

Low Temperature Heating

INTRODUCTION

Canadian residential buildings use a great deal of energy. In 1996, 19 per cent of secondary energy use in Canada was in residences. More than 80 per cent of that energy use was for space heating and cooling and water heating.

A research study by Canada Mortgage and Housing Corporation (CMHC) and Natural Resources Canada (NRCan) investigated the use of low-grade energy sources, low-temperature heating systems and high-temperature cooling systems as sources for building energy. The study outlines technical features, applications, benefits, opportunities and obstacles associated with these systems.

BACKGROUND

Using fossil fuels to generate heat is inefficient. Resistance electricity and fuel oil or natural gas combustion flames produce temperatures around 2,000°C. That temperature is far higher than the temperature needed to warm household air to 20°C and heat household water to its required temperature of 55°C.

Alternative heating and cooling sources do not produce the high temperatures of fossil fuel systems. Heat pumps, fuel cells, micro-co-generation units, geothermal energy sources, district heating systems and solar panels generate lower temperatures, in the 50-120°C range—ample for domestic water heating and space heating.

The basic rationale for “low-temperature heating, high-temperature cooling” (LTH/HTC) technologies is rooted in the second law of thermodynamics. The law states that energy always degrades to a lower level, that is, lower temperature. Energy can be considered to have two values: the quantitative value, measured in joules, BTUs (British Thermal Units), calories or kilowatt hours, and the qualitative value, measured as “exergy,” which relates to the temperature at which the energy can be released.

Using energy that is available at high temperatures for tasks that require low temperatures is wasteful—it is like using a sledgehammer to crack a nut. Fossil fuels, which are “high-exergy” energy sources, are easily converted to electricity, which is also a high grade of energy, and certainly the most versatile. Low-temperature, and therefore low-exergy, sources are more difficult to convert to electricity.

An essential feature of buildings designed to be sustainable is easy adaptability to accommodate future changes. This study considers changes that might be expected in residential heating and cooling systems and system adaptability. The price and availability of conventional fuels, climate change and the inevitable evolution of equipment required to create a comfortable and healthy indoor environment are perhaps the most relevant factors.

RESEARCH PROGRAM

The study is a preliminary attempt to answer the following questions:

- Is there a reason to change current building practice, especially the design of mechanical equipment, in anticipation of shifts in:
 - technology
 - economic conditions
 - environmental conditions?
- If there is a reason to change practices for the design of mechanical equipment, what should the changes be?

In practical terms this means, for example, comparing the relative merits of a hydronic system with a non-hydronic system—typically forced air, current and low-temperature heating/high temperature cooling (LTH/HTC) systems.

The study explores heat pumps and district energy systems, LTH/HTC technologies now in use, and emerging LTH/HTC technologies; discusses what is involved in using them and makes recommendations.

The energy source for a district energy system is most often a “combined heat and power” (CHP) plant or industrial waste heat. Although water-supply temperatures are typically about 90°C, some systems now operate at temperatures as low as 70°C. Diesel-powered CHP equipment has been operating for many years, especially in off-grid communities. There is now considerable effort to make micro-scale CHP plants cost-effective for multiple housing and individual houses.

Technological development is progressing on three fronts: further improvements to small diesel generators; development of small gas turbine units and development of fuel cells specifically designed for buildings.

LTH/HTC can be enhanced by thermal storage, for example, in the form of sensible heat as hot water or in a latent form as ice for cooling.

Heating and/or cooling systems require just as much thought and investment in how heat or cool is distributed as the equipment that generates it. And the lower the temperature difference between the supply water or air and the space to be conditioned, the higher the volume of heated or cooled water required.

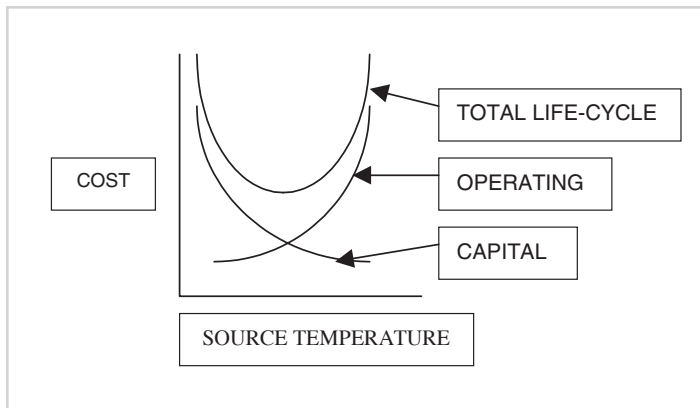


Figure 1 Trade-off between capital and operating costs

For hydronic heating systems, the lower the temperature of the supply water, the larger the pumps, pipes, and radiators need to be; and consequently, the higher the capital cost. Likewise, with forced-air systems, the lower the source temperature, the larger the fan and ducts need to be. Counterbalancing the higher capital cost is a lower operating cost, either immediately or after some years when the system is adapted to accommodate to changed circumstances. Figure 1 shows the typical trade-off between capital and operating costs.

If the future could be predicted, then a system designer could determine the value of building in additional system adaptability. For example, the designer could oversize pipes and radiators in anticipation of the future installation of low-temperature energy sources, notwithstanding some compromise on initial operating efficiency. In other words, it would be possible to determine a temperature band that met immediate operating requirements without prejudicing future options.

The work includes a report submitted by the author of a study for the five-year International Energy Agency project on low-exergy systems. A Natural Resources Canada staff member participates in this project.

RESULTS

The author concludes that a clear case cannot be made for changing current practice to practices that are more expensive to make houses ready for LTH/HTC systems. Energy price escalations, incentives to reduce greenhouse gases and widespread introduction of LTH/HTC technologies do not appear to be at hand. However, escalation of fossil-fuel prices in the third quarter of 2000 and California's electricity woes in the first quarter of 2001 are clues that justification for anticipatory design may now be more relevant than it was in 1999, when the study was written.

Nevertheless, the examples of changing design practice in Europe given in the study indicate a design trends towards LTH/HTC. There, energy prices and an awareness of the limitations of future energy reserves influence system design much more than in North America.

The study found that:

- 40 per cent of new homes in Germany have radiant floor heating, and that the typical supply temperature to those new homes is about 40°C
- in the Scandinavian countries and the Netherlands, regulations require or guidelines encourage community energy systems to supply heat at no more than 70°C
- in Canada the development of domestic fuel cells is accelerating, suggesting there is growth in micro-co-generation and hydronic systems.

In the case of an engine-driven co-generation system, heat can be recovered from three sources, each with different recovery temperatures: exhaust (100 to 120°C); water and oil cooling (85 to 90°C) and exhaust of latent heat (35 to 40°C).

The study explains how widespread adoption of LTH/HTC systems could make a significant contribution to Canada's goal of lowering greenhouse gas emissions in conformity with its Kyoto commitments.

The Canadian Hydronics Council has drafted extensive design guidelines for residential hydronic systems, with the prospect of their being referenced in future building codes. However, it is understood that they do not take account of the advantages of LTH/HTC systems.

IMPLICATION FOR THE HOUSING INDUSTRY

The study concludes that at this time it appears to be more cost-effective to further upgrade envelope insulation and use the highest energy efficiency heating and cooling equipment commercially available than to absorb the cost of building-in adaptable LTH/HTC systems for which there is no immediate return. This conclusion may be considered somewhat tentative in the absence of thorough costing case studies.

At a supply temperature as low as 40° to 45°C—common in many European systems—radiators would need to be uneconomically large to dissipate the heat. The only practical means of transferring the heat at such a low temperature is by floor, wall or ceiling radiant surfaces. The cooling complement of this is equally valid. A market pull towards LTH/HTC hydronic technology is therefore through the appeal of such radiant systems from a comfort standpoint. The lower the supply temperature, the greater the acceptability of using less-expensive plastic distribution piping.

It is neither cost-effective nor esthetically acceptable to upgrade the envelopes of most existing houses, especially those with high-quality brick or stonework. For such houses, the long-term prospect of improving thermal efficiency will therefore need to focus on upgrading their mechanical systems, and at the same time, providing the opportunity to incorporate, where possible, lower exergy systems. Economies of scale dictate that these systems will be more readily justified when equipment is at least semi-centralized, that is, for multiple and clustered housing – be it new or existing. Thermal storage to achieve even further operating thermal efficiency is also more readily justified at this scale.

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Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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