RESEARCH HIGHLIGHT

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ENERGY NEEDS AND AVAILABILITY IN HOUSING

BACKGROUND

In the early 1990s, a study to investigate housing energy needs, use and availability was undertaken for Canada Mortgage and Housing Corporation by Marbek Resource Consultants. This study attempted to derive the amount and type of energy needed to provide various household services, to estimate the efficiency of components, equipment and other devices employed to meet these needs, and to determine the amount of energy available from the house and lot. A report documenting this work was published in April 1993.

SYNOPSIS

Since 1970, there have been considerable advances in the efficiency of Canadian housing, to the point where space heating now requires only a fraction of the energy used in earlier designs, and new appliances are available which consume much less energy. However, the question remains as to how far the energy used to build and maintain housing can be reduced, and how much the environmental impacts can be minimized, without compromising occupant comfort, safety, health or convenience. This study estimates the amount and type of energy required to provide a variety of household services, compares these needs with the energy consumed, and determines the sources of energy available in the house and on the lot. The thermodynamic efficiency of the devices used to meet those needs has also been determined.

ENERGY SOURCES AVAILABLE TO MEET HOUSING NEEDS

Three types of energy sources are available on a dwelling lot: ambient, internal and external. Ambient energy sources include direct and diffuse solar radiation, wind, geothermal energy, water supply heat and mains pressure, ambient air temperature and moisture, night sky radiation, and biomass-derived heat and fuel. Internal energy sources include ventilation exhaust, human heat and moisture, cooking heat and moisture, lighting heat, heat from power, cleaning and other devices, grey and black water heat, and heat and fuel from waste decomposition. External energy may also be purchased (brought on to the lot); sources include electricity, natural gas, coal, fuel oil, wood, propane.

MINIMUM ENERGY REQUIREMENTS TO MEET HOUSING NEEDS

Energy demand in housing is driven by human needs and desires. These needs include light, comfort, food, cleaning, entertainment, etc. An analysis of the minimum energy associated with human needs has been presented, and estimates of the efficiencies of devices and technologies used to meet these needs have also been provided. The needs for energy services in housing can be separated into two types: intrinsic and extrinsic. Energy intrinsic services include those dwelling service needs in the form of energy itself, and include lighting, food preparation, clothes washing and drying, personal washing and drying, surface cleaning, snow clearing, audio-visual entertainment, home repair and maintenance. Examples of energy extrinsic services in housing include maintaining space comfort, air quality and security in a home.

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DEVICES USED TO MEET ENERGY NEEDS

Each energy service requirement in a dwelling unit or on a dwelling lot is satisfied using a device or system. A device or system can be a single piece of equipment such as a refrigerator, or a combination of materials, equipment and measures such as a building envelope and heating system. Some devices meet more than one need (e.g., a heat recovery ventilator provides both air exchange and heat recovery). Devices both embody energy (in their materials and production) and use energy to meet an energy requirement (that is, to perform their function). Some devices can utilize both ambient and on-site waste heat to meet an energy requirement (e.g., a heat pump or a dynamic wall). Others, such as a battery, embody the required energy and require no ambient or external energy. Some devices are designed to convert an ambient energy source into useful energy by either concentrating it or upgrading its quality (e.g., heat pump or solar photovoltaic generator). There are many interactions between energy processes and devices. Improved efficiency can be realized by using waste heat from one energy service to supply energy for another. In addition, the design of one device can have a significant effect on the absolute energy efficiency of another. For example, the location, size, and performance of windows affects the energy required to maintain comfort levels and to meet lighting needs.

RESEARCH PROGRAM

The absolute energy requirements were estimated for each energy intrinsic service for a typical housing unit and family. In some cases, it was not possible to determine absolute energy requirements, particularly where complex physical transformations occur and where there was no experimental data on energy requirements for processes. In these cases, a surrogate energy requirement was used. In many processes, the best surrogate was found to be the energy intensity (or power level) delivered by a human occupant undertaking the task. For energy extrinsic services (space heating and air quality), the devices addressed include National Building Code housing, Energy Efficient (R2000 type) housing, advanced housing with increased thermal mass, dynamic wall and other features, equipment and measures for control of comfort parameters, standard and advanced space heating systems, heat pumps, ventilation systems, and photosynthesis. For energy intrinsic services (lighting, clothes washing and drying, personal washing and drying, food preparation, audio/visual entertainment, and outdoor maintenance services), the devices addressed in the study include standard and high efficiency lamps and fixtures, lighting controls and daylighting, handwashing, standard and advanced washers, hot and cold water washing, standard and advanced water heaters, clothes lines, standard and advanced clothes dryers, shower, bath, sauna, towelling, hair dryer, conventional and microwave ovens, crock pots, electric and solar dryers, standard and advanced refrigerators and freezers, portable radios, standard radios and televisions, shovels, snow blowers, and hand and power lawn mowers.

REFERENCE SITE

For the purposes of this study, a flat residential lot situated in the Ottawa climate zone, 10 m by 35 m (about 35 feet by 120 feet) in size, was selected as a reference site. There was assumed to be no shading from outside of the lot boundaries, no streams or other surface water flows, and no major wind obstructions in the vicinity.

BUILDING ENVELOPE COMPONENTS AND STRATEGIES

Comfort is normally maintained by controlling the interior environment of a building. Many combinations of air temperature, surface (radiant) temperature, air flow, humidity, clothing level, and air speed may be used to maintain comfort. The energy used to maintain these conditions vary with the combination of comfort conditions selected; with the size, structure and materials of the envelope; and with the efficiency of devices used to convert purchased off-site or external energy into usable heating and cooling, moisture control and air movement. Devices used to maintain comfort may be divided into two component groups: envelope components, and conversion components. Envelope components determine heating or cooling, humidification or dehumidification, and air movement loads. Conversion components transform external and ambient energy into useful heating, cooling, humidification, dehumidification, or air movement, sufficient to meet the energy load of an envelope. Heating and cooling loads for several combinations of envelope components and comfort conditions were estimated. Increasing insulation levels, adding seasonal and diurnal heat/cold storage, utilizing modified dynamic walls which collect more of the incident solar energy falling on the house wall, and using natural cooling and 90 per cent heat recovery, all could be used in combination to provide an envelope which requires no external energy. The heating and cooling loads for various building envelope strategies are presented in Tables 1 and 2.

Table 1 - Heating Loads for Various Building Envelope Strategies

Home Type	Strategy	Window Placement	Gross Heat Load (GJ/a)	Free Heat (GJ/a)	Net Heat Load (GJ/a)
Code housing	Optimum temperature, normal clothes level	Equalized	163.5	47.6	115.9
Code housing	Minimum acceptable temperature, high clothes level	South Optimize	105.9	43.4	62.5
Code housing with dynamic wall	Optimum temperature, high clothes level	Equalized	115.2	48.3	66.9
Energy efficient housing with 75% heat recovery	Minimum acceptable temperature, high clothes level	Equalized	58.5	36.5	22
Energy efficient housing with 10% radiant heat	Minimum acceptable temperature, high clothes level	Equalized	62.9	34.2	28.7
Advanced house with heavy mass and 90% heat recovery	Minimum acceptable temperature, high clothes level	Equalized	27.4	27.4	0

Table 2 - Cooling Loads for Various Building Envelope Strategies (Equalized Window Placement)

Home Type	Strategy	Gross Cooling Load (GJ/a)	Free Cooling (GJ/a)	Net Cooling Load (GJ/a)
Code housing	Optimum temperature, normal clothes level	18.3	8.6	9.7
Code housing	Maximum acceptable temperature, low clothes level, and natural cooling	2.2	0.9	1.3
Code housing	Maximum acceptable temperature, low clothes level, natural cooling, air movement, and radiant cooling	0.3	0.1	0.2
Advanced house with heavy mass	Maximum acceptable temperature, low clothes level, and natural cooling	0	0	0

INDOOR AIR QUALITY

The basic requirements for air quality in a dwelling are a supply of oxygen for respiration, and the removal of carbon dioxide and other toxic substances. The maintenance of indoor air quality (IAQ) involves many separate tasks, not all of which may be required in every home. Moreover, some homes accomplish these tasks using very different systems and technologies, and at varying levels of service for each task. The most common device used to control air quality is the combination of natural air infiltration and mechanical ventilation.

LIGHTING

Lighting is a means of facilitating other human needs for survival, comfort and enjoyment. The need for lighting is also dependent on lifestyle. Before electricity became available, the options for producing artificial light had hardly changed in several thousand years; something had to be burnt to produce light. Lighting can be provided with natural daylight, light from fuel combustion (such as kerosene), and electric lamps. The perfect lighting system would translate 100 per cent of energy used into light, and illuminate only specific areas. In reality, however, lighting systems do not come close to this. Inefficiencies occur in the lamp itself (as measured by its efficiency), in the fixture (as measured by its coefficient of performance), in its usage (area and deviation), and its frequency distortion.

DAYLIGHTING

The availability of daylight to meet household lighting requirements depends on a vast range of conditions and factors. These include: geographic latitude, weather patterns, site, time of year, building envelope characteristics (number, shape, size, location, type of windows and other daylight-transmitting devices/strategies), as well as many aspects of lifestyle (time spent in the house, daily regime, number of persons present, the various costs of providing artificial illuminance, household "will" to use daylighting, etc.). The amount and intensity of daylight incident on a vertical wall at each cardinal point of the compass were determined. Estimates were then made of the interior lighting requirements which could be satisfied using daylight.

CONCLUSIONS

Absolute Energy

The absolute or minimum energy necessary to provide a service is often subject to the occupant's desired level of service. Absolute energy also needs to be expressed in terms of the required power level and energy quality. Lighting, for example, requires a minimum light level for each task. It also requires a high quality energy form, light. Energy quality is particularly important when the energy need is for a low quality energy form, for example, warm water or heat.

Energy Availability

There are many sources of energy available to meet household energy demands. It was found that the amount of solar, wind and geothermal energy available on a residential building lot are significantly greater than the relatively small needs of intrinsic energy services, or the amounts of energy used to meet energy extrinsic services such as comfort maintenance and air quality. The energy quality of two of these sources, solar and wind, also match many of the energy quality needs of intrinsic services. The gathering of this ambient energy into a useful form requires the use of conversion and storage devices. In the case of geothermal energy, an external source (usually electricity) is also needed to upgrade the quality of the source to a useful quality level. Even this energy, however, could be provided from solar systems with adequate storage capabilities.

Thermodynamic Efficiencies

The thermodynamic efficiencies of household devices used to meet energy requirements were, with a few exceptions, found to be extremely low. Many have efficiencies that are lower than one per cent, and most have efficiencies less than 20 per cent. There is, however, significant room for improvement. The following recommendations are made.

Improve Conversion Efficiencies

Improved efficiencies are realized with better matching of energy source quality to energy need. Many household devices do not convert electrical or fossil fuel energy efficiently into the energy actually required. Most of the losses are in the form of heat, either because of inefficient electricity transformation or because of simple heat losses. By reducing conversion losses of devices, their energy efficiencies can be improved, often dramatically.

Matching Household Device to the Need

Improved design is required to match household devices to energy needs. Many devices, such as the typical refrigerator, are far larger than necessary. Also, devices often provide a constant output even though energy need fluctuates, as in the case of lighting and refrigerators. Efficiency can be improved by introducing control systems to match output to need, and by designing the device to meet a variety of loads, as in a compartmentalized refrigerator.

Match Energy Quality Through Choice of Fuel

Many household devices use a high quality energy source (electricity or fossil fuel) to meet a low quality energy need (heat). This reduces efficiency. Also, low generation efficiency of external, purchased energy sources (as low as 29 per cent for nuclear generated electricity), coupled with resource extraction and transmission losses, results in significantly reduced efficiencies in the overall system. Using more waste heat and energy sources with high fuel cycle efficiencies would greatly improve energy ratios and efficiencies.

Increased Use of Ambient Energy Sources

Use of on-site heat recovery and ambient energy should be increased. Significant amounts of energy are available from ambient sources on the dwelling lot or within the dwelling, or as waste heat. Household devices should take advantage of these free sources. Solar and wind energy, and geothermal heat could, with the appropriate conversion devices, be utilized to meet significant portions of an efficient dwelling's energy needs.

RECOMMENDATIONS FOR FUTURE STUDY

Further investigation should attempt to improve the simulation of building envelope heating and cooling, including more appropriate treatment of walls, heat and cold storage, moisture storage and release, solar gains and natural ventilation. Strategies should also be enhanced so that the complex interactions between devices can be analysed. Complex housing services, such as air quality requirements (including toxic substance removal), should be addressed in more detail. The need to use surrogate absolute energy estimates for some household services, such as food cleaning and stirring, should be reduced by conducting more detailed analysis of specific energy requirements.

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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.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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