DISTRICT ENERGY DIGEST

No. 2, June 2022

DISTRICT ENERGY DIGESTS provide brief accounts of recent writing relevant to district energy.

This issue of the DISTRICT ENERGY DIGEST focuses on the costs and other challenges involved in the retrofitting of existing buildings, which are likely to comprise over 70% of buildings standing in 2050 both across Canada and in the Greater Toronto and Hamilton Area (GTHA). By then, the federal government wants to have Canada's buildings produce no or almost no greenhouse gases (GHGs). Winter heating, nearly all fuelled by natural gas, is the main source of GHG emissions in the GTHA and elsewhere. If most of this fuel is replaced by electricity – powering heat pumps and resistive heating – more than a million buildings could need to be retrofitted in the GTHA by 2050 – over 35,000 per year, considerably more than the number of buildings planned for construction each year and there are already not enough skilled workers for that. Retrofitting costs are high if you can find the people to do it. The City of Toronto has estimated that the retrofitting cost for the average single-family home will be upwards of $160,000 and there are higher estimates.

District energy systems[1] reduce dependence on the electricity grid. There may still be need for some degree of building retrofit, but likely much less extensive than required for electric heating and thus more affordable for building owners, homeowners, and tenants.

The issue ends with an announcement of the formation of the ***Boltzmann Institute****, which now produces this Digest. The Institute was established to identify solutions and strategies towards reducing unwanted emissions from human energy use, including GHG emissions.*

To begin near at home: The table below is based on a May 2021 report prepared for the City of Toronto [link]. The report estimated that the overall costs of attaining a recommended 82% reduction in GHG emissions from all buildings in Toronto by 2050 would total C$302 billion. (See the report's Figure 22 for costs, Figure 14 for reduction targets, and Table 1 for other details.) The cost per single family dwelling (SFD) would be over $167,000 and perhaps above $200,000 now that Toronto's net-zero target year is 2040 and not 2050. Another report notes there are some 650,000 apartments in the City of Toronto [link]. The cost estimate in the table suggests retrofitting them would require over $100,000 per unit. The high cost per SFD could be a great

Building type	No. buildings	Floor area (square metres)	Current GHGs (kg/m²/y)	GHGs reduction target	Total cost ($ billions)	C$ retrofitting cost per: building	m² floor area
Large commercial/institutional	1,267	23,707,499	56.0	69%	$70.0	$55,248,619	$2,953
Small commercial/institutional	32,591	44,753,543	39.6	68%	$93.0	$2,853,549	$2,078
Multi-unit residential	6,162	50,832,972	44.1	93%	$66.0	$10,710,808	$1,298
Single-family dwellings	436,117	68,332,053	35.9	90%	$73.0	$167,386	$1,068
Totals/averages	**476,137**	**187,626,067**	**41.5**	**82%**	**$302.0**		**$1,610**

[1] Space heating and cooling in buildings served by **district energy systems** use hot water (for district heating) and/or cold water (for cooling) provided through underground piping. The pipes link the buildings to energy sources that can be emissions free. They include summer heat harvested and stored as hot water in massive lined and covered pits, deep geothermal heat drawn from kilometres below ground, and cold water from deep in Lake Ontario. Buildings on modern district energy networks can sell surplus energy to the system – e.g., heat rejected from supermarket chillers – for use by other buildings.

burden on owner-occupiers (86% of the total). Apartment owners, 75% of whom *don't* live in them, may show even less willingness to pay. Owners of commercial and institutional buildings, large and small, could show similar reluctance. A slide in a recent City of Toronto presentation suggests that the City may be seeking authority to compel payment for retrofits [link].

Toronto's estimates of the costs of deep retrofits may not be out of line. The highest retrofit cost noted in the current literature appears to be in Italy, where the government provides 110% marketable tax credits for retrofitting, i.e., reductions in owed taxes that are larger than the retrofit costs. A Canadian report on the program is chiefly a video interview with a benefitting contractor [link]. A UK newspaper article notes that the program – which also covers costs of protection against seismic activity – has produced a "surge in green home renovations" [link]. The program has cost the Italian government about C$230,000 per retrofitted dwelling. The European Union is covering at least part of that government's cost.

A criterion for receiving funding from Italy's Superbonus 110% program is that a building must rise two levels in the European building energy rating scheme, a complex arrangement whose implementation varies by climate and even by country. The German version is perhaps the easiest to understand. Buildings are divided into nine classes according to annual energy use per square metre of floor area (kWh/m^2/y): A+ <30, A <50, B <75, C <100, D <130, E, <160, F <200, G <250, H >250 [link]. For Europe as a whole, almost all new buildings fall into Germany's Classes A or B. For existing buildings, only Ireland appears to have more than half its buildings in Class C or better. The average across Europe for all buildings appears to be 208 kWh/m^2/y [link], equivalent to Germany's Class G. Residential buildings in Canada happen also to use an average of 208 kWh/m^2/y, but consumption in other buildings is 403 kWh/m^2/y [link]. Among several uses of the classification scheme is provision of potentially useful data to building purchasers, but energy efficiency may not yet make a significant contribution to selling prices [link].

Another recent indication of the high cost of retrofitting consistent with Toronto's is in a comparison of Finnish and U.S. costs for retrofitting multi-unit residential buildings (link]. Totals of 1092 Finnish units and 404 U.S. units were examined. The "most likely" respective costs per square metre were C$4,267 and C$1,949 – both much higher than the C$1,298 given for Toronto in the above table. The 127% higher cost for the Finnish vs. the U.S. properties was attributable mostly to 258% higher soft costs (design, management, etc.) and a 57% higher cost for improving the building envelope.

Lower estimates of retrofitting cost are available. Perhaps the most prominent such estimates in Canada are those developed by Brendan Haley and Ralph Torrie at Carleton University (link). They proposed these cost ranges: $56,000 to $96,000 per single family detached house, $46,000 to $66,000 per dwelling unit for single family attached housing, and $33,000 to $43,000 per unit for apartment buildings. These retrofit cost estimates for residential buildings are mostly less than half those estimated for Toronto (see the above table). However, they appear to be for much smaller reductions in energy use than the Toronto estimates. Smaller reductions may be inadequate for heating by electricity on the coldest days (see the box below). Haley and Torrie are less clear about their estimated retrofitting costs for commercial and institutional buildings, suggesting they would be within the range of $250-$500 per square metre of floor space. This is much below what has been estimated for Toronto where, as shown in the above table, the cost is above $2,000 per square metre. It's hard to reconcile this huge discrepancy between the Toronto report and that of Haley and Torrie because both reports may have estimated for similar reductions energy use and GHG emission for commercial and institutional buildings.

A European study also suggests lower costs for retrofitting. The Bureau Européen des Unions de Consommateurs (BEUC) – an umbrella group for 46 consumer organisations in 32 countries – examined four low carbon heating options for four archetypal homes and applied the results to 12 EU countries [link]. Median deep retrofit costs for pre-1970 single family dwellings were close to C$40,000, reducing energy use by 53-61% (again, much less than in the Toronto study, to the extent that European and North American SFDs may be compared).

A note on the coldest days. None of the above estimates, nor others we've seen on the costs of retro-fitting, deals with what happens when outside temperatures are below -20^{o}C for several days, a vital matter in much of Canada even in 2050 because electricity grids fail when overloaded and people can die without adequate heat. When temperatures go so low, heat pumps stop working or work no more efficiently than baseboard heaters [link], with huge demands on the grid. Transport electrification will add much demand especially because in cold weather vehicles use more energy and batteries hold less charge [link]. Much renewable electrical generation – wind and solar – may not be productive on the coldest days, and little storage of electricity may be available. These challenges are well addressed by district heating because of its low dependence on electricity and very low cost of storing energy.

Reducing the cost of retrofitting has been a priority in Europe, mostly addressed in two ways. One is to industrialize the process, largely by using building envelope sections, windows and frames, etc. produced away from the building. The best known of such industrialized systems is EnergieSprong, developed in The Netherlands, which may show promise for use in Canada [link]. However, this and other such systems, available with much government support for more than a decade, appear to have made little progress towards meeting the 20-fold increase in Europe's retrofit rates said to be necessary to meet emissions reduction targets [link].

One-stop shops for retrofitting homes, often linked with industrialized retrofitting, are designed to help building owners navigate a complicated and sometimes dysfunctional sector of the economy. The European Union funded a 96-page document, "How to set up a ONE-STOP-SHOP for integrated home energy renovation: A step-by-step guide for local authorities and others" [link], produced in July 2020. It details 11 case studies. Most had been active for less than two years and were without results to report. The longest-running, in The Netherlands, had involved six one-stop-shops established at a total cost of about C$1.7 million. Four of these have been closed and only one continues without the government support needed to offset lack of business. A total of 4,000 retrofits had been performed by 2020.

In conclusion, it seems logical to reduce emissions by achieving major cuts in energy use, but the cost and other barriers to doing this for large numbers of existing buildings may be formidable. Solutions that don't depend on huge amounts of retrofitting may well be required.

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BOLTZMANN INSTITUTE
INSTITUT BOLTZMANN

A Canadian organization seeking to help eliminate harmful emissions from human energy use, named for Ludwig Boltzmann, a 19th-century Austrian founder of the science of thermodynamics.

Une organisation canadienne qui cherche à éliminer les émissions nocives de l'utilisation humaine de l'énergie, du nom de Ludwig Boltzmann, un fondateur autrichien de la science de la thermodynamique au XIXe siècle.

- The Boltzmann Institute is a federally incorporated, not-for-profit corporation, founded in 2022.
- The Institute aims to contribute research and education towards securing climate neutrality by 2050, initially focusing on thermal energy use (i.e., heating and cooling) in buildings.
- An early goal is to compare plans for climate neutrality in buildings through producing thermal energy at buildings (e.g., using electricity) and for delivering the energy via thermal networks (e.g., district heating), and to develop ways of assessing the most cost-effective balances of the two kinds of plan.
- Ludwig Boltzmann was a 19th-century Austrian physicist and philosopher of science, a founder of the science of thermodynamics, which concerns the relations between heat and other forms of energy, and an early exponent of the atomic theory of matter.
- According to a biographer, Boltzmann was an “irascible, extraordinary, difficult man, an early follower of Darwin, quarrelsome and delightful, and everything that a human being should be.” A 1966 assessment of his philosophical work included, “In his realization of the hypothetical character of all our knowledge, Boltzmann was far ahead of his time and perhaps even our time.”
- The founders and current board of directors of the Boltzmann Institute are listed below.

MICHAEL WIGGIN worked for the federal government for many years as a specialist in district energy technology, helping to expedite and advising on development of district heating projects across Canada, most recently the $1 billion steam-to-hot-water conversion of the Public Works Canada systems in the National Capital Region. He’s past chair of the International Energy Agency’s Executive Committee in District Heating and Cooling R&D. (jmwigginconsulting@gmail.com)

JOHN STEPHENSON was Director of Project Development with FVB Energy Inc., advising on district energy projects across Canada (2001-2016). Prior to that he served as Manager of Generation Projects with Toronto Hydro and before that Senior Business Development Engineer with Ontario Hydro. He was elected to President of the Canadian District Energy Association and as a Director of the International District Energy Association. (jstephenson806@gmail.com)

MARTIN GREEN has a PhD in physics (Toronto, 1981). He was a research scientist for 17 years at the Ontario Hydro Research Division, with projects spanning transmission, distribution, generation and IT. After the privatization of Ontario Hydro Research, he shifted to information security, operations risk management, governance and enterprise architecture in financial services, healthcare and telecommunications. (mgreen.phys@gmail.com)

RICHARD GILBERT was a Toronto city councillor (1976-91), president of the Federation of Canadian Municipalities, and first CEO of the Toronto District Heating Corporation, now Enwave (acquired in 2021 by a pension fund for $2.8 billion, 25 times what Toronto invested in it). For many years he worked on energy issues for the Paris-based Organization for Economic Cooperation and Development (OECD) and for the International Energy Agency. (rg@richardgilbert.ca)

ALEX CAMERON is a retired information technology architect. He spent the last 20 years of his career working for a major financial institution, dealing with many large applications projects, technology transitions, security issues, and assuring that the technical teams were being understood by upper management. Since retiring, he’s been very active in several community groups focused on climate change. (alex@alex-cameron.ca)

For further information please consult the Boltzmann Institute’s website at www.bi-ib.ca or write to info@bi-ib.ca.