosen for P2 and Ontario is chosen for P3.

Data (example)	Ontario	Alberta	Minimum
Emission factor during P1 ($gCO_2eq./kWh$)	218	641	218
Emission factor during P2 ($gCO_2eq./kWh$)	568	265	265
Emission factor during P3 ($gCO_2eq./kWh$)	492	636	492

Power demand variations and marginal technologies

In practice, it is irrelevant whether the provincial power demand increases or decreases to identify the marginal technologies. In the former case, it is assumed that the power plants that have extended their generation capacity to meet the increase in provincial power demand will also power the GSTC. In the later case, it is assumed that the GSTC power demand will be met by maintaining the generation capacity of the power plants that would have reduced their power generation capacity in the absence of the GSTC power demand. Thus, in both cases, the GSTC is powered by the marginal sources of electricity.

Identification of the average sources of electricity (example)

The share of each technology composing the average mix of electricity is obtained by dividing the power generated by each technology by the total power generated at a given time (t1 in the following example).

At t1, the share of nuclear power in total power generation is 11382 ÷ 19668 = 57.9 %.

Data (example)	Nuclear	Coal	Gas	Hydro	Other	Wind	Total
Power Generation at t1 (MW)	11382	221	1747	5487	690	141	19668
Average mix at t1 (%)	57.9	1.1	8.9	27.9	3.5	0.7	100.0

Calculation of the average emissions factor (example)

The average emissions per kWh at a given time (t1 in the example below) are obtained by multiplying and summing the share of each technology to the corresponding emissions factor.

Average emissions factor at t1 = $57.9 \times 23 + 1.1 \times 1065 + 8.9 \times 559 + 27.9 \times 16 + 3.5 \times 310 + 0.7 \times 39 = 90$ $gCO_2eq./kWh$.

Data (example)	Nuclear	Coal	Gas	Hydro	Other	Wind	Total
Average mix at t1 (%)	57.9	1.1	8.9	27.9	3.5	0.7	100.0
Emission factors ($gCO_2eq./kWh$)	23	1065	559	16	310	39	90

Minimization of the real-time average GHG emissions (example)

The average GHG emissions are minimized by choosing the region where the average emissions factor is the lowest over a given period. Considering the three periods P1, P2 and P3 (in the table below): Ontario is chosen for P1, P2 and P3.

Data (example)	Ontario	Alberta	Minimum
Emission factor during P1 ($gCO_2eq./kWh$)	234	850	234
Emission factor during P2 ($gCO_2eq./kWh$)	255	844	255
Emission factor during P3 ($gCO_2eq./kWh$)	242	828	242