The Steam Plant emissions quantification experiment

Debra Wunch[1], Jennifer Murphy, Raymond Monteiro
Mark Panas, Eric Ward, Alexandra Corapi, Lawson Gillespie, Jon-Paul Mastrogiacomo
University of Toronto
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We measured the emissions of methane from the fenced-in area in front of the Central Steam Plant on Ursula Franklin Street at the University of Toronto's St. George Campus. This area encloses both Enbridge natural gas pipes and equipment, and the University's own pipes and equipment. There is a brick wall that encloses most of the area, and there are two chain-linked gates on either side up against the Steam Plant main building. Figure 1 shows images of the enclosed area where the Enbridge and University of Toronto pipes enter the Central Steam Plant.

Figure 1. The Central Steam Plant enclosed area. The top-left image shows the north-west corner of the enclosed area. The top-right image shows the view into the enclosed area from the western chain-linked gate. The grey pipes are owned by Enbridge. The bottom-left image shows the enclosed area from the east. The bottom-right image shows the view into the enclosed area from the eastern chain-linked gate.

Our experiment enclosed the volume within the fenced-in area by placing a fire-retardant poly sheeting cover over it while controlling the air flow through the space such that the air in the volume is replaced with fresh outdoor air using a ducted blower (see Figure 2 and Figure 3). We measured methane concentrations upwind and downwind of the enclosure constantly throughout the experiment, using equipment that can measure a range of concentrations from <2 ppm to thousands of ppm with a <10 ppb precision and accuracy. The experiment ran for several hours on August 26, 2024, from 11 am – 3 pm. The experiment was fully supervised and monitored, Facilities and Services were informed, as was Enbridge, and a representative from the Fire Prevention team at U of T was on-hand throughout the experiment with two fire extinguishers. We placed an audible alarm that sounds at 25% of LEL (12,500 ppm) within the enclosure (Figure 3). The alarm did not sound during the experiment.

[1] debra.wunch@utoronto.ca

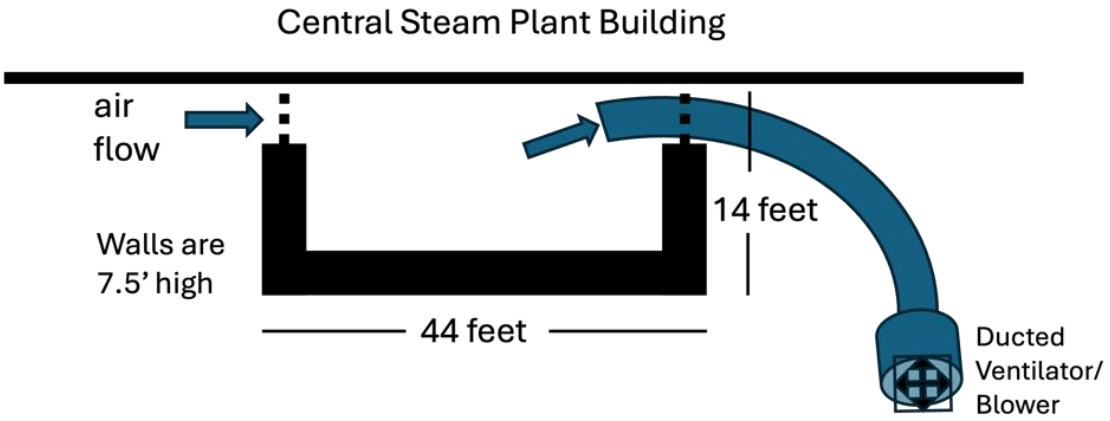

Figure 2. The enclosed area on the North side of the Central Steam Plant. The thick black walls are made of brick, the dashed lines represent the chain-linked gates at either end of the enclosed area.

In preparation for the experiment, we met with Enbridge on June 6, 2024, to discuss our plans with them. Prior to our June 6 meeting, Enbridge sent a maintenance crew to the steam plant to lubricate and tighten the Enbridge-owned piping in the enclosed space to reduce methane emissions from their infrastructure. Therefore, the results we report are mainly for the University of Toronto portion of the pipes.

Figure 3. The ducted blower inside the enclosed area next to the audible alarm (running on batteries) (left image), and the blower itself outside the enclosed area with the downwind methane sensor (right image).

Ladders were placed on either side of the enclosed area to allow us to safely pull the poly sheeting over the top of the brick walls (see Figure 4). The sheeting was pulled as taut as possible to seal up the volume. There were gaps between the sheeting and the wall of the steam plant, which we could not seal well without taping the sheeting to the wall, which we did not feel comfortable doing as it would require someone to be inside the enclosed space with the sheeting in place. There were gaps in the chain-linked gates, but we sealed those up to the best of our ability with poly sheeting.

Figure 4. The enclosed area covered in the fire-retardant poly sheeting. In the left image, you can see the sheeting across the enclosed area. In the right image, there was an additional piece of sheeting used to cover the chain-linked gate. The upwind methane analyser (grey box) is placed on the ground next to the door.

The methane enhancement we measured between the upwind and downwind instruments ranged from 70 ppm to 260 ppm when the poly sheeting was covering the enclosed area, with an average enhancement of 122 ppm. Background methane concentrations are around 2 ppm, so this is a significant enhancement. The smell of mercaptans was strong in the area throughout the experiment, and when the poly sheeting was not in place.

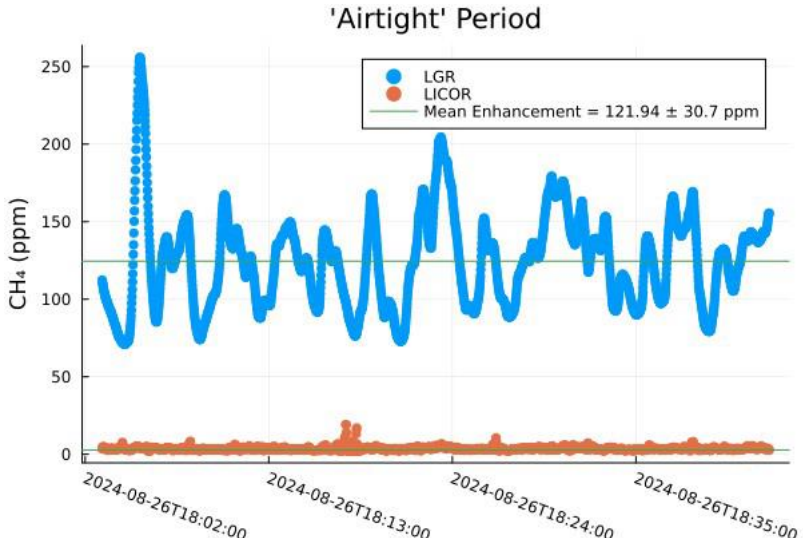

Figure 5. The methane measured upwind (orange) and downwind (blue) of the enclosed area when the poly sheeting was in place.

Because we were unable to completely seal up the space, particularly against the steam plant wall, the following calculations will be an underestimate of the total emissions, because fresh air can pass into and out of the enclosed space independently of the air forced through the blower, lowering the overall enhancement that we measure.

If we take the average enhancement as 122 ppm, and the blower's flow rate as its specified value of 1948 CFM, we can calculate the methane emissions. Here, we're assuming that there are 44.66

moles of air per m^3, that the molecular mass of CH_4 is 16 g / mole, and that 1 kg of natural gas has a volume of 1.406 m^3.

Flow rate = 1948 cfm = 0.92 m^3/s = 44.66 moles air / m^3 * 0.92 m^3/s = 41 moles air / s.

Enhancement = 122 ppm = 122 µmoles CH_4/mole air = 16 g CH_4 / mole * $122x10^{-6}$ moles CH_4 / mole air = 0.001952 g CH_4 / mole air.

Emission = 0.001952 g CH_4 / mole air * 41 moles air / s = 0.08 g CH_4 / s = 0.288 kg CH_4 / hour = 0.405 m^3 CH_4 / hour.

If the emissions are constant throughout the year, this represents 2523 kg CH_4 / year, or 3547 m^3 CH_4 / year. Since we performed this experiment on a single day, we do not have a sense of the day-to-day or seasonal variability of these numbers. Additional measurements at other times of the year would be required to assess the variability.

We believe that natural gas costs the University around[2] $0.130185 / m^3, so this represents $461.77 in lost CH_4 per year. The emissions we estimate increase to 5379 kg /year if we use the maximum enhancement (260 ppm), representing $983/year in methane losses. However, we attempted to measure the flow rate of the blower, and our measured flow rate is about half of the value in the blower's specification sheet. If our measurements are more accurate than the specs, these emissions and costs would therefore be halved.

In either case, the emissions from the Central Steam Plant pipes from where they connect to the Enbridge pipes and enter the Steam Plant facility represent only a small financial cost to the University in terms of fugitive methane losses. Including the social costs of methane fugitive emissions, which are reported at $2,494 per tonne of methane[3], would amount to $6,300 – $13,400 / year. Regular maintenance, including lubrication and tightening of the pipe fittings, would reduce these emissions and save the University around 70-150 tonnes CO_2e per year[4].

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[2] https://www.oeb.ca/consumer-information-and-protection/natural-gas-rates, using the "Enbridge Gas Inc. - Union South Rate Zone"

[3] https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html, Table 1.

[4] https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/quantification-guidance/global-warming-potentials.html, using the global warming potential (28) from the 5th assessment report.