**Decreasing greenhouse gas emissions from churches**

## Issue:

Supporting the Anglican Diocese of Ontario parishes in achieving 50% reduction in GHGs by 2030.

## Considerations

- The primary source of emissions is heating of church premises.
- Most churches operate on limited budgets and large-scale investments are not easy without outside funding support or special fundraising.
- Heating with oil or gas uses equipment that has to be periodically replaced.
- In Ontario, electricity is now the main nearly GHG-free option.
- Making substantial investments in a church is subject to the approval of all parishioners and a persuasive case for a project is typically required.
- Depending on the case, an investment by church should also consider the most appropriate technology to be used in that particular setting.
- Where changes are needed they should be implemented as soon as possible because the Synod resolution requires results by 2030.

## Options

The first question a church is facing is how much GHGs it is producing. If it is heated with gas/propane/oil, compliance with the Synod Resolution implies that the heating systems will have to be changed to achieve a 50% reduction – unless other measures (improved insulation, elimination of draft) can achieve that level of reduction, which is unlikely for such a large reduction. A good estimate can be obtained by using heating bills: they will give the amount of fuel used, and that can be easily converted to annual CO2/GHG emissions (see the following table from https://www.eia.gov/environment/emissions/co2_vol_mass.php). By 2030, this amount should be reduced to one-half.

**Carbon Dioxide Emissions Coefficients by Fuel**

| Carbon Dioxide ($CO_2$) Factors: | Pounds $CO_2$ Per Unit of Volume or Mass | Kilograms $CO_2$ Volume or Mass | Pounds $CO_2$ Per Million Btu | Kilograms $CO_2$ Per Million Btu |
|---|---|---|---|---|
| **For homes and businesses** | | | | |
| Propane | 12.68 gallon | 5.75 gallon | 138.63 | 62.88 |
| Diesel and Home Heating Fuel (Distillate Fuel Oil) | 22.46 gallon | 10.19 gallon | 163.45 | 74.14 |
| Kerosene | 21.78 gallon | 9.88 gallon | 161.35 | 73.19 |
| Coal (All types) | 4,027.93 short ton | 1,827.04 short ton | 211.06 | 95.74 |
| Natural Gas | 120.96 thousand cubic feet | 54.87 thousand cubic feet | 116.65 | 52.91 |
| Finished Motor Gasoline[a] | 17.87 gallon | 8.10 gallon | 148.54 | 67.38 |
| Motor Gasoline | 19.37 gallon | 8.78 gallon | 155.77 | 70.66 |
| Residual Heating Fuel (Businesses only) | 24.78 gallon | 11.24 gallon | 165.55 | 75.09 |

In responding to the challenge, two situations are likely to arise: replacing the current heating system (Option 1), and making other improvements while keeping the current approach (Option 2).

## *Option 1: New equipment*

If a decision is made to change the heating system, the services of a consultant should be employed. The main reason is that there are various electricity- based heating technologies, and the best approach will depend on the specific settings (type of building, number of rooms, ..), existing infrastructure (air ducts or not,....). funding available, etc.; the most efficient and effective (GHG reduction per dollar) approach will therefore vary. A consultant will also be aware of possible improvements of the existing heating system and the timing of replacement necessary (regardless of the GHG imperative). He/she will be informed about the status of various existing technologies (see below), their performance over time, costs etc. and other measures the church could take to improve its environmental performance.

Electricity can be used to warm up church interiors using various technologies and systems:

A. <u>Electric resistance heaters</u>: electricity heats coils, heat is transferred to air as it passes through the coils. (Used e.g. in St. Philip's Church in Milford; the heaters installed in the 1980s have operated reliably since).
B. <u>Infrared radiant heaters:</u> electricity heats coils, coils emit infrared radiation that 'illuminates' people and exposed surfaces, thus warming them up. (Installed e.g. in the Church of the Redeemer in Rockport, have operated successfully for over 20 years).
C. <u>Air-Source Heat pumps:</u> Electricity is used to operate a heat pump which functions as a (reversed) refrigerator taking thermal energy from the outside air and transferring it to the air inside the building. They are available for ducted ("ducted air-source") and ductless ("ductless air-source") settings.
D. <u>Geothermal heat pumps:</u> electricity is used to pump liquid through underground coils, the warmer liquid is transported indoors, and through a heat exchanger and ducts/fan the heat is passed to the surrounding air.
E. <u>Other:</u> e.g. Solar air heaters: https://reductionrevolution.com.au/blogs/review/solar-air-heater.

The system finally chosen, its sizing and location should be chosen in consultation with an energy specialist. For example, Sustainable Kingston (613-547-8122) is a non-profit organization that offers such services in the following postal codes: K0E, K0G, K0H, K0K, K6V, K7A, K7C, K7K, K7H, K7L, K7M, K7N, K7P, K7R, K7S, K8P. Faith and Common Good (https://www.faithcommongood.org/audits#green) also offers walk-through or virtual audits for church facilities. A good overview of the issues found in heating churches was given by Ian Kilborn, P.Eng. at a Green Group webinar (https://www.youtube.com/watch?v=DZiZFowBfbg&t=157s).

## *Option 2 – Existing equipment*

If - for whatever reason – it is decided to continue with the existing equipment, the main challenge is minimizing the need for heating, i.e., improving heat retention inside the building as much as possible.

There are three main ways in which heat escapes: conduction through the ceiling, conduction through the walls, and air draft through the windows, doors and any openings in walls.

The following insulation values apply to <u>**ceilings and walls**</u> in Ontario Zone 2, where the Diocese is located (https://greensaver.org/insights/everything-you-need-to-know-about-insulation/ :

| | Good | Better | Best |
|---|---|---|---|
| Ceiling with attic space | R-60 | R-70 | R-80 |

| | | | |
|---|---|---|---|
| Ceiling, no attic space | R-31 | R-35 | R-40 |
| Walls above ground | R-24 | R-32 | R-39 |
| Basement walls | R-20 | R-24 | R-39 |

The insulation values are highest for the ceiling because indoors the warm air rises to the ceiling. The insulating layer in ceilings and walls should also be uniform (for example, some types of insulation compress over time and leave spaces that are poorly insulated).

The table below helps translate the above R values into the insulation layer thickness. For example, walls insulated with fiberglass batts should contain at least 6 inches (R value 18.6-20.4) and preferably more than 8 inches (R value 24.8-27.2) of insulation.

| **Material** | **R-value/in** | **12"** |
|---|---|---|
| Fiberglass (batt) | 3.1 - 3.4 | 37.2 - 40.8 |
| Fiberglass blown (attic) | 2.2 - 4.3 | 26.4 - 51.6 |
| Fiberglass blown (wall) | 3.7 - 4.3 | 44.4 - 51.6 |
| Mineral Wool (batt) | 3.1 - 3.4 | 37.2 - 40.8 |
| Mineral Wool blown (attic | 3.1 - 4.0 | 37.2 - 48.0 |
| Mineral Wool blown (wall) | 3.1 - 4.0 | 37.2 - 48.0 |
| Cellulose blown (attic) | 3.2 - 3.7 | 38.4 - 44.4 |
| Cellulose blown (wall) | 3.8 - 3.9 | 45.6 - 46.8 |
| Polystyrene Board | 3.8 - 5.0 | 45.6 - 60.0 |
| Polyurethane Board | 5.5 - 6.5 | 66.0 - 78.0 |
| Polyisocyanurate (foil-faced) | 5.6 - 8.0 | 67.2 - 96.0 |
| Open Cell Spray Foam | 3.5 - 3.6 | 42.0 - 43.2 |
| Closed Cell Spray Foam | 6.0 - 6.5 | 72.0 - 78.0 |

Source: https://www.ecostarinsulation.ca/blog/insulation-r-value

For **windows**, heat losses due to both conduction and air movement is of concern. Double (or triple) glazed windows are the best current solution, although nighttime loss can also be reduced by covering the windows (https://www.energy.gov/energysaver/energy-efficient-window-coverings). Insulated **doors**, vestibules and not leaving doors open longer than absolutely necessary are various ways of reducing heat loss through doors.

Knowing where heat loss occurs (and how much) is a useful guide to deciding on the most efficient remedial measures. Natural Resources Canada  (https://www.nrcan.gc.ca/energy-efficiency/10832 describes various inexpensive ways of improving energy efficiency of buildings, including detection of air leaks. The US Department of Energy website (https://www.energy.gov/energysaver/heating-and-cooling) is also a good source of information about building heating issues and options. The use of thermal imaging is becoming a preferred way to find where the heat loss takes place. However, it must be done under suitable environmental conditions to be effective.

A very important part of devising a church heating approach during the winter is a decision on the minimum temperature that is maintained during the week/ when the church is not used. This is because although the temperature is low, it is kept for a much longer time period than the high one (in a church with one weekly service, the duration is 7x24 minus about 3 (=2 for preheating and one for service) hours, or 161 hours, close to 98% of the heating time. Since heat loss is proportional to the difference between outdoor and indoor temperature, the indoor temperature should be kept as low as possible to minimize GHG emissions AND to save money. A recent informal pool of a few churches in the Diocese found that ranges of no heating to 13 Celsius (55.4 Fahrenheit) temperatures were used this past winter, in all cases without adverse impacts on the building or the indoor equipment (including electronics). Since the settings have in most churches been initially established without testing for the minimum acceptable setting, it is advantageous for churches to do such testing and respond accordingly.

## On minimum winter temperature in unoccupied buildings

As noted above, minimum temperature maintained during the week (when the church premises are not used) is a critical consideration. It should be as low as possible while the structure or equipment are not adversely affected. In the opinion of a building heating expert familiar with conditions and practices around Kingston, **"*many churches should be able to lower set points much more aggressively than they do, and the savings are substantial and nearly free to implement.*"** The major reasons for current practices include the following: concerns about damage to the buildings and indoor equipment; lack (absence) of reliable advice or experience for churches; the differences in church building types, construction, etc.; and the fact that virtually all such advice available on the web is aimed on private homes occupied for much of the winter.

Church premises typically include (i) a large church that may include electronic equipment but no water, and various other rooms or spaces (ii) without or (iii) with running water. For case (iii), the advice given to homes is most directly applicable, and typically centers on 10$^{o}$C (i.e., above freezing with a safety margin); however, it should be noted that trace heating (heating cables) are a better safeguard to prevent freezing. For (i) and (ii), the interior wall and window surfaces may cool low enough to reach the 'dew point' of the indoor air. If this happens condensation on that surface will occur, which could cause mold or in the extreme, rot. Dry air has a low dew point, so it is more tolerant of contact with cold surfaces. Freezing on indoor surfaces would be less common and the hazard would not be the freezing itself, but the wetting as it thaws out.

Whether and how fast condensation occurs will depend primarily on the humidity and temperature differences between the interior and the exterior, the insulation in the ceiling and walls, and the airtightness of each space. It will therefore also vary between individual church premises and over the winter. The challenge is therefore finding whether this occurs under the 'worst' winter conditions, and making sure the indoor temperature remains just high enough to avoid such condensation. This implies that the conditions should be determined for each church/ physical structure, ideally separately for cases (i) and (ii) above.

In practical terms, the above can be achieved by aggressively lowering the indoor temperature and, using a hygrometer, to measure how close the interior temperature is to the dew point. Hygrometer is an inexpensive but accurate device that measures relative humidity in percent; when it shows 100%, the dew point of the air was reached and a check for condensation is advisable. In fact, a hygrometer/thermometer combination ($10-20) should be kept in every interior space of concern. – If condensation is found, temperature can be raised a bit and the process repeated. The experience from St. Philip's Church in Milford, ON (so far kept at 6$^{o}$C during the heating season) shows that many churches can both reduce greenhouse gas emission and save money, a win-win for the congregation and the environment.