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HVAC in a Post-Carbon World

The HVAC industry is in transition. Heating and hot water production, traditionally fossil-fuel based, is quickly moving to low-carbon electricity. Currently, 70% of the energy used to heat homes in BC and Ontario comes from fossil fuel, the lowest cost source of heating energy. In Ontario rural homes account for the majority of fossil fuel use -- predominantly propane due to lack of natural gas infrastructure. In fact, Ontario consumes more propane for home heating than the rest of Canada combined. However, fossil fuel prices are increasing with carbon pricing/taxation and shrinking supply of cheap oil sources.

But it's not just heating that we need to concern ourselves with: summer air conditioning is pretty much becoming a necessity for the 24 million Canadians (about 70 per cent) who live south of the 49th parallel. For the GTA, there are typically 10 degree days above 24 ^{0}C every year (cooling degree day or CDD). By 2040, we can expect 180 cooling degree days, an 18-fold increase. The degree days below 18 ^{0}C (heating degree days or HDD) are expected to reduce by 32%, while the category of below 0 ^{0}C is reduced by approximately 85%. Humidex above 30 will increase by a whopping 63%, making mechanical dehumidification a necessity for healthy living. Basically, by 2040, it is predicted that GTA will be Climate Zone 4a, equivalent to the current climate in North Carolina with equal annual heating/cooling demand.

Cooling and dehumidification require electricity. Similarly, electricity is the choice if we are dramatically to lower the carbon-intensity of heating. Transitioning to "near-zero greenhouse gas emissions" essentially means moving to all-electric buildings. Electricity can be carbon-intensive where it is generated by burning other fuel sources. However, electricity generation in the most populous provinces - BC, Ontario and Quebec - has the lowest carbon footprint in North America. Almost all the electricity Hydro-Québec distributes is generated from renewable resources with few or no greenhouse gas (GHG) emissions. Ontario's grid is 90% GHG free, mainly due to nuclear, hydroelectricity and renewables (wind and solar). Approximately 90 percent of the electricity generation in BC is from hydroelectric dams in southeastern, central and northeastern BC.

It is no surprise that BC, Ontario and Quebec, provinces with low-carbon grids, are the ones shifting towards a low-carbon economy. Vancouver's Greenest City 2020 Action Plan will require that by 2020 new homes must be carbon neutral and use 50 percent less energy than homes did in 2007. All existing and new larger (Part 3 and Part 9 non-residential buildings) must meet energy reduction targets 20 percent below 2007 levels by 2020 and be "carbon neutral" by 2030. Toronto City council has unanimously supported the TransformTO climate plan to transition Toronto to a low-carbon city by 2050. The plan aims to reduce the city's greenhouse gas emissions by 80 per cent below 1990 levels by 2050, with an interim target of 65 per cent reductions by 2030. To reach those goals, all new buildings need to have near-zero greenhouse gas emissions by 2030.

Because of the relative higher cost of electricity for heating (versus fossil fuels), it is essential to first reduce building heating loads as much as possible. This is where ultra-low building methodologies like Net Zero and Passive House come in. Passive House is an economic solution developed to minimize life-cycle cost and cost of ownership, optimizing return on investment for improving building envelope to reduce heating and cooling loads. The main reason that passive homes can "tunnel through the cost barrier" is that they are much simpler buildings, trading active, expensive, energy-intensive heating/cooling systems for cheaper, passive approaches like better envelope and windows and thermal bridge-free details.

For ultra-low energy buildings, energy modeling is essential. A building's space heating and cooling needs are significantly affected by its location, orientation (for passive solar), envelope, and simplicity of design (reduced emergent corners). The HVAC solution is context specific and does not lend itself to catalog design. To quote David Butler, Optimal Building Systems:

> *In the real world, poor HVAC design and installation practice accounts for more energy waste in new homes than any other single factor. Unfortunately, in the real world it's easier to sell high efficiency boxes than high efficiency systems, a distinction invariably lost in a competitive marketplace. As a result, HVAC remains the weakest link in most high performance homes.(3)*

Given the low loads associated with Passive House, the challenge to HVAC designers is "right-sizing" equipment, especially since small (<1 Ton) heating and cooling equipment is not as readily available in North America as it is in Asia and Europe. As homes have become more efficient, oversized HVAC equipment is not only a waste of money but can also lead to comfort and moisture problems.

Oversizing cooling equipment results in cycling. Each time the air conditioner starts up, it takes time for the coil to get cold enough to condense water vapor. Shorter run-times reduce the dehumidification that the unit can achieve. This is where the mini-splits shine since they run at a variable rate and can be set to control humidity at low cooling loads. The comfort in an ultra-low energy house is even more compromised by oversized heating equipment which can spike interior temperatures.

In a Passive House with ultra-low heating/cooling loads, much of the heating and cooling can be provided via the ventilation system (HRV or ERV). Conditioning ERV's - like Minotair and BuildEquinox's CERV - are able to provide in a single compact unit a significant portion of the required heating, cooling and dehumidification. On two current passive house projects, Local Impact Design is using an earth tube in combination with a conditioning ERV to provide 100% of heating and cooling. Not only is this HVAC solution less expensive to install, it's also much cheaper to operate and maintain.

The other transformative trend in the residential HVAC industry is the emergence of cold climate electric air source heat pumps (CCASHP). Overall, it's easier and less expensive to get a heat pump small enough to match the loads of a high-performance home than it is to get an appropriately sized furnace and A/C.

The Ontario Government has recently come out in support of ground-source heat pumps (GSHP) believing this technology will play a key role in battling climate change (4). GSHP have fallen out of favour in recent years after incentives dried up. The business case is still strong for larger projects, especially as cooling demands start to approach heating demands allowing annual ground recharge. Local Impact Design is using a GSHP and horizontal geoexchange loop to heat and cool two 27-unit Passive House condominiums in Creemore, Ontario. The GSHP offers the lowest cost of operation, sufficient to cover amortized cost of installing the equipment. The in-ground equipment is expected to last the life of the building- upwards of 100 years, lowering maintenance costs.

Along with geothermal, the Ontario Government sees solar thermal as a key part of the solution to rapidly addressing climate change. For a Passive House project in Haliburton, Local Impact Design is applying a solution that integrating aspects of solar thermal and heat pump technology. The Sunpump hybrid solar heating system is like a Geothermal Heap Pump, except it uses refrigerant direct-exchange through a black solar panel. This means it has high solar efficiency gains during the day, and works like an air source heat pump during the night. The system supplies both heating and hot water.

On-site solar solutions like Sunpump are crucial to reducing grid loads as we transition to an electric society. The business case for solar PV is strong, even in the absence of incentives, and Net Zero Energy buildings are not only possible but are essential. Local Impact Design has worked on over 200 solar PV projects over the past 5 years. In a Passive House with ultra-low heating/cooling loads, getting to net zero is easy, often requiring less than a 300 sf (6kW) solar PV array. Adding a further 4kW will power an electric vehicle for a year.

The HVAC industry is in transition. HVAC designers and suppliers need to be nimble to meet the new challenges of ultra-low energy electric buildings, like Passive House. The purpose of HVAC hasn't changed - to provide comfort and healthy living conditions at least cost. How we achieve that will look different in a post-carbon world.

1. Caring for the Air Metro Vancouver 2016 http://www.metrovancouver.org/services/air-quality/AirQualityPublications/Caring_for_the_Air-MV2016.pdf

2: "Toronto's Future Weather & Climate Driver Study" 2040-2049, SENES Consultants Ltd, Toronto Environment Office
October 30, 2012 http://www.toronto.ca/legdocs/mmis/2013/pe/bgrd/backgroundfile-55150.pdf
While the Study was completed in 2012, RWDI Consultants have updated the graphs to 2016
http://rwdi.com/assets/factsheets/Modelling-weather-futures.pdf

3. The Elephant in the Room, David Butler of *Optimal Building Systems*

3. http://plumbingandhvac.ca/geothermal-will-lead-climate-change-battle-says-ont-environment-minister/

For more information, see the following Passive House organization websites:

- Passive House summary - http://localimpactdesign.ca/home/passive-house/
- The Passive House encyclopedia - passipedia.org
- Passive Buildings Canada - passivebuildings.ca
- PassiveHouse Canada - http://www.passivehousecanada.com
- Passive House Institute US (PHIUS) - http://www.phius.org/home-page

Data and weblinks current as of July, 2016