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Full Name of Author — Nom complet de l'auteur

Carol Ann Hinde

Date of Birth — Date de naissance

26 September 1954

Country of Birth — Lieu de naissance

Toronto, Ontario

Permanent Address — Résidence fixe

77 Wayling Avenue
Vanier, Ontario
K1L 6A5

Title of Thesis — Titre de la thèse

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Name of Supervisor — Nom du directeur de thèse

D.M. Anderson

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AN INVESTIGATION OF THE LAND USE IMPLICATIONS
OF SMALL UNIT RESIDENTIAL SOLAR ENERGY SYSTEMS
IN ONTARIO

by

Carol Ann Hinde, B.A.

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A thesis submitted to the Faculty of Graduate
Studies and Research in partial fulfilment
of the requirements for the degree of Master
of Arts
in Geography

Department of Geography

Carleton University

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submitted by Carol Ann Hinde, B.A.
in partial fulfilment of the requirements for
the degree of Master of Arts.

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Carleton University

October 05, 1984

ABSTRACT

As energy prices continue to rise, homeowners are looking for ways to reduce their dependence on costly, and potentially unreliable, fossil fuels. One energy source under investigation is the sun. The major objective of this thesis is to investigate the geographical impediments to the viable utilization of solar energy as an energy source in the Canadian urban environment. Of particular interest is the lack of protection available for solar access in the built environment.

Various solar system and solar capture techniques are examined and evaluated. Of these, four solar options are considered to be potentially viable in the foreseeable future and the land space requirements of these options are identified.

Current and potential planning mechanisms, intended to protect the solar user's access to solar energy, are discussed. The best potential mechanism for protecting solar access in built-up areas in Ontario is determined to be the solar zoning by-law.

PREFACE

This thesis has taken a number of years to complete. When I started, the cost of fuel was rising dramatically and there was a concerted effort to reduce the individual's and the nation's consumption of that non-renewable resource. The increased use of solar energy was seen as one possible means to that end.

Over the last few years fuel prices have stabilized and, although there is greater awareness of energy conservation, the panicking and rationing has disappeared. This provides us with a breathing time to plan intelligently for the integration of facilities to use alternate forms of energy and techniques to conserve energy. It is the intention of this thesis to provide some insight into the unique requirements of solar energy usage, and to identify the implications these requirements have on land use in the urban area.

I wish to acknowledge a number of people without whose support and assistance this would never have been a reality: Professor Duncan Anderson, my advisor, who provided valuable direction and comments for every page of the text; Don Buchan, my husband, who taught me everything I know about solar energy; my parents, whose example over the years encouraged me to strive for this achievement; Mark Lawton, Don's partner, and the rest of the gang at the office, for their comments and help in preparing the text.

Ottawa, Canada
13 September, 1984.

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CHAPTER 1

INTRODUCTION

1.1 Background

The use of solar energy has been under development for many years in various parts of the world. Solar water heating is a standard method of providing domestic hot water in parts of Australia, Israel, and Japan (Duffie and Beckman, 1974). In the United States, since the late 1930's, the Massachusetts Institute of Technology has undertaken extensive studies of the utilization of solar energy for space heating (Beckman, Klein and Duffie, 1977).

In Canada, since the mid seventies, significant effort has been expended in developing and demonstrating solar energy systems. The federal government established the Solar Programs Office in 1978 to manage three solar energy programs with 130 million dollars in funds (Solar Programs Office, 1981).

During that same period the Ontario government more than tripled the Ministry of Energy's solar energy budget from a half million in 1977 to \$1.75 million in 1980-81 (Ontario Ministry of Energy, 1981).

To date, solar energy systems have not gained widespread acceptance in this country as a viable alternative to conventional energy sources. As of 1983 a fraction of one percent of Ontario's total energy demand is satisfied by solar (Buchan, 1983). In its 1981 status report, the Ontario Ministry of Energy optimistically predicts that by 1995 solar energy could contribute as much as two percent of Ontario's energy needs (Ontario Ministry of Energy, 1981). Although small in relation to the total energy demand, two percent would be equivalent to 15 million barrels of oil--enough to heat more than half a million homes a year (ibid).

Solar energy systems vary greatly in their configuration. They range from small package systems supplying the domestic hot water heating requirements of an individual dwelling to large central thermal electric utility systems supplying electric power to a distribution network (Bennington, Curto, Miller, Rebibo and Spewak, 1978).

In Canada, the widespread utilization of solar energy systems would require significant changes to land use planning. Energy systems currently in use, including hydro, fossil and nuclear electrical

generation and oil and gas supply, are, in general, relatively divorced from the point of end use.

In and around major urban centres these energy systems are not considered to be large consumers of land (Hoare, 1979). Solar, on the other hand, particularly large central systems in the form that supplies direct heat to the consumer, requires large areas dedicated to collection and storage facilities. These areas must be located very close to the point of use for the heat--that is, to urban areas--in order to maintain high system efficiencies and decrease equipment costs. Small residential solar systems, although individually not requiring large tracts of land, do place major constraints on surrounding developments--these units must have access to the sun.

The requirements of solar energy systems in urban areas would further complicate an already complex situation. As well as requiring all the traditional rights of existing residential buildings, the solar development would require sites with a southerly exposure. In order to protect solar use sites, adjacent areas of land must be restricted to development which would not shade the southern exposure of these developments. Thus, preservation of the potential for solar energy systems would necessarily become an important component of a system of carefully integrated land use planning.

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The urban geographer, in his study of the urban environment, is concerned with the factors that have molded its form. In the past, the availability of energy has played a major role in shaping the urban form. For example, the advent of an inexpensive means of rapid transportation -- the car -- led to extensive urban sprawl during the twentieth century.

At present, and perhaps to a greater extent in the future, the use of solar energy may have a significant impact on the form of the urban environment. A number of geographers have realized the potential interaction and have begun to investigate the impact of solar energy on land use. Professors Harold Foster and W.R.D. Sewell of the University of Victoria's Geography Department have been involved in the energy field for some time. In March of 1980 they jointly chaired a symposium on energy conservation in land use planning (Sewell and Foster, 1980).

Professor Duncan Anderson of the Geography Department at Carleton University addressed the impact of solar energy utilization in his 1980 paper "Energy for Tomorrow" (Anderson, 1980). Other geographers have investigated the geographical aspects of solar energy including Anthony Hoare and Peter Suckling (Hoare, 1979; Suckling, 1982).

Over the last decade, urban infill has become a significant trend in the residential construction sector. The oil crisis of 1973 and the apparent, slow decay of the urban core created the incentive for citizen and

politician to re-examine the benefits of upgrading core residential neighbourhoods (Ralph and Przybyłowski, ed., 1982). If solar energy systems are to be effectively integrated into these developments, the trade offs of unit density versus solar exposure must be carefully examined.

With the long lead time required to develop and implement new energy systems, it is important that the land use implications of all solar energy systems be examined now. Steps should be taken today to identify the land use impacts, develop the means to lessen the adverse impacts and emphasize any beneficial attributes that the future retrofitting of solar systems would have on land being developed today.

The examination of the land use implications of all solar energy systems is too broad a subject to cover for a master's thesis. This thesis concentrates on one facet of the subject: small solar systems which can be applied to low-rise residential buildings in the built environment.

The province of Ontario provides the backdrop for this examination.

Ontario and the federal government have been at the forefront in the development of solar technology in Canada. It is at the provincial level however, that meaningful changes will be implemented and, therefore, it is the land use implications within the Ontario context that are under consideration.

Efforts have been made in a number of studies to examine the land use implications of small solar systems for low-rise residential buildings, however, the major focus of these studies has been on new subdivision construction. The City of Brampton, Ontario, for example, has developed a by-law incorporating solar energy policies and criteria in the design of a residential subdivision (Ross, 1979a). The city of Davis, California, is another example of a municipality making full use of its powers affecting subdivision and site planning to achieve energy conservation (Lang and Lounds, 1979).

- Estimates indicate that 75 percent of the Canadian housing stock for the year 2000 is already built (Energy, Mines and Resources, Canada and Ontario Ministry of Energy, 1982). A significant proportion of the remaining 25 percent will be urban infill construction. With these facts, it is extremely important that the urban infill and retrofit land use aspects of solar energy implementation be carefully examined.

1.2 Objectives

The major objectives of this thesis are to:

- Examine small unit residential solar energy systems which show some promise for present and future use in Canada and identify the land

use constraints and benefits that are associated with each system or technique.

Determine those factors which must presently be considered so that when and if the need arises in the future, small unit residential solar energy systems can be incorporated into the existing building stock.

Within this objective particular emphasis has been placed on the examination of solar heating systems designed to be retrofitted to existing buildings and for proposed urban infill dwellings.

Develop a set of preliminary planning guidelines to ensure the compatibility of residential land development with the future introduction of solar energy use.

1.3 Methodology and Material Organization

This section outlines both the methodology of this thesis and the organization of the material. The methodology is presented first, as a series of seven tasks within two distinct phases. The various tasks within the phases are then outlined in more detail in the discussion of the organization of the material following the methodology.

1.3.1 Methodology

Phase I: Categorization of Land Space Requirements of Solar Capture Techniques

Task 1: Literature Review

Task 2: Identification of Possible Solar Capture Techniques for Small Unit Residential Applications

Task 3: Selection of Those Solar Capture Techniques Considered to be Viable in the Foreseeable Future

Task 4: Identification of the Land Space Requirements of the Viable Solar Options

Phase II: Assessment of the Land Use Implications of the Land Space Requirements Detailed in Phase I

Task 5: Examination of the Spatial and Temporal Implications of the Land Space Requirements Identified in Task 4

Task 6: An Assessment of the Existing and Potential Mechanisms Available to Protect Solar Access

Task 7: Development of a Set of Preliminary Planning Guidelines for Protecting Solar Access for a Specific Location in Ontario

1.3.2 Organization of the Material

The use of solar energy to heat space or water for residential applications is still relatively uncommon. In Canada, the federal government and the Province of Ontario are two of the major sources of information on solar energy. A few Canadian and American municipalities have begun to develop solar access protection legislation as more citizens are investigating the use of solar capture devices, however, it is not a well publicized energy source. Most of the sources of information for this paper were either studies conducted by a government department or were private studies funded by government agencies. No specific chapter encompasses a review of the literature, instead, relevant works are discussed where appropriate throughout the text.

Canadian, American and some European sources were reviewed. Although a wealth of information is available discussing the mechanics of solar energy use, very little documentation exists in the area of solar access protection.

The following chapters examine the relationship of energy and land use and the impact of a concern for the utilization of solar energy.

Chapter two provides a brief glimpse at the division of the "energy pie" in Ontario and continues with an introduction to land use planning. The

chapter is summed up by examining some of the relationships between energy and land use.

An identification of the various possible methods of collecting solar energy and its potential uses are contained in chapter three. The viability of the various methods and uses are discussed within the context of the Canadian (and particularly the Ontario) energy and climatic situation. At the end of the chapter the author, with assistance from Mr. Donald Buchan, has developed an evaluation of the various methods and uses of solar energy. Mr. Buchan is a principal with the consulting engineering firm of Buchan, Lawton, Parent Ltd. and is a leading authority on solar systems in Ontario and across Canada.

The fourth chapter incorporates a discussion of the mechanics of determining the shade cast by objects at various times during the day and during the various seasons of the year. The land space requirements of the first four solar options identified in chapter three are then examined based on the considerations identified in the first part of this chapter.

Having identified the land space requirements of the four most viable solar options, a shift is made, in chapter five, to a discussion of the potential options available to protect the user's access to solar energy. The current situation in Ontario and the legislative framework within which solar protection could be provided is examined.

The City of Ottawa has recently completed the development of solar design guidelines in the form of a voluntary conformance instrument. The first sections of chapter six contain a summary and a critique of these guidelines. Their effectiveness to protect solar access for the urban dweller is examined and the guidelines are compared with legislation from various other municipalities.

The City of Ottawa is one of the first municipalities in Canada to develop solar protection guidelines for established residential areas. Because of the uniqueness of the guidelines and the author's familiarity with the Ottawa situation, the City of Ottawa's Solar Design Guidelines were used as a basis for the development of a set of preliminary planning guidelines. The guidelines are intended to restrict development to protect a solar user's access to a reasonable amount of sunshine without unduly restricting surrounding development.

The seventh chapter summarizes and synthesizes the contents of the thesis. The major recommendation is that legislation, similar to that outlined in chapter six, is required to protect solar access. The question is raised, as to whether there is the political will in Ontario (or elsewhere in Canada) to implement the necessary legislation to protect solar access for the solar user.

CHAPTER-2

ENERGY AND LAND USE

2.1 Energy

Energy is a fundamental component of life. In Canada, we require energy for a wide variety of purposes, including the heating and lighting of residential, commercial and industrial buildings, for the transportation of goods and people and to run our industries. In Ontario the total consumption of energy by the four major sectors of society is estimated to break down as illustrated in Figure 2.1.

In Canada and other western nations during the 1970's and early 1980's, as world fuel prices continued to rise, governments and individuals attempted to identify alternate sources of and means to reduce the consumption of energy (Gander and Belaire, 1978, Ontario Ministry of Energy, 1977).

A wide range of solutions have been proposed. The proponents of conservation have developed homes that are so well insulated that even on the coldest winter day essentially no source of heat is needed beyond that

Figure 2.1
ENERGY CONSUMPTION
BY SECTOR

(Source: Ontario Ministry of Energy, 1981b)

provided through lighting and the use of appliances (Orr, 1983).

Futurists have proposed large fields of mirrors tracking the sun and reflecting the radiation to a high tower where the heat is transferred to a working fluid used to run a turbo-generator (Bennington et al, 1978).

Others continue to search for new sources and means to further develop our fossil fuel and nuclear resources, while still others investigate the potential of renewable energy sources including the wind and the sun (Swartman, 1978; Enerplan Consultants Ltd., 1982).

2.2 Land Use

Effective land use planning requires significant foresight and political will; not only must current land uses be considered, but changes in land requirements, and the associated social, environmental and political constraints of these new uses must be evaluated. It is never possible to completely assess in advance the impacts of a new technology, but steps can, and should be taken to identify as many of these potential impacts as possible.

Numerous technologies have been introduced in this country over the past decades, some of which have had very serious impacts on society in general, and land use specifically.

The advent of the automobile for example, in a few years totally changed the development patterns of cities. Extensive suburban development around intensively developed urban cores has necessitated the construction of expressways and public transit systems to facilitate the movement of people.

The need for these transportation routes in some large urban areas was anticipated and land was set aside for this use. In most cases, however, extensive amassing of land was necessary after urban development had occurred with resultant high costs, and often a very detrimental effect on existing neighbourhood structures.

Numerous examples of how advanced steps were not taken to accommodate future land requirements, either through the lack of foresight or through the lack of significantly stringent guidelines and regulations can be seen. For example, the encroachment of urban development on expanding major airports has resulted in serious noise and in some cases, safety problems. The need for larger airport sites due to the potential for increased aircraft travel, and the projection of larger and larger aircraft requiring bigger facilities was in some cases seen in advance. At Malton, in what is now Metropolitan Toronto, a large tract of land was reserved for aviation in the 1930's. Had measures been taken at that point to restrict noncompatible types of development in certain areas surrounding the airport site, the question of relocating the airport to

a more remote site with the inherent higher cost and reduction in convenience would not likely have been raised as it has been in the past.

2.3 Energy and Land Use Planning

Recent literature suggests that land use planning can be instrumental in reducing energy used primarily in two sectors: the transportation sector and the residential sector. Studies done by Lang and Armour in Canada and Hemphill and Erley in the United States all indicate that reducing the number of and length of trips travelled and the amount of energy consumed for residential heating are the two major areas land use planning can have an impact on energy consumption (Lang and Armour, 1980, 1982a; Lang and Lounds, 1979; Hemphill, 1980; Erley, 1980).

Transportation involves the movement of goods and people between different locations. If the distances and/or number of trips travelled between locations can be reduced, fuel can be saved. Planning the location of related goods, services and people within close proximity would reduce the distances travelled and therefore conserve energy.

One potential means of reducing travel through land use planning is to encourage the development of nodal centres within urban areas in which residential, commercial, services and light industry are intermixed.

(Sewell and Foster, 1980). Traditionally, the goal of land use planning has been to separate conflicting uses, for example commercial and residential, to achieve orderly, economical and convenient development of communities (Lash, 1977). This zoning of areas exclusively for a single use might have to be abandoned and a new approach of limited integration adopted to achieve the desired end.

The identification, within the urban area's official plan, of the goal to encourage mixed use nodal development could be an important step toward reducing energy consumption. The land use planner can therefore play a major role in reducing the movement of goods and people through the strategic zoning of mixed use developments in appropriate locations throughout the urban area.

Lang and Armour have identified a total of fifty measures available to the municipal planner to conserve energy. The limitation of urban sprawl, the orientation of local street systems to minimize transportation energy and the restriction of strip development are three further measures identified to reduce transportation energy (Sewell and Foster, 1980).

The encouragement of infilling with medium and high density residential development on vacant or underutilized land in the urban core and along major public transportation routes is a fifth means available to the planner to reduce energy consumption in the transportation sector. Higher

urban residential densities would make public transit facilities a much more viable option for the urban area, preserve valuable food lands from continuing urban sprawl, facilitate the potential for district heating installations; and provide greater opportunity for pedestrian and cycle transportation.

The encouragement of medium and high density residential development should also contribute to reduced energy consumption in the residential sector. Various studies have determined that higher density developments, in which one or more walls of a housing unit are adjoined to another unit, results in a savings of heating energy for both units (Ontario Ministry of Municipal Affairs and Housing and Ontario Ministry of Energy, February, 1982). As well, it has been found that heat loss is partly a function of the ratio of roof to floor area (ibid.). According to the Ontario Ministry of Municipal Affairs and Housing, when comparing dwellings of equal floor area, the heat load of a two storey house can be fifteen percent less than that of a bungalow. A further twenty to thirty percent savings is possible if one or two of the walls of the two storey dwelling adjoin other similar units (ibid.).

Increasing residential densities in the urban area is one measure the planner can incorporate into his efforts to reduce energy consumption in the residential sector. As well, the planner can promote the use of passive and active solar systems and the use of district heating and

cogeneration plants. In 1980, for Energy, Mines and Resources, Canada, Bruce Gough estimated that one third of Canada's gross annual heating energy requirement could be met by passive solar design. This would involve good thermal standards and the placement of at least 75 percent of the dwelling's glazing area on the south side (Lang and Armour, 1982a).

Having briefly examined the relationship between energy use and land use, it becomes clear that encouraging the use of solar capture techniques is one area in which land use planners can contribute to a reduction in the residential use of traditional energy sources.

A variety of solar capture techniques are available. The following chapter identifies the various techniques and investigates the relative feasibility of the solar system options.

CHAPTER 3

SOLAR SYSTEM OPTIONS

Uses for solar energy in the residential environment cover the full range of space heating, space cooling, heating of domestic hot water, swimming pool heating and supplying electrical energy needs. Within each of these areas there are different means of collecting the solar radiation, and of converting and storing the energy for use.

Solar systems can be of two different types, solar thermal systems and photovoltaic systems. In solar thermal systems, solar radiation is converted into heat energy. In photovoltaic systems, solar energy is converted directly into electrical energy. The following sections provide further elaboration.

3.1 Active and Passive Solar Thermal Systems

Methods of collecting solar thermal energy are generally divided into two major categories, active solar collection and passive solar collection.

Although these two methods in some cases overlap, the general division is usually made on the basis of whether or not mechanical devices, such as fans or pumps, are required to transfer the collected solar energy to the load being served.

A typical example of an active solar heating system would have collectors mounted on the roof of a building with either air or a liquid, such as propylene glycol and water, circulated through the collectors (see Figure 3.1.1). The heated air or liquid would be pumped either to the space requiring heat or to a storage system for later use. The storage system is usually a large tank or tanks containing a medium (for example, water or rocks) which is heated by the warm fluid from the collectors. The heat is stored in the medium until required.

A typical example of a passive solar system would be a building with large south facing windows designed to allow the maximum input of solar radiation (see Figure 3.1.2). This solar radiation would directly heat the space without any mechanical means of transferring the heat. During periods of sunshine, the walls and floors of the space are warmed by the sun. Due to the thermal mass of the absorption surface, the heat is retained and slowly released when the room cools.

From a land use viewpoint, passive systems generally impose greater constraints because, not only the roof, but the south facing wall of the

Figure 3.1.1
ACTIVE SOLAR SYSTEM SCHEMATIC

Figure 3.1.2
PASSIVE SOLAR FEATURES

building must be oriented to properly receive the solar radiation. With an active system, only the collector array must be oriented toward the sun. This array can be separate from the building to which it is supplying energy.

3.2 Uses of Solar Energy *

As mentioned earlier, numerous uses for solar energy exist in the residential environment. A cursory review of federal and provincial solar programs indicate that some of these options are currently in widespread use while others are only at the conceptual stage (National Research Council, Canada, 1982, 1983; Buchan, Lawton, Parent Ltd, 1983b; Tutton, 1983). Those options currently experiencing a growing acceptance include:

- heating of domestic hot water,
- passive solar space heating,
- swimming pool heating.

Those potential options not yet experiencing a significant degree of market penetration, largely because of present relative cost, include:

- active solar space heating,
- active solar space cooling,
- photovoltaic electrical generation.

It should be noted that significant changes in technological efficiency and relative cost (either lowered cost of the system or higher cost of fossil fuels) could change this picture sharply in the future (Hoare, 1979).

3.2.1 Solar Domestic Hot Water Heating Systems

Domestic hot water production in the residential sector in Canada is a rapidly growing enterprise with several thousand units currently installed (Buchan, 1983). Support from the Federal government and several provincial governments through various demonstration and subsidy programmes have accelerated development in this area. The Federal Department of Public Works' PUSH programme, for example, was initiated for the specific purpose of building an integrated solar industry in a shorter period of time than would be possible in a normal market situation (Solar Programs Office, Public Works, Canada, 1981). Under that programme more than 800 systems have been installed, many of them domestic hot water (DHW) systems (ibid.).

A typical solar domestic water heating system consists of a small collector array, usually between four and eight square metres in area, a small storage tank and associated mechanical equipment and piping (See Figure 3.2.1). The collector array is mounted facing south on the roof of

Figure 3.2.1
SIMPLE DOMESTIC HOT WATER HEATING SYSTEM
SCHEMATIC

the house, on a south facing wall of the house or on a ground-oriented, framework near the house.

Most current models of solar heating systems for domestic hot water heating are designed to provide a portion of the hot water requirements throughout the year. A new trend developing in the industry is toward the use of systems designed to provide energy only during the period of the year when freezing outdoor conditions are not encountered (Buchan, 1983).

• These systems are referred to as seasonal solar domestic hot water systems. The major advantage of these systems from a technical viewpoint is the elimination of the need for protection against freezing. From a land use viewpoint these systems have an additional advantage in that the collectors do not have to be located in such a way that they can receive the low angle winter solar radiation.

It is not economically feasible to expect a solar domestic hot water heating system to supply all the hot water requirements of a household. The cost of obtaining a system large enough to provide hot water even on cloudy days or days of heavy hot water demands would be prohibitive. As well, it would be extremely inefficient. A conventional, back-up hot water tank is an integral part of any solar DHW system. For an average application, a solar system would be expected to contribute about forty percent of the annual hot water heating requirements of a household (Canadian Solar Industries Association Inc., 1981).

Solar domestic hot water systems can be installed in a wide variety of locations. A particular orientation of the dwelling is not required if the system is to be wall or ground mounted and hence these systems are often suitable in retrofit situations. To date, the majority of systems installed in Canada, have been retrofitted to existing dwelling units (Buchan, 1983).

3.2.2 Passive Solar Heating Features

Passive solar heating is generally used for space heating purposes. Three passive collection techniques are generally used (see Figure 3.2.2).

These are:

- direct gain,
- attached sunspace,
- Trombe wall.

A house using the direct gain method of solar collection would, in most cases, appear to be a conventional house. A direct gain system allows sunlight to enter the living space of the house through large south facing windows to directly heat that space. Window areas on other faces of the house are minimized. With a direct gain system, overheating of the space and undesirable temperature fluctuation can be a problem, if careful thought is not given to summertime shading of windows.

DIRECT GAIN

When the sun shines, the inside air, furniture, walls and floor are heated.

ATTACHED SUNSPACE

The attached sunspace is allowed to heat up and the heat is brought into the living area when needed (by a fan or just through a series of vents).

TROMBE WALL

A massive wall (brick, concrete or occasionally water columns) is constructed just inside a window and the absorbed heat is slowly released to the room.

Figure 3.2.2

PASSIVE SOLAR HEATING FEATURES

An attached sunspace consists of a south facing glazed-in area of the residence that is not considered to be primary living space. It often takes the form of a greenhouse. In this area temperatures are permitted to swing outside the normally accepted range for living space with the transfer of heat to the primary living space controlled by doors, vents or fans.

A Trombe wall is essentially a window with a massive wall built behind it. Solar radiation passes through the window and is absorbed by the massive wall. The wall acts as a storage system for the collected energy and releases it over the period of a day or so. A similar effect to the Trombe wall can be achieved by installing a concrete and tile floor. The floor absorbs heat retains it, and releases it to the cooler house air in the evening.

All passive solar capture techniques require direct exposure of the building to solar radiation during the period of the year when space heating is required.

Although some existing dwelling units lend themselves to the addition of passive solar collection features, the requirement for the proper building orientation precludes the uses of passive solar heating in the majority of existing dwellings. Most passive solar residences in Canada were designed with passive solar features from the outset (Buchan, 1983).

3.2.3 Solar Heating of Swimming Pools

The use of solar energy for swimming pool heating is currently the most economically viable active solar energy use in Canada. A practical solar swimming pool heating system can consist simply of an array of solar collectors through which the circulating poolwater is diverted if heating is required (see Figure 3.2.3). Storage is provided by the large thermal mass of the water in the pool.

3.2.4 Active Solar Space Heating Systems

The development of active solar heating systems first saw widespread effort in Canada with the onset of the energy crisis in the early 1970's. The major initial effort was in the space heating of single family residences. Development in this area has largely been abandoned due to the poor technical and economic performance of these types of systems (Buchan, 1983).

A typical residential space heating system consists of a collector array covering most of the south facing roof of the house, a large storage system of either rock, for an air based system, or water, for a liquid based system, pipes or ducts, pumps or fans and numerous other components (see Figure 3.2.4). In many cases a means of using some of the collected energy for domestic hot water heating is also provided.

/ Figure 3.2.3
SOLAR HEATED SWIMMING POOL
SCHEMATIC

Figure 3.24
ACTIVE SOLAR SPACE HEATING SYSTEM
SCHEMATIC

As with passive solar space heating, a clear southern exposure is required to ensure that a significant amount of the low angle winter radiation reaches the collectors. Unlike passive solar, however, this requirement relates only to the collectors, not the south face of the building. Building orientation is again important because it is seldom practical to build a free standing collector array of sufficient size for space heating.

3.2.5 Active Solar Space Cooling Systems

The use of solar energy for space cooling purposes in Canada has yet to receive any significant degree of attention (NRCC, 1982, 1983). Efforts in the United States have demonstrated the technical feasibility of such systems, however, initial capital costs, system complexities, and the short residential cooling season in Canada will likely preclude any significant work in this area for the foreseeable future. No residential solar space cooling system is known to exist in Canada (Buchan, 1983).

3.2.6 Photovoltaic Solar Systems

Photovoltaic systems for residential use in Canada are unlikely to see any significant development in the urban environment. With the relatively low electrical energy rates in Canada and the problems associated with converting and storing the photovoltaic electric energy, the current and foreseeable cost-effectiveness of this type of system is extremely poor (Buchan, 1984). In rural and remote areas where electrical generation is

through the use of costly diesel generation systems, photovoltaic solar electric generation systems may become cost-effective in the future. There is considerable research underway to improve the technical efficiency and reduce the cost of photovoltaics. A breakthrough and/or a dramatic rise in the cost of fossil fuels could change the equation.

3.3 Solar Radiation Resources

In spite of its location at relatively northern latitudes, Canada receives an enormous amount of solar radiation. As one moves north, however, the available radiation concentrates itself more and more in the summer months. With a solar energy collector inclined at the optimum angle for collection, the potential solar energy available in Regina, Saskatchewan is approximately equal to that in Southern Texas on a year round basis (Lang and Armour, 1982a). Even at Resolute Bay in the Northwest Territories, with steeply inclined collectors, approximately the same annual total energy is available. This, of course, ignores local climatic conditions, such as the frequency of cloudy days.

Because of the mismatch between the solar insolation and the heating load in Canada, the use of seasonal heat storage facilities is very attractive. In order to maximize the overall system efficiency and minimize the construction costs of the required storage systems, systems incorporating

seasonal storage must be very large. The use of these large central systems shows promise for the supplying of space heat, domestic hot water, and industrial process heat (Buchan, 1984). Because of the large size and centralized utility nature of these systems, they are not dealt with in this thesis.

The concentration of available solar radiation in the summer months in Canada means that summer uses for the energy will tend to be the most cost-effective, followed by year round uses, and finally winter time uses.

The maps on the following three pages illustrate mean global solar radiation in Canada. This is a measure, in megajoules per square metre, of the amount of solar radiation striking a level surface. Maps for the months of June and December, and the annual mean, are included.

The measurement of solar radiation striking a level surface paints a bleaker picture than is actually the case in Canada. A comparison of the mean daily global solar radiation falling on various sloped surfaces at Mont Joli, Quebec in December, indicates twice as much radiation (7.6 MJ/m^2) falls on a surface sloped at a 60° angle facing south than on a flat surface (3.4 MJ/m^2) (Phillips and Aston, 1980:11). In June, at the same location, a surface sloped at 60° receives somewhat less (17 MJ/m^2) than the flat surface (22 MJ/m^2) (ibid).

From a land use point of view, summertime collection of solar radiation is further favoured by the fact that solar collectors require a less clear southern exposure because of the higher elevation of the sun in the sky (see Figure 3.3.1).

In Canada the sun is never directly overhead and hence in the case of small urban residential lots the rays of the sun cross numerous properties before striking the earth. Controlling development to allow for access to solar radiation becomes a greater problem the further north one goes and the closer to the winter solstice one wishes to collect the energy.

3.4. Evaluation of Potential Solar System and Capture Techniques

There are significant criteria which can be applied to evaluate the feasibility of the various solar systems and solar capture techniques.

Hoare, in a 1979 paper published in Progress in Human Geography examined the geography of alternate energies. He identified four sequential tests of feasibility that all alternate energy systems would have to pass:

- on the drawing board -- theoretical feasibility
- on the ground -- technical feasibility
- in the marketplace -- economic feasibility
- among ultimate decision-makers -- political feasibility

(Hoare, 1979:518)

Figure 3.3.1

CHANGE IN ALTITUDE OF SUN'S RAYS
BETWEEN SUMMER AND WINTER

Illustrating increased restricted area required
to protect access to the winter sun.

In Hoare's evaluation, solar energy had passed the theoretical test and was positioned somewhere between the level of technical and economic feasibility. No alternate energies had progressed past the level of economic feasibility.

Lang and Armour, in their evaluation of the constraints to the use of solar energy, identified four similar criteria:

- feasibility of solar systems
- marketability
- cost-effectiveness
- institutional constraints

(Lang and Armour, 1982a:71-74)

As with the criteria identified by Hoare, the evaluation begins with the question: "is it possible?". Lang and Armour consider Hoare's first two criteria as a single criterion and include under it the applicability of solar energy to the density of the residential area:

Marketability refers to the "sale-ability" of the proposed solar capture technique. Will people buy it -- how is it perceived?

Cost-effectiveness asks the question: How much energy will be saved and at what cost? It relates to the third criterion identified by Hoare -- the economic feasibility of the system.

The fourth criterion, institutional constraints, incorporates Hoare's fourth criterion and goes further. It addresses the acceptability of the solar energy option within the existing institutional structures. For example, local building regulations are often counter productive -- energy conserving techniques are often restricted or at least not encouraged.

In this evaluation of potential solar system and capture techniques, five relevant criteria have been identified. Derived from the work of Hoare and Lang and Armour, they have been modified and increased to more accurately evaluate the specific solar options.

The five criteria are:

- technical feasibility
- economic viability
- size of the market sector
- strategic importance of the sector
- institutional feasibility

In particular, the size of the market sector and the strategic importance of the sector vary from the previously identified criteria. The size of the market sector refers to the total potential households for which a particular solar option is available. The strategic importance relates to

the relative importance of the energy use to society. Swimming pool heating is not as important as space heating in the Canadian environment.

3.4.1 Technical Feasibility

All of the solar energy systems and capture techniques discussed here have been shown to be technically possible; however, the technical merits of the various options are widely different. The future technical merits of an option must also be considered when planning for land use requirements.

When examining technical feasibility, one must look at, not only the feasibility of producing working systems, but the potential for being able to maintain the systems in working order in the environment in which they will be placed.

As an example, designing a solar system for use in a single family home for supplying domestic hot water has been shown to be technical feasible, with several thousand units currently installed in Canada. However, the problems associated with maintaining the systems in an operating state are far from solved. Because solar systems in this environment are intended to be equipped with an automatic back-up source of energy, usually electricity, gas or oil (for times when solar radiation is insufficient to supply the entire energy demand) it is often not obvious to the homeowner when the solar system is not functioning properly (Buchan, 1984).

3.4.2 Economic Viability

The economic viability of a system is directly related to the initial capital cost of the system, the ongoing maintenance costs and the cost of the energy the system is displacing. The first two items are relatively constant throughout Canada, however, energy costs vary dramatically with location. As an example, electrical energy used for residential space or domestic hot water heating varies from less than three cents per kilowatt-hour in Winnipeg, Manitoba to in excess of ten cents per kilowatt-hour in Charlottetown, Prince Edward Island (Buchan, Lawton, Parent, Ltd., 1983).

An additional factor which is related to the economic viability of a solar heating system is the comfort level or convenience level it affords. The value of a solar heating system that supplies hot water only when the sun is shining or allows large temperature swings if used for space heating has less value than conventional systems. This factor is, however, very difficult to assess.

3.4.3 Size of the Market Sector

The potential market share for a particular solar option is important because it relates to the long-term potential payback on efforts invested in protecting solar access for that particular option. The development of solar access protection is a long and costly endeavor. It makes sense to invest the effort in protecting access for those uses which are likely to

have the most widespread use first, for example, domestic hot water heating.

3.4.4 Strategic Importance of the Sector

The strategic viability of a particular solar option, the fourth criterion considered, addresses the importance of a particular energy use to society. Heating domestic hot water is a more important social consideration, for example, than heating swimming pools.

3.4.5 Institutional Feasibility

The regulations, codes, and practices governing land development are rooted in an era of abundant energy, and often do not support (and may even oppose) energy conservation (Lang and Armour, 1982a). The lack of a mechanism to protect solar access is a prime example.

Institutional feasibility relates to the social acceptance of the solar option. Do existing zoning by-laws permit its construction? Can insurance, liability as well as comprehensive, be obtained for the solar structure and the house it is associated with? Is there general public acceptance of the solar option? Is there a mechanism to protect solar access, if not, is it likely to be forthcoming in the foreseeable future? These and other political constraints are important considerations when ranking the solar options.

3.4.6 Ranking of Solar Options

The relative importance of each of the discussed assessment criteria is not, perhaps, equal; however, assigning different weighting values would be purely subjective at this stage. For the purpose of this thesis these criteria have been assigned equal weightings.

The ranking of the various solar options discussed at the beginning of this chapter is shown in Table 3.1. Each option has been given a score out of 25 in each of the first four assessment categories. The fifth category, institutional feasibility, has not been included in the evaluation. It has been omitted because, to date, there has been insufficient experience with the various options to indicate significant differences in institutional barriers between options.

The rationale for each ranking is based on the author's familiarity with the various solar options and has been developed with considerable assistance from Mr. Don Buchan. Mr. Buchan is a consulting engineer who, for the past ten years, has worked with and for numerous federal and provincial agencies and departments in the field of renewable energy technology. He is recognized as an authority on the technical aspects of solar energy utilization. Mr. Buchan has directed most of the evaluation programs undertaken by both the Federal government and the Province of Ontario.

Table 3.1 MATRIX OF SOLAR OPTIONS VERSUS ASSESSMENT CRITERIA

	technical feasibility	economic viability	sector size	strategic importance
domestic hot water heating	20	15	25	20
passive solar, space heating	20	20	15	25
swimming pool heating	25	25	10	0
active solar space heating	15	5	20	25
active solar space cooling	10	2	10	5
photovoltaic electrical generation	5	2	20	10

The confidence level for the absolute values presented in the matrix is not very high; however, the relative position of an option with respect to the other options is felt to be justifiable.

Technical Feasibility: In theory, each of the solar options is technically feasible. A variety of problems arise, however, when theory is applied to practice.

The silicon chips used to convert solar energy into electricity in the solar photovoltaic process are extremely costly and fragile. Because the power produced by photovoltaic cells is not directly compatible with normal household electric power, either costly and complex converters are required or special appliances and back-up batteries must be used.

At present, large batteries are required to store small amounts of electricity. Photovoltaics will become more viable for remote installations with the development of a superior battery capable of storing greater amounts of electricity.

The long-term durability of the components, problems with freezing in winter and problems with storing heat to match demand with supply, have, to varying degrees, an effect on the technical feasibility of the other solar options.

Swimming pool heating, the simplest and most technically feasible system, requires no freeze protection and the pool acts as its own storage tank. Solar energy is available when it is most desired.

For space heating, the mis-match between solar availability and heat demand is the greatest. The size of storage required to cover all periods of insufficient radiation would be so large, it would be unfeasible. A back-up conventional heating system would be required.

Economic Viability: Three factors affect the economic viability of a solar option: the complexity and therefore the capital cost of the system, the match between the supply of solar energy and the demand for the converted energy, and the cost of fuel. The payback period associated with all forms of solar heating varies directly with the costs of other forms of energy across the country.

As mentioned previously (Section 3.4.2), the cost of maintaining a system must also be considered. In general, the simpler the design of the system and the more common and easily available the components of the system are, the cheaper it is to maintain.

In terms of economic viability, the technically simplest system is generally the most economically viable. Piping and a simple solar collector are the major requirements to solar heat a swimming pool.

Because of the small investment, and the savings gained by not burning expensive oil and gas, the cost-effectiveness of swimming pool heating is usually good (Ontario Ministry of Energy, 1980c). At present, if properly designed, the inclusion of passive solar captive features on a dwelling can also result in a reasonable favourable return on investment.

In Prince Edward Island, where electricity costs approximately three times as much as in Winnipeg, the payback period for solar domestic hot water (DHW) heating can be as low as five years. In an average Ontario situation, at present, without a government subsidy, a system would probably never show a complete return on the investment (Buchan, 1984).

The greater complexity and the mismatch of supply and demand are the two major factors affecting the economic viability of active solar space heating systems.

Although active solar space cooling systems do not have a problem of mismatched supply and demand, because of technical problems, they have not been developed beyond the theoretical stage. The capital cost associated with these systems and the relatively short residential space cooling season in Canada, makes them economically very unattractive. For residential applications, other, more cost-effective, means are available for air cooling. It appears unlikely that solar cooling systems will be developed for general use in Canada.

The economics of photovoltaic electrical generation is similar to that of active solar space cooling. In the immediate future, it is unlikely that photovoltaic cells will be able to generate electricity as cost-efficiently as the more traditional sources of electricity in the major urban centres. The great advantage to the use of photovoltaic electrical generation is in remote, inaccessible and unmanned sites where a dependable source of small amounts of power is required, as in lighthouses, for example.

Sector Size: The criteria of sector size relates to the overall conventional energy use that a solar option could potentially displace.

All residences with access to the sun have the potential to heat a portion of their DHW requirements with solar energy, and a very large portion of this demand could be served by solar.

Because active solar space heating requires greater solar access than DHW heating (see Section 4.5.3), not all residences will have the present potential to supply a significant portion of their heating requirements with an active solar system.

The generation of sufficient photovoltaic electricity would require approximately the same solar access level as active solar space heating.

As the requirements for solar access become more precise or fewer people require solar energy for a particular purpose, the sector size decreases.

Pool heating and space cooling appeal to a limited group of people, it therefore ranks lower in the category of sector size.

Passive solar heating is only possible if the residence is oriented towards the south with appropriate large windows.

Strategic Importance: The strategic importance criterion addresses the question of social priority. Space heating during a Canadian winter is of much greater importance to man than swimming pool heating. The six solar options are ranked accordingly. Space heating is of greatest importance, then water heating, then electrical generation, and then, the luxuries of space cooling and swimming pool heating.

Based on this ranking technique, the options listed in decreasing order of importance from the viewpoint of land use planning are:

- domestic hot water heating (80/100)
- passive solar space heating (80/100)
- active solar space heating (65/100)
- swimming pool heating (60/100)
- photovoltaic electrical generation (42/100)
- active solar space cooling (27/100)

Because of the very low overall score for photovoltaic electrical generation and active solar space cooling, it is felt that these options show little real viability at this time and in the foreseeable future for use in the urban area. They will not be considered further from a land use planning viewpoint.

It is worth noting, however, that the requirements for photovoltaic electrical generation are generally the same as those for DHW solar heating systems. By planning for the potential to retrofit solar DHW systems in the urban area, the planner is essentially protecting solar access for potential solar photovoltaic systems, as well.

CHAPTER 4

LAND SPACE REQUIREMENTS OF SOLAR OPTIONS

Four solar options were determined in chapter three as being the most potentially viable tools for the land use planner to use to reduce energy consumption. These included:

- heating of domestic hot water
- passive solar space heating
- active solar space heating
- swimming pool heating

In this chapter the land space requirements of these options are examined. Before examining the land space requirements, the mechanics of determining the shade cast by objects at various times during the day and during the changing seasons needs to be discussed. Two coordinates are required to determine the sun's position in the sky at any given time. They are the azimuth and the altitude (Hix Consultants Ltd., 1982). These coordinates are site specific and, therefore, the following discussion focuses on local conditions in Southern Ontario.

4.1 Determining Shade Cast by an Object

Several publications by the Ontario Ministries of Energy and Municipal Affairs and Housing provided the background information for this chapter (Hix Consultants Ltd., 1982; and Ontario Ministry of Municipal Affairs and Housing and Ontario Ministry of Energy, 1982a, 1982b).

"Site planning for solar access is achieved by knowing the shadow pattern--which is the composite shape of a shadow cast by an object over a given period of time" (Ontario Ministry of Municipal Affairs and Housing, 1982b:3).

Three factors determine whether a building can have access to direct solar radiation:

- the height of surrounding objects and their distance from the building,
- the latitude of the site, and
- the topography of the land.

The location of the sun at a given time also needs to be known before calculation of the shadow cast by objects is possible. As mentioned previously, the solar azimuth and altitude are the two coordinates

indicating the sun's position in the sky (see Figure 4.1.1). The solar azimuth is the angle along the horizon of the position of the sun to the east or west of true solar south (Hix Consultants Ltd., 1982). South is the solar azimuth 0° , and movement to the east of south is negative (south-east for example is -45°).

The position of the azimuth can also be indicated in degrees from true north. The true azimuth for south is 180° , east of south being less than that and west of south being greater.

The solar altitude is the angle measured between the horizon and the position of the sun above the horizon (ibid.). It starts at 0° when the sun rises, increases until the sun is at its highest point at solar noon, and decreases to 0° at sunset.

Table 4.1.1 presents the solar azimuth and altitude for locations at 45°N latitude (for example, Ottawa) on January 21.

AZIMUTH AND
 ALTITUDE ANGLES
 X = ALTITUDE ANGLE
 Y = AZIMUTH ANGLE

Once the altitude and azimuth are
 known, the sun can be located in any
 position in the sky for any hour, day
 and month of the year.

Figure 4.1.1

DIAGRAMS ILLUSTRATING SOLAR AZIMUTH ALTITUDE

(Source: Hix Consultants, 1982: 2)

Table 4.1.1

SOLAR AZIMUTH AND ALTITUDE ON JANUARY 21 FOR LATITUDE 45°N

Time of Day	Azimuth	Altitude
8:00	-54.8	5.2
9:00	-43.0	13.2
10:00	-29.9	19.5
11:00	-15.4	23.6
12:00	0.0	25.0
1:00	+15.4	23.6
2:00	+29.9	19.5
3:00	+43.0	13.2
4:00	+54.8	5.2

(Source: Ontario Ministry of Municipal Affairs and Housing 1982b:14)

Figure 4.1.2 illustrates the shadow cast by a two storey house in Ottawa on January 21. The winter solstice (December 21) is the day of the year when shadow lengths are longest and, therefore, if solar access is available on that day it will be throughout the year. The Ontario Ministry of Municipal Affairs and Housing considers the separation between buildings required to achieve solar access in an urban area in Ontario on that date to be too great and has, therefore, substituted January 21 as the day on which to compute shadow lengths (Ontario Ministry of Municipal Affairs and Housing, 1982b).

A six hour period, from 9:00am to 3:00pm, is generally accepted as the time frame over which to calculate the shadow cast by objects. At low altitudes, the sun's rays must travel a greater distance through the atmosphere with a loss of solar radiation. The useful heat available before 9:00am and after 3:00pm amounts to a very small percentage (less than 15%) of the total day's heat and to achieve it would require much greater separation between shading objects (ibid.).

The previous discussion has related to shadows cast during the winter months. The criteria used to establish the solar access required for swimming pool heating and non-freezing DHW systems would be based on the azimuth and altitude of the equinox. The shadows at that period of time are shorter and less separation would be required between objects.

SHADOW CAST
DURING THE DAY OF
JANUARY 21st
IN OTTAWA

Figure 4.1.2

DAILY SHADOW CAST BY A HOUSE

(Adapted from: Ontario Ministry of Municipal Affairs
and Housing, 1982b: 12)

4.2 A Typical Shadow Calculation

Figure 4.1.2 illustrates the shape of the shadow cast by a house from 9:00am to 3:00pm on January 21, in Ottawa. All objects cast shadows across a similar path; a long shadow projecting to the northwest in the morning, a shorter shadow to the north at noon and a long shadow to the northeast in the afternoon.

The solar azimuth and altitude dictate the shape of the shadow. The altitude of the sun determines the north projection of the shadow (see Figure 4.2.1) and the solar azimuth determines the lateral projection of the shadow (see Figure 4.2.2) (Ontario Ministry of Municipal Affairs and Housing, 1982b).

It is possible, knowing the solar azimuth and altitude, the height of the object and the slope of the land, to calculate the shape of the shadow cast by an object at any time. A trigonometric equation (Equation 1) is the most accurate method for calculating shadow lengths:

$$S = \frac{H}{\tan A + B (\cos(C-D))}$$

Equation 1

Figure 4.2.1
NORTH SHADOW PROJECTION
AS DETERMINED BY THE ALTITUDE OF THE SUN

Figure 4.2.2
LATERAL SHADOW PROJECTION
AS DETERMINED BY THE SOLAR AZIMUTH

Where: S is the shadow length

H is the height of the object casting the shadow

A is the altitude angle of the sun at a particular design hour

B is the percentage slope of the land

C is the azimuth angle of the sun

D is the direction of the slope of the land

(Source: Ontario Ministry of Municipal Affairs and Housing, 1982b:20)

A simpler equation (Equation 2) can be used when the shadow falls on level ground.

$$S = \frac{H}{\tan A}$$

Equation 2

Where: S is the shadow length

H is the height of the object casting the shadow

A is the altitude angle of the sun at a particular design hour

(Source: Ontario Ministry of Municipal Affairs and Housing, 1982b:19).

For shadows on level ground the shadow length can also be determined using geometry. As with Equation 2, the height of the object and the solar altitude for a particular date and time are the two variables required to determine the shadow length. To determine the shadow pattern, further information is required: the solar azimuth for the specific date and time and the shape of the building. The process involved in drawing a shadow pattern is illustrated in Figure 4.2.3.

1. Scale drawing of outside elevation of house:

2. Latitude of site is 44° N.
Solar Altitude at 9:00am on January 21 is 13.9° .

3. Length of shadow cast by edge of roof at corner, determined from solar altitude (13.9°):

4. Length of shadow cast by peak of roof, determined from solar altitude (13.9°):

5. Plan view of house.
Poles represent corners and ends of peaks. The shadow is plotted as if from six distinct poles and then joined.

Figure 4.2.3

DETERMINING THE SHADOW PATTERN USING GEOMETRY

(Adapted from: Ontario Ministry of Municipal Affairs and Housing, 1982b: 15)

6. Using the lengths determined in 2 and 3, shadows for the poles were drawn:

7. By connecting the ends of the "pole" shadows, an approximate shape of the building's shadow is determined:

8. The 3:00pm and noon shadow patterns are determined using the same procedure as listed in steps 2 to 7.

9. Final Plot:

Figure 4.2.3 (continued)

DETERMINING THE SHADOW PATTERN USING GEOMETRY

(Adapted from: Ontario Ministry of Municipal Affairs and Housing, 1982b: 16)

Although the calculation is more complex when the land has a slope, once the shadow length is determined, the methodology to identify the shape of the shadow is essentially the same as in steps 5 to 9 in Figure 4.2.3.

- Figure 4.2.4 illustrates the steps required to determine the shadow pattern for a house located on a slope falling to the south with a gradient of 5° .

The Planning and Development Department of the Regional Municipality of Hamilton-Wentworth (1980) developed a series of templates to provide a relatively simple method of constructing the shadow patterns of a house.

The Ontario Ministry of Municipal Affairs and Housing (1982b) has derived a series of templates for the province based on the same concept. Figure 4.2.5 is a reproduction of one of the templates from the Ministry's publication.

The templates are clear plastic. For each corner of the building and its peaks, the correct length multiplier for the specific slope gradient and direction is identified from the table in the corner of the template for the three critical time periods in the day. The angles are transferred from the template onto a plan view of the object and the corresponding lengths marked on the drawing. A process similar to steps 6 to 8 in Figure 4.2.3 is then followed.

The shadow length multiplier templates are much simpler to use than Equation 1 but do not, in most cases, provide the same degree of accuracy.

1. Calculation of the shadow length of the corner and peaks of the building on a 5% south falling slope:

5% south falling slope

the shadow length of representative pole 5.3 m high =

$$\begin{aligned}
 &= \frac{H}{\tan A + B [\cos (C-D)]} \\
 &= \frac{5.3 \text{ m}}{\tan 13.9^\circ + 0.05 [\cos (-43.2^\circ - 0^\circ)]} \\
 &= \frac{5.3 \text{ m}}{25 + 0.05 [0.73]} \\
 &= \frac{5.3 \text{ m}}{25 + [0.04]} \\
 &= \frac{5.3 \text{ m}}{29} \\
 &= 18.3 \text{ m}
 \end{aligned}$$

the shadow length of representative pole 6.8 m high =

$$\begin{aligned}
 &= \frac{H}{\tan A + B [\cos (C-D)]} \\
 &= \frac{6.8 \text{ m}}{\tan 13.9^\circ + 0.05 [\cos (-43.2^\circ - 0^\circ)]} \\
 &= \frac{6.8 \text{ m}}{25 + 0.05 [0.73]} \\
 &= \frac{6.8 \text{ m}}{25 + [0.04]} \\
 &= \frac{6.8 \text{ m}}{29} \\
 &= 23.5 \text{ m}
 \end{aligned}$$

Figure 4.2.4

DETERMINING THE SHADOW PATTERN USING EQUATION 1

(Adapted from: Ontario Ministry of Municipal Affairs and Housing, 1982b: 19)

2. Shadow lengths drawn on plan view of building using solar azimuth angles for January 21st, 9:00am.

3. By connecting the ends of the "pole" shadows, an approximate shape of the building's shadow is determined:

4. The 3:00pm and noon shadow patterns are determined using the same procedure as listed in steps 1 to 3.

9. Final Plot:
Indicating shadow pattern for building located on a south facing slope on January 21st.

Figure 4.2.4 (continued)

DETERMINING THE SHADOW PATTERN USING EQUATION .1

(Adapted from: Ontario Ministry of Municipal Affairs and Housing, 1982b: 20)

Slope %	NORTH		NORTHEAST		EAST		SOUTHEAST		SOUTH		SOUTHWEST		WEST		NORTHWEST	
	North	East	North	East	North	East	North	East	North	East	North	East	North	East	North	East
0%	4.0	2.1	4.0	2.1	4.0	2.1	4.0	2.1	4.0	2.1	4.0	2.1	4.0	2.1	4.0	2.1
1%	4.2	2.3	4.2	2.3	4.2	2.3	4.2	2.3	4.2	2.3	4.2	2.3	4.2	2.3	4.2	2.3
2%	4.4	2.5	4.4	2.5	4.4	2.5	4.4	2.5	4.4	2.5	4.4	2.5	4.4	2.5	4.4	2.5
3%	4.6	2.7	4.6	2.7	4.6	2.7	4.6	2.7	4.6	2.7	4.6	2.7	4.6	2.7	4.6	2.7
4%	4.8	2.9	4.8	2.9	4.8	2.9	4.8	2.9	4.8	2.9	4.8	2.9	4.8	2.9	4.8	2.9
5%	5.0	3.1	5.0	3.1	5.0	3.1	5.0	3.1	5.0	3.1	5.0	3.1	5.0	3.1	5.0	3.1

$$\text{Shadow length} = \frac{\text{Shadow length multiplier} \times \text{Height of representative pole}}$$

4.3 The Solar Window

The previous section has focused on the techniques used to determine the shadow pattern of an object. These techniques can identify the shadow pattern of existing or proposed buildings or vegetation. These techniques do not, however, determine the zone or window in the sky to which access is desired. From the perspective of protecting access to sunlight, it is necessary to determine what is to be protected and, therefore, to identify this "solar window".

As mentioned previously, according to the Ontario Ministry of Municipal Affairs and Housing (1982a), the optimum design period of access to sunlight in southern Ontario is between 9:00am and 3:00pm on January 21. The solar window of the heating season would then be a window shaped aperture in the sky through which sunlight could pass unobstructed to the windows or solar collectors receiving the sun between 9:00am and 3:00pm on January 21.

The lower boundary of the solar window for the heating season is defined by the 9:00am or 3:00pm altitude of the sun. The upper boundary is defined by the noon altitude of the sun on March 21 (43° (City of Ottawa, 1984)). The vertical boundaries of the heating season solar window are defined by the 9:00am and 3:00pm solar azimuth on January 21. Figures 4.3.1 to 4.3.3 illustrate the concept of the solar window for the heating season.

Figure 4.3.1

ALTITUDINAL LIMITS OF THE SOLAR WINDOW
FOR THE WINDOW ILLUSTRATED DURING THE HEATING SEASON

Figure 4.3.2

AZIMUTHAL LIMITS OF THE SOLAR WINDOW
FOR THE WINDOW ILLUSTRATED

Figure 4.3.3

THREE DIMENSIONAL SKETCH OF
THE CONCEPT OF A SOLAR WINDOW FOR THE HEATING SEASON

(Adapted from: City of Ottawa, 1984)

A solar window for a swimming pool would be based on the solar azimuth and altitude of the summer sun. The width would be less and the altitude greater than that of the heating season window illustrated in Figures 4.3.1 to 4.3.3.

4.4 Collector Angles and the Optimum Collection of the Sun's Radiation

The altitude and azimuth of the sun varies with the time of day and the day of year. To maximize the collection of the sun's energy hitting a particular location on earth, the receiver would have to slowly rotate in an arc to maintain a perpendicular position to the sun. The complexity and cost of incorporating a tracking system for the solar collectors far outweighs the additional energy gained over a fixed position collector. For most active solar energy applications, therefore, a fixed position, flat-plate collector is used (Beckman, Klein, Duffie, 1977:11).

A variety of authors have addressed the problem of determining the optimal angles for the placement of a solar collector (Duffie and Beckman, 1974; Planning Collaborative Inc., 1982; Suckling, 1982; National Research Council, Canada, 1975). Although there is some discrepancy, it is generally accepted that year round systems be placed at the same angle as the degree of latitude, and winter space heating systems be placed at the degree of latitude plus 15° . The ideal orientation for the collectors is facing due south, however deviations up to 15° from due

south would result in only minor losses in performance (Planning Collaborative Inc., 1982,:13).

In Ottawa, for example, the optimum collector angle for year round use would be 45° and for winter space heating would be 60° . In Toronto both values would be one degree less and in Edmonton they would be eight degrees greater.

It is interesting to note that, in Canada, very few collectors have been installed at their optimum angle (Buchan, 1984). Most systems are placed on roofs ranging from 18.5° (a 1' in 3' slope) to 45° , with the majority between 18.5° and 30° . To compensate for the reduction in efficiency, additional collectors are often added.

4.5 Land Space Requirements for the Four Solar Options

As mentioned in the introduction to this chapter, four solar options were identified in the third chapter as being potentially the most viable at the present time. These included:

- heating of domestic hot water (DHW)
- passive solar space heating
- active solar space heating
- swimming pool heating

The solar requirements of these options differ greatly. DHW heating has a constant year-round demand for solar energy, passive and active space heating require solar access only through the winter heating season, and swimming pool heating requires solar access only during the summer months.

As well, the various options require differing amounts of solar energy.

The passive solar space heating option, for example, requires that solar energy reach all windows on the southern and, in some cases, eastern and western exposures of the building. Active solar space heating or DHW heating, on the other hand, require solar access only for the solar collectors which may be rooftop mounted or separate from the building.

The following subsections examine the solar access requirements of the various solar options.

4.5.1 Domestic Hot Water Heating

In Section 4.4 the optimum angle for the placement of the collector was identified at 45° for Ottawa for year-round use. For most domestic installations two or three collectors, approximately one metre by two and one half metres each, are required (Buchan, 1984). The collectors for DHW systems are usually located on the roof of the house but may also be located on a wall or on free standing structures (ibid). Figure 4.5.1 illustrates the solar altitude access requirements of DHW collectors. In

Figure 4.5.1
SOLAR ALTITUDE ACCESS REQUIREMENTS
OF DHW COLLECTORS

keeping with Ontario Ministry of Municipal Affairs and Housing (1982b) guidelines, the solar azimuth and altitude for January 21 are used as the minimums for the year, and not December 21 which technically would be the case.

In areas where freezing is common through most of the winter, there is some seasonal use of DHW systems. These systems require solar access from the spring equinox to the fall equinox and are not used during the winter months.

4.5.2 Passive Solar Space Heating

Passive solar space heating requires the greatest access to solar radiation of the various options. The heating season is primarily during the winter months of the year. It is, therefore, necessary for the low winter sun to enter all the apertures of the house with a southern exposure.

The low angle of the morning and afternoon winter sun places considerable restrictions on the height of objects to the south of the passively heated house. Figure 4.5.2 illustrates the magnitude of these height restrictions.

Not only are the altitudinal limits (see Section 4.3) of the solar window large, but the azimuthal limits are also quite wide. The protected area is

Figure 4.5.2
SOLAR ALTITUDE ACCESS REQUIREMENTS
FOR PASSIVE SOLAR SPACE HEATING

almost the full width of the house for passive solar space heating, whereas, for example, DHW systems require only the width of the collectors be protected.

4.5.3 Active Solar Space Heating

The solar access requirements of an active solar space heating system are similar to those of a DHW system. Usually, a portion of the south slope of the roof area is covered in collectors or, occasionally, the collectors may be mounted separately on a wall or free standing structure (Buchan, 1984).

The optimum placement angle of solar collectors for the purposes of solar space heating is 60° in Ottawa (Section 4.4). Figure 4.5.3 illustrates the solar altitude access requirements of solar collectors in an active solar system.

As with DHW systems, the width of the collectors dictates the azimuthal limits of the solar window. The number of collectors in an active space heating system will usually be greater than for a DHW system; how much larger, however, is very site specific (Beckman, Klein, Duffie, 1977:54).

The size and type of house, the amount of insulation, the living habits of its occupants and the percentage of the heat load to be provided by solar energy are some of the variables affecting the size of the collector array

Figure 4.5.3
SOLAR ALTITUDE ACCESS REQUIREMENTS
FOR ACTIVE SOLAR SPACE HEATING

(ibid). It would be extremely unusual, however, for the collector array to cover more than the south face of a roof (Buchan, 1984).

Suckling (1982) analysed the percentage of annual space-heating energy demand that could be met by solar in the USA and Canada for two houses: the first had an active solar system only and the second was a combined active and passive solar house. Both houses were the same size, with the same heating requirements. As well, both houses were assumed to have 75m^2 of collector area located on the roof, which is about half the floor area of the one storey house. This assumption was made in order to assess the maximum potential for active solar energy use (1982:161). One American study identified an average ratio of 40% collector area to floor area for residential buildings (Holte, Kelly, eds., 1981).

Suckling concluded that, in much of Canada, the potential for residential solar heating is as high as that in the United States or even higher (1982:164) and the incorporation of passive solar energy design features increases that potential significantly.

The combination of passive solar design features with an active solar collection system on a house would involve the solar access requirements of both an active and passive system. (See Section 4.5.5 for a discussion of the concept of the various levels of solar access.) This would involve protecting solar access to the base of the south facing windows and to the

full southern width of the house as well as the access to the active solar collectors. The increased altitudinal limits are indicated by a dashed line on Figure 4.5.3:

4.5.4 Swimming Pool Heating

In southern Ontario most residential pools are for summer time use only. Basically, therefore, the heating of the pool water is only required from mid May to mid September. For most swimming pool applications the collectors are mounted on the roof of a nearby building or on a free standing structure close to the pool. Although not necessary, it is advantageous to maintain the solar access to the pool to permit the solar radiation to directly heat the pool water. Figure 4.5.4 illustrates the altitudinal limits required for solar access to the collectors and for the pool.

4.5.5 The Three Levels of Solar Access

The land use planner, when faced with establishing a policy on solar access, has basically three levels of access to deal with. Figure 4.5.5 illustrates the three levels: the south slope of the roof, the south face of the house (to the base of the windows) and the south area of the yard.

Protecting solar access to the roof area of a house involves the least restrictions on the surrounding land uses. Solar access for most DHW,

Figure 4.5.4
SOLAR ALTITUDE ACCESS REQUIREMENTS
FOR SWIMMING POOL HEATING

Figure 4.5.5
THE THREE LEVELS OF SOLAR ACCESS

OF / DE

active space heating systems and swimming pool systems would be included under the first level (subsections 4.5.1, 4.5.3, and 4.5.4).

The restrictions on surrounding land use are substantially increased if solar access protection is provided for the second level. The benefit associated with this increased solar access is the potential for using passive solar heating (subsection 4.5.2).

The protection of the south area of the yard has the greatest impact on surrounding land uses of the three levels of solar access. From the energy usage point of view this area has little to offer and protecting access to this area could, in fact, result in the far greater consumption of energy because of the spread out land use patterns it would cause. From the viewpoint of aesthetics and gardening, however, it may be politically desirable to protect solar access for a portion of level three.

It may also be desirable to protect solar access for a portion of a yard if solar access is not available at level one or level two. In existing urban areas where residences are located close together on north/south streets, it may be desirable to protect a section of the rear yard for the placement of the collectors of an active solar system. Technically it is feasible to construct active solar systems on free standing structures and pump the heated air or liquid to the house for use as needed.

In this chapter the land space requirements of the four viable solar options were examined. Chapter 5 shifts from the technical to the political arena to discuss the current and potential future legislation for protecting solar access.

CHAPTER 5

PROTECTING SOLAR ACCESS

At present the Canadian urban homeowner who decides to make use of the solar energy reaching his dwelling has no readily available means to ensure that sunlight will continue to reach his dwelling. The neighbour to the south could plant a row of trees along the property line between the two homes, shading the solar features of his house and there is little recourse open to the homeowner. The inability of the potential solar energy user to secure legal access to the sunlight is one of the major constraints to the increased use of solar energy today.

The major costs associated with the use of active and passive solar systems occur during the conception and installation stages. Without the knowledge that this heavy "up-front" investment is assured of its source of energy -- the sunlight -- few people are willing to take full advantage of that sunlight.

The urban geographer, in the study of factors affecting the form of the urban environment, can identify the relationship between solar access and

restricting surrounding development to protect that solar access. Local municipal legislators, working with urban geographers and land-use planners, have the opportunity to protect equitable access to sunlight. This chapter is devoted to examining current and potential regulations that could be used to protect the solar energy user's access to sunlight.

The prime area for conflict for solar energy users is in the urban area. The rural dweller usually has sufficient distance between himself and his neighbours that there is little likelihood of competition for solar access. The residential solar energy system is the system in greatest need of regulations to protect it. Industry and service organizations, the other major groups in the urban area who are potential users of solar energy, usually have large enough tracts of land that they can basically guarantee their own access to the sun.

Perspectives on Access to Sunlight, an Ontario Ministry of Energy (1980a) publication, provided considerable background to the preparation of this chapter. The Ontario government publication is a "working paper" which outlines the existing law with respect to solar access and develops several potential mechanisms for the protection of solar access in Ontario. The focus of the working paper is on both new and retrofitted solar installations on urban dwellings. The sections in the working paper referring to retrofitted and infill developments formed the major basis for this chapter.

5.1 Existing Ontario Laws

Under the existing laws of Ontario, the homeowner who has invested in a dwelling with solar energy features has only a few options to protect his sunlight (Ontario Ministry of Energy 1980b). Unlike several other countries (for example, Great Britain, with its Doctrine of Ancient Lights) Canadians have no natural "right to light" (ibid). As long as proposed alterations to buildings and vegetation are acceptable under existing zoning laws, the solar energy user can only rely on the goodwill of his neighbours to restrict any interfering development.

5.1.1 Nuisance

The law of nuisance is one existing law which the solar energy consumer might argue provides him with some protection. "Under the law of nuisance, landowners may generally prevent or be compensated for, unreasonable interference with their use and enjoyment of their land, where the harm caused by the interference would be substantial." However, as the author of the Ontario government report goes on to say, past precedence indicates that "the erection of new buildings is a more important public and private interest than the competing desire for unobstructed light and air to existing buildings" (Ontario Ministry of Energy, 1980a:3).

5.1 Existing Ontario Laws

Under the existing laws of Ontario, the homeowner who has invested in a dwelling with solar energy features has only a few options to protect his sunlight (Ontario Ministry of Energy 1980b). Unlike several other countries (for example, Great Britain, with its Doctrine of Ancient Lights) Canadians have no natural "right to light" (ibid). As long as proposed alterations to buildings and vegetation are acceptable under existing zoning laws, the solar energy user can only rely on the goodwill of his neighbours to restrict any interfering development.

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An appeal against the construction or renovation of a neighbouring building, citing the law of nuisance as a defence, is considered likely to be unsuccessful. As traditional energy resources become scarcer, however, such an appeal may be successful against the planting of vegetation and may eventually be one tool for protecting solar access. Past precedence would seem to indicate, however, that, at present, the law of nuisance would be of little value.

5.1.2 Easements

The acquisition of a separate "easement of light" from potentially conflicting neighbours could protect the solar user's access to a defined period of sunlight reaching a defined aperture. Aside from the legal question of whether a solar collector would meet the definition of an "aperture" according to the law, there appears to be one major drawback with obtaining an easement of light. The owner of the land to be restricted must establish this restriction in writing. It is doubtful, even if the owner did not intend to obstruct the sunlight, that he would be willing to place such an encumbrance on this land -- an encumbrance which would very likely devalue the worth of his property. As with the law of nuisance, easements, although possible, would not appear to be a viable option.

5.1.3 Covenants

In the case of new developments it would be a fairly simple matter for the subdivider of the land to attach a restrictive covenant to each of the subdivided properties. Basically a restrictive covenant is a "condition involving the land imposed by a landowner on himself and any subsequent purchasers of the land." (Ontario Ministry of Energy, 1980:25). The placement on the land title of a covenant preventing construction above a specified height and/or preventing the planting of vegetation in specified locations is an example of the type of covenant necessary to protect solar access. As it was discussed in chapter three, the sun's position is never located directly overhead of Canadian territory. Restrictive covenants, therefore, are appropriate only in the development of large residential subdivisions in which the access to solar radiation is a planned goal for all or most of the subdivision. The same major drawback associated with easements would preclude the use of restrictive covenants for infill and retrofit construction. There is little or no incentive for the owners of neighbouring properties to place restrictive covenants on their land to protect someone else's access to sunlight.

5.2 The Official Plan

The official plan of a municipality forms the basic policy framework for most municipal planning actions. By-laws, for example, cannot breach an official plan and, in certain cases, cannot even be passed without an appropriate underpinning in the official plan (Ontario Ministry of Energy, 1980b). The protection of solar access would, therefore, have to be done in accordance with the official plan and by a municipality interested in protecting solar access.

In the new Ontario Planning Act, it is identified that one provincial goal is to reduce the per capita growth rate of the demand for all forms of energy (Ontario Ministry of Municipal Affairs and Housing, 1982c). As the basic planning tool of the municipality, it follows that it is appropriate to take energy matters into consideration in formulating official plan policies (Alcock and Kosny, 1980).

The protection of solar access is one aspect of energy conservation. Other aspects, for example, the minimization of fuel for transportation, tend to encourage greater densities in the urban area and could, therefore, conflict with individual access to solar energy.

5.3 Potential Mechanisms to Protect Solar Access

A previous section identified the existing mechanisms available to the landowner to protect his access to sunlight. The protection of solar rights for infill and retrofit construction is very difficult and the one potential mechanism for new subdivision development requires the foresight and determination of the subdivider as well as the necessary policies and support of the municipality -- a tenuous requirement at best. It appears to follow, therefore, that to encourage the use of solar energy, particularly in the built up urban environment, new means need to be developed to protect the landowner's access to sunlight.

The official plan would have to acknowledge that goal. It may be appropriate to designate specific areas as protected solar zones (where higher densities would not be permitted to infringe on solar access) and encourage higher densities in other areas (along mass transit routes for example).

In the policy statements of the official plan, general goals and policies for energy related land use issues should be included to encourage the use of solar energy (Lang and Armour, 1982a). Specific statements would indicate the municipal council favours retrofitting and renovation, incorporating active and passive solar features and permitting minor variances and zoning amendments when required. As well, council could

indicate it supports development concepts which incorporate passive solar considerations such as siting and road layout and the use of active solar systems.

The official plan could further emphasize the use of solar access by detailing the planning and design of lot and building orientation to maximize solar access where practicable. It could indicate that lots should be arranged and buildings sited to have major southern exposure. As well, it could encourage the design of buildings to take advantage of solar access and the landscaping around buildings to complement solar access and enhance energy conservation. For example, deciduous trees planted to the south of a building will provide summer shading while permitting access to the winter sun, and coniferous plantings to the west and north to serve as wind breaks and hence reduce heat loss.

However, the general policies of the official plan alone cannot provide the protection necessary to achieve widespread utilization of solar energy. Mechanisms must be devised to ensure reasonable access to solar energy for those wishing to use it in the built up urban area.

Dianne Saxe, the author of Perspectives on Access to Sunlight, identified nine potential mechanisms for protecting legal access to sunlight. Some of the mechanisms are more appropriate to new subdivision construction, while others would be most useful in the protection of solar rights for

infill and retrofit construction (Ontario Ministry of Energy, 1980a). Not all of the proposals appear viable. However, they have all been proposed and seriously examined as solutions to provide protection for solar rights in different locations in North America. Various other authors discussing the need for solar rights have identified similar mechanisms (Erley, 1980; Robbins, 1976; Lang and Armour, 1982a; Alcock and Kosny, 1980).

In Canada, the municipal level of government is the appropriate level at which to provide solar access rights. The inclusion of solar features on a dwelling is, to a great extent, an individual affair. The decision by a federal or provincial government to legislate the use of solar energy could result in chaos -- mechanisms that would be appropriate to infill development in the centre of downtown Toronto may have little relevance to suburban Thunder Bay, for example. The various proposed mechanisms basically involve provincial approval for initiatives developed at the municipal level.

The following discussion of the potential mechanisms of providing secure access to sunlight is not placed in order of priority. Each option is presented and its potential usefulness outlined.

5.3.1 The Doctrine of Ancient Lights

In Great Britain an historical precedent has existed for over four centuries, establishing a right to the "reasonable enjoyment" of light.

Basically, the doctrine of Ancient Lights stipulates that if you enjoy light coming over a neighbour's property for a period of 27 years, you are entitled to continue to enjoy it (Regional Municipality of Hamilton-Wentworth, 1978).

At present, in Canada and the United States, this right does not exist and it is extremely unlikely that it will be instituted. In the rapidly changing urban areas of North America, it would have little relevance generally and, because of the long period of unobstructed use of sunlight before it could be enforced, the doctrine of Ancient Lights does not seem to offer a mechanism to secure access to sunlight.

5.3.2 Aquisition of Solar Rights By Private Agreement

Similar in concept to an easement, the aquisition of solar rights by private agreement would involve a landowner acquiring a portion of the space above a neighbour's property. However, under the current Ontario law of property, even if all parties involved wanted to do so, it is not possible to register and enforce such an aquisition (Ontario Ministry of Energy, 1980a).

If the current law was amended to accommodate private agreements for solar rights, it could provide a mechanism whereby individual action could secure solar access without government involvement. As with easements, however, private agreements are unlikely to have much success. Because of

the potential devaluation of his property, a landowner is unlikely to encumber his land with such an agreement.

5.3.3 Prior Appropriation

An American legal concept which relates to the use of water in the arid west, prior appropriation is similar to the concept of "first come, first served". It is based on the principle that whoever first begins to use (appropriate) a source of water is entitled to continue such use at the same rate (Ontario Ministry of Energy, 1980a:23).

The concept could easily be applied to the use of solar energy in those areas familiar with prior appropriation in the allocation of water rights. It would be more difficult and potentially very confusing to apply in the province of Ontario, in which water is governed by riparian rights (land owners whose property abuts a body of water are entitled to use whatever water they wish for any reasonable purpose) (ibid:22).

A further problem associated with prior appropriation would relate to priorities. In those states where prior appropriation regulates water useage, an existing appropriation can be invalidated if a use with a higher priority is applied for. Full compensation is made to the landowner with the lower priority. Establishing priorities in the use of solar energy could prove to be very difficult -- does home heating have priority over growing a vegetable garden? As well, it could become costly

compensating lower priority appropriations if one landowner's use of solar energy blocks someone else's.

5.3.4 Government Acquisition of Solar Rights

This proposed mechanism involves the nationalization of airspace above all lands across the nation. This nationalized airspace would then be leased to property owners subject to specific conditions (Regional Municipality of Hamilton-Wentworth, 1978). Although the concept has some merit -- minor cost to the individual solar user -- it would be a complex, costly, and probably virtually impossible concept to implement. It would also be perceived by many as an unacceptable use of the power of government to benefit a few individuals.

The expropriation of solar rights by a municipality for the private use of a landowner would have the same major disadvantage. It would very likely be politically unacceptable.

A concept similar to the nationalization of airspace would be the granting of a "natural" solar right. Every landowner would have a continued right to the sun they presently receive. As with nationalization, it would be complex, costly and virtually impossible concept to implement, not to mention the fact that such a major reordering of land use priorities is radical and unlikely to be accepted by the Ontario public (Ontario Ministry of Energy, 1980a).

5.3.5 Solar Zoning

By far the most widely advocated mechanism for protecting solar access in the built environment is solar zoning (Lang and Armour, 1980a; Regional Municipality of Hamilton-Wentworth, 1978; Ontario Ministry of Energy, 1980a, 1980b; Sewell and Foster, 1980; Alcock and Kosny, 1980). Solar zoning involves the identification of zones within an urban area where solar energy use is compatible with existing structures and is to be encouraged to conserve energy. Areas, for example, with streets oriented predominantly in an east-west fashion and housing units of a similar height could likely become solar zones, whereas areas containing tall apartment buildings would not.

Solar zoning has a number of advantages over most other potential mechanisms for protecting solar access. The mechanism to create solar zones is already in place. Through the official plan, a municipality can identify the goal to conserve energy through advocating the use of solar energy. The municipality could then establish a solar zoning by-law in the same manner they stipulate existing requirements for other types of use and density of coverage of land in the urban area.

Solar zoning by-laws would be compatible with existing zoning by-laws in the urban area and would be enforced through the same mechanisms. Because of the public's familiarity with the concept of zoning, the addition of

solar zones to an urban area's official plan would be relatively simple to comprehend. And because the mechanisms for zoning already exist, once established, zoning should not increase the cost or delay a potential solar user in the same way as the obtainment of, for example, an easement.

The zoning of entire areas as "solar" would tend to reduce the possible adverse impact on the value of a particular property. Although a landowner would be restricted from the unreasonable shading of his neighbour's property, he would have a guarantee that his neighbour would not shade his property. As well, the solar zoning restrictions would not tend to be unduly restrictive because the zoning by-law would be prepared by an elected municipal council which would tend to weigh the competing interests of both the potential solar users and their neighbours (Ontario Ministry of Energy, 1980a).

Zoning by-laws are area-specific and, as a result, would permit the solar rights to be tailored to such factors as local climate, existing building orientations and heights and topography. Further tailoring could encourage solar space heating in some areas, while only DHW heating would be zoned for in other areas. This flexibility would make solar zoning more politically palatable.

Solar zoning does have its disadvantages. Zoning by-laws can be changed at anytime by council and, therefore, solar access is not securely

protected. This problem, however, is unlikely, particularly if zoning for solar access becomes a widespread zoning practice.

The area-specific advantage of zoning also increases the cost and duplication of effort from a provincial perspective. As well, it means that "solar pioneers" with unreceptive municipal councils would have to find other means to secure solar access. The technical aspects of solar design may be beyond the capabilities of some councils and committees of adjustment.

The control of vegetation is not possible under present Ontario zoning by-laws. A useful supplement to solar zoning would be a "shade control law" prohibiting vegetation from shading collectors in solar zones. This law would basically state that the use of solar energy is of greater public value than trees and, therefore, takes precedence over them. As with solar zoning, exemptions in the form of a local variance would offer an avenue of appeal (ibid).

Solar zoning, with the addition of some form of shade control law appears to offer the potential to be the principal long-term mechanism to protect solar access. In Ontario, the cities of Hamilton, Brampton, and Ottawa, among others, are making preliminary steps in that direction.

5.3.6 Certification of Solar Sites

The certification of solar sites has been proposed in the Ontario Ministry of Energy publication Perspectives on Access to Sunlight as the best short-term means to protect solar access. Solar site certification would involve a municipal council acting to coerce the restraint of all neighbours of a solar user (Ontario Ministry of Energy, 1980a:47). Each certification would be site-specific and granted subject to whatever terms and conditions the certifying body established. Some form of compensation could be granted to the adversely affected landowners.

The creation of transferable development rights has been proposed as one means of compensating the restricted landowner without incurring potentially prohibitive compensation costs for the solar user.

Transferable development rights would be conveyed to the restricted landowner which would permit development in excess of the 'zoned limit in a district capable of supporting that excess development (i.e., down-town highrise areas)(ibid). The restricted landowner could then sell that development right to a developer wishing to take advantage of the permitted increased density. This would provide the restricted landowner with fair compensation for the imposed restriction and would be accompanied by reduced taxes because of the devalued worth of his property.

The novelty and complexity of transferable development rights makes them a less desirable solar access protection mechanism for the long-term.

Solar zoning appears to offer the greater long-term potential. However, in the short-term and for certain situations in unzoned solar areas of a city, it could be a potentially useful tool.

Providing the mechanisms to protect solar access would encourage the use of solar energy by those persons who are knowledgeable about the field and wish to take advantage of this source of energy. In this age of depleting non-renewable energy resources, there is a need to generally encourage both the home builder and renovator to incorporate energy conservation measures and the use of renewable energy sources in all construction. With measures to protect solar access in place, a necessary follow-up would be the establishment of energy conservation standards for buildings in the National Building Code (Anderson, 1980).

In summation, it would appear that the first steps toward protecting solar access would be, at least in the Ontario context, to include an energy conservation policy statement in a municipality's official plan, to establish energy conservation goals to be achieved and to educate the public about the benefits of solar energy utilization.

In conjunction with these, mechanisms have to be put in place to protect the solar user's access to sunlight. As a supplementary or interim power,

the certification of solar sites appears to be one available mechanism. Over the long-term, solar zoning appears to hold the most promise with restrictive covenants being used for new solar subdivision developments. With the appropriate mechanisms in place, it would then be necessary to further encourage the use of solar energy techniques.

Chapter six is a brief examination of the process the City of Ottawa has undertaken recently to provide protection for the users of solar energy in two areas within the city. The pioneering efforts of the City of Ottawa provided a relevant and valuable reference for this thesis.

CHAPTER 6

A REVIEW OF PROPOSED SOLAR LEGISLATION FOR THE CITY OF OTTAWA

In January of 1984, the Community Development Department of the City of Ottawa presented council with its "Solar Design Guidelines". Basically the result of a two year undertaking with funding from the Ontario Ministries of Energy and of Municipal Affairs and Housing, the guidelines form a voluntary by-law ensuring solar access to two communities in the City of Ottawa.

The guidelines are being proposed as voluntary measures that, it is hoped, will be generally accepted by the communities involved. At present, it is felt that a mandatory by-law is politically unacceptable and, that by introducing the voluntary measures, the public can be educated to the benefit of solar access protection.

6.1 The Historical Context of Solar Legislation in Ottawa

The idea of protecting solar access was suggested during the course of neighbourhood studies in Ottawa South in 1977 and 1978. As a result, the 1979 Ottawa South Plan included a recommendation to initiate a feasibility study for solar access protection (City of Ottawa, 1984). The city acted on this recommendation and in the early spring of 1981, the city's energy planner issued a discussion paper titled Planning Measures to Safeguard Solar Access. The purpose of the paper was "to explore a simple method of establishing this novel property right and encourage people to 'think solar'" (City of Ottawa, 1982:2).

During the same period of time, the Regional Municipality of Ottawa-Carleton was addressing the aspect of energy conservation at the regional level. In the fall of 1979, the regional council directed their Planning Department to "prepare a compilation of desirable energy saving features that may be included in subdivision plans, including, among other items, housing orientation, window size and location, and landscaping features aimed at passive solar heat gains and active solar heating" (Regional Municipality of Ottawa-Carleton, 1981).

The Planning Department of the Regional Municipality published its findings in the late fall of 1981. Its first recommendation was that a major goal concerning energy be added to the Regional Official Plan. It

was proposed that goal read: "To develop the Region in a manner which uses energy efficiently and maximizes energy conservation wherever possible" (ibid:19). Two of the recommended five specific energy goals were of relevance to solar energy: a) "to develop energy conserving patterns of land use" and b) "to encourage innovation relating to efficient energy use" (ibid:19).

The Regional Municipality has since incorporated the energy goals into the regional plan and is currently in the process of reviewing them (Kardish, 1984). The first step toward protecting solar access (as indicated in the previous chapter) has been achieved at the regional level -- conservation of energy is a goal identified in the regional plan.

Efforts by the City of Ottawa focused on the second step toward protecting solar access -- providing an effective mechanism of protection. The City's 1981 discussion paper, mentioned previously, concluded that the simplest method of legally establishing solar access in Ottawa would be through the modification of existing zoning laws and the requirements affecting developable space and landscaping in and around a lot (City of Ottawa, 1984).

The provincial government, in 1981, made financing available to municipal governments to fund a re-examination of their land use planning standards and practices to ensure the most efficient use in the community of Ontario's

energy resources (Ontario Ministry of Municipal Affairs and Housing, 1981). In a continuing effort to be at the forefront in energy conservation, the City of Ottawa applied for and received grants for three projects. Part of one grant, \$25,000, was designated to further the study on safeguarding solar access with the intention of drafting a solar by-law.

Citizen participation was encouraged, and the Department of Community Development established local committees in Westboro, Ottawa South and the Glebe to help draft a by-law protecting the right-to-sunlight (City of Ottawa, 1982). Two approaches were taken. The Westboro concept was to shape the developable envelope of space that current zoning by-laws define for every lot in a way that would allow maximum penetration of the sunshine for surrounding lots. Glebe and Ottawa South joined to form the Capital Ward Committee. Their concept involved defining a solar window which would receive unobstructed solar insolation over eighty percent of its area (ibid:3).

For legal reasons, the solar window concept was abandoned. The City Hall Legal Department determined it might easily take two years for passage of a property right through the Provincial Legislature (Anonymous, 1984a). Public meetings were held to discuss the concepts during 1982, a public awareness campaign was undertaken and two opinion surveys were carried out in the Westboro community. Just under fifty percent responded to the first general opinion survey and the majority were overwhelmingly in

favour of the principle of protecting solar access. Of the one third that responded to the second, more detailed questionnaire, reaction was mixed (City of Ottawa, 1984). In early July 1982, a series of proposals were drafted by the Westboro group, with the aid of city officials, and presented to the public (Spencer, 1982).

The resulting principles were circulated to all departments in City Hall and constructive input was received from the legal department, the zoning operations division, the planning branch and from non-profit housing. A second circulation was made to all technical agencies in Ottawa including those of the federal government and the Regional Municipality of Ottawa-Carleton. A third circulation was sent to the relevant Ontario Ministries and those individuals specializing in or expressing an interest in solar access matters. The Planning Branch critically examined all comments received and valid points were incorporated into the final proposed solar access principles (City of Ottawa, 1984).

It is interesting to note, that the Energy Advisory Committee, a volunteer group established with funding from one of the other grants received in early 1982, was not asked to comment on the proposed solar access by-law until January of 1984 (Lawton, 1984). At that time they were asked to either approve or reject the proposed solar guidelines but were given no avenue for constructive input. It seems extremely negligent to ignore

the advice of a committee established expressly to advise city council on energy matters relevant to the City of Ottawa (City of Ottawa, 1982).

The current status (summer 1984) of the proposed voluntary by-law is still unresolved pending a decision from the city council.

6.2 The City of Ottawa Solar Design Guidelines

The following section is a summary of the Solar Design Guidelines submitted by the Community Development Department of the City Council in January of 1984. The guidelines provided basic information on the design of various solar features, solar access criteria to be considered when assessing development proposals, and an assessment of the administrative aspects of the design guidelines.

6.2.1 Solar Energy Utilization

Five acceptable uses of solar energy were identified for which solar access protection to neighbourhood properties would be considered when assessing a development proposal:

1. Growing food;
2. Sunbathing;
3. Heating fluids - i.e., air and water;
4. Cooling fluids;

5. Converting solar energy into electric current or other forms of usable energy.

(City of Ottawa, 1984:A4)

One means of obtaining usable heat from the sun is discussed in the guidelines. The "greenhouse effect" involves sunlight shining through glass or a transparent surface, and heating the inside air. This heated air is trapped inside and can be used for space or water heating. Both passive and active solar systems use the greenhouse effect.

Two brief definitions of active and passive solar systems are presented in the design guidelines, and a solar collector is defined. A solar collector "is expected to carry out the functions of collecting and storing heat, by active or passive means, in order to be acceptable for solar access protection" (City of Ottawa, 1984:A6). The south-facing window of a house would, therefore, be considered a solar collector. The placement of the solar collector at an angle perpendicular to the sun's rays throughout the day would lead to the optimal utilization of the sun's radiation. A collector that would tilt and rotate to follow the sun's rays is prohibitively expensive for most applications and a fixed surface placed at an optimal angle is the best solution. The guideline establishes the optimum tilt for a collector located in the City of Ottawa at 60° , based on the formula "Latitude + 15° " (ibid:A8), and it should be facing directly south.

It is not always feasible to position the collector at a 60° angle facing south. A series of tables are presented in the guidelines documenting the sun's position during the day and the various seasons of the year. From these an acceptable range of positions was determined. It was concluded that "surfaces designed to collect solar energy should (a) face south at 90° and not less than 45° ; and (b) they may be vertical or tilted not less than $21^{\circ}30'$ to the horizontal, in order to be acceptable for solar access protection" (ibid:A9).

An interesting concept mentioned in the design guidelines is the "sol-air" orientation. For maximum comfort, the best orientation for a dwelling is considered to be 12° east of south at a true azimuth of 168° . This maximizes the warming capabilities of the morning sun and reduces the afternoon sun when the rooms are already warm.

6.2.2 Solar Access Protection

If property owners in the City are to be encouraged to invest in solar energy exploitation, evidently their right to receive and enjoy sunshine on their property for a viable number of hours must be protected. Solar access protection on a particular lot implies the following types of control:

1. Control on the shape and volume of building development on the neighbouring lots;
2. Control on site coverage on all lots;
3. Control on the extent and duration of shade by signs, accessory buildings, fences, and vegetation located on neighbouring lots.

(City of Ottawa, 1984:A18)

The previous quote forms the basis of the proposed voluntary solar access protection by-law of the City of Ottawa. Key terms, principles, and methods of application were then examined in the second section of the Solar Design Guidelines.

Controls on Building Shape, Volume and Coverage

The Solar Envelope

The maximum development permissible on a lot is defined as the 'building envelope'. The voluntary by-law redefines this as the solar envelope. The front, side and rear setbacks remain the same but the shape of the envelope is altered. Rather than a horizontal ceiling on the development potential of the lot, the ceiling would be defined along the east, north, and west sides as having a height of 8.0 metres. From the three sides, the ceiling would project towards the centre at an angle of $21^{\circ}30'$ up from the horizontal as shown in Figure 6.2.1. The south face of the envelope would project up to the sloped ceiling.

~~This~~ proposed solar envelope would apply to all new development and any additions to existing development on lots in the City of Ottawa.

Figure 6.2.1

THE BUILDING ENVELOPE

(Adapted from: City of Ottawa, 1984)

Shade Control

A control on the duration and area of shade produced, or likely to be produced, on a 'protected surface' by proposed building development, sign or growing vegetation.

(City of Ottawa, 1984:A21)

The protected surface referred to in the above definition is the surface for which solar access is protected. Figure 6.2.2 contains an illustration and a description of the protected surfaces on the planes of the solar envelope.

The 'protected garden' (area D in Figure 6.2.2) has been included to "extend protection to sun decks or vegetable gardens which may not be part of the building structure" (ibid). It is also intended as compensation for those lots with dwellings shaded by existing buildings or vegetation (for example on north-south streets).

With respect to shade control, six principles have been specified in the proposed voluntary by-law.

a) registration of the transfer of a protected garden:

A landowner can apply to transfer his protected garden from the south side of the principal building on the lot to another location on the lot.

b) permit for the installation of a solar collector:

When retrofitting one or more solar collectors to an existing

PROTECTED SURFACES ON A SOLAR ENVELOPE

- A — The sloped or horizontal planes of the envelope ceiling,
- B — The south vertical plane;
- C — A 100cm strip on the east and west planes;
- D — 10% of the lot area on the south side of the property, or any other reasonable location selected and registered by the owner with the City Energy Planner, to be referred to as the 'protected garden'.

Figure 6.2.2

ILLUSTRATION AND DESCRIPTION
OF THE CITY OF OTTAWA
PROTECTED SURFACES ON A SOLAR ENVELOPE

(Source: City of Ottawa, 1984)

structure, a permit will be required. No special permit will be required for new development incorporating solar collectors.

c) variance, notification, and representation:

It will be possible to apply for minor variances from the existing land use zoning regulations in order to comply with the solar design guidelines. Neighbours adversely affected will have the right to be notified and their objections heard.

d) obstruction by growing vegetation:

Fifteen percent obstruction of sunlight on a solar collector is permitted on any day of the year. If, through the natural growth, new vegetation shades more than fifteen percent, the owner of the solar collector can notify the City of the trespass.

e) new vegetation:

Any new or replacement vegetation should preferably be located such that its ultimate height and volume will also not intrude on the solar window.

f) fences and hedges:

As with growing vegetation, fences and hedges should not obstruct the surface of the solar collector by more than fifteen percent on any day of the year.

Any obstruction erected prior to January 1, 1984, is exempt from the voluntary by-law. Any structure or vegetation erected or planted after that date shall not exceed fifteen percent of the area of the solar collector or protected surface of a neighbouring property (City of Ottawa, 1984:A25).

The final section of the Solar Design Guidelines presents seven charts outlining the administrative processes required for the application of the guidelines. The zoning process, the building permit procedure, the site plan control process, and specific procedures relevant to the application of the guidelines are presented. They are presented to assist applicants in following the progress of their proposals and are of little relevance to the thesis topic.

The following section contains comments and reactions to the Solar Design Guidelines. Where possible, comparisons with the solar access by-laws of other urban areas have been included.

6.3 Comments on the City of Ottawa Solar Design Guidelines

In the guidelines, five acceptable uses of solar energy were identified. The choice of categories could have been better. The solar requirements for space heating with passive solar energy are quite different from

active solar space heating, and different again from solar domestic hot water heating (as explained in detail in Chapter 3). To lump the three together as one category is misleading. As well, the identification of sunbathing as a category is questionable in terms of the stated goal of the guideline -- to conserve energy. Vegetation, the one major category left out of the proposed Ottawa uses, has as great a benefit to society as sunbathing. Vegetation provides oxygen, wind and noise barriers, shade, and beauty in the urban environment.

Based on the research undertaken for this thesis, it is suggested that more applicable categories would have been:

1. Growing food
2. Space heating
3. Domestic hot water heating
4. Swimming pool heating

Solar design guidelines that only addressed the goal of energy conservation and were sold as a positive contribution, on the part of the municipality, towards that end would be much more acceptable to the community. It is important that the restrictions on development be as few as possible. For that reason, the main criterion for assessing the acceptable uses of solar energy should be 'does it have the potential to conserve energy now or in the foreseeable future?'

The subsection of the design guidelines discussing the optimum utilization of solar energy at the latitude of Ottawa includes a number of highly questionable facts with regard to 60° being the optimum tilt for a solar collector. As mentioned in the fourth chapter, a tilt of latitude $+15^{\circ}$ is the best fixed position for solar space heating requirements. However, for domestic hot water heating, the optimum tilt is of the same angle as the latitude and it is even more shallow for solar heating an outdoor pool. DHW heating and pool heating are two important applications for solar energy -- at present both are more cost-effective than active solar space heating.

The limits established in the guidelines within which the collector surface must fall appear too restrictive in one sense and too broad in the other. A considerable portion of the roofs on new house construction are being built at any angle of 18.5° (4' in 12'). The simplest and best method of installing active solar collectors on such a roof is to flat mount them on the existing slope (Buchan, 1984). Under the criteria established in the guidelines, such collectors would be unacceptable for solar access protection, and yet, they would be acceptable by those knowledgeable in the industry.

Additionally, the criterion that the face of the collector surface can face from 45° to the east of south to 45° to the west of south, is a much broader range than generally accepted. Facing directly southeast or

southwest, a building receives less than three quarters of the direct solar radiation it would receive if it faced due south. A more accepted range is from 30° east of south to 30° west. At 30° off south, the direct radiation is only reduced by fifteen percent (Ontario Ministry of Municipal Affairs and Housing, 1982a:10). It is suggested that a more practical range of acceptable positions would be to face an azimuth of between 150° and 210° , and be tilted at an angle from 15° to 90° from the horizontal.

Two areas requiring further experimentation in the field of solar design, which may have some impact on the required solar window, are in the storage of excess heat and the use of screens to modify sunshine intensity. Unfortunately, the examples presented in the guidelines to back up the author's statements refer to the state of the technology in 1970 and not 1983. The comments are considered to be incorrect and misleading (Buchan, 1984).

The previous comments have related to the first section of the guidelines on solar energy utilization. The following comments relate to the voluntary by-law itself -- the proposed voluntary solar access protection by-law.

Controls on surrounding development are necessary to protect the solar user's access to sunlight.

The concept of a protected solar envelope is one of the viable tools available to establish the potential areas requiring solar protection. By requiring the same restrictions for all lots (rather than only protecting what is presently occupying the lot), the system is more equitable to all landowners. As well, the voluntary by-law is applied in addition to all other by-law requirements and should not conflict with any zoning regulations. The concept of defining a "solar window" for the maximum developable area of a lot is another viable tool and would have similar advantages to the solar envelope concept. A further advantage of the solar envelope is that only one is needed to assess the impact of any development. In the case of the solar window, the window would have to be identified for each lot with potential conflict.

A question arises as to the slope of the ceiling of development: Why place it at $21^{\circ}30'$? The angle $21^{\circ}30'$ is the altitude of the sun at noon on December 21 in Ottawa (City of Ottawa, 1984:A9). Not only is such an angle difficult to accurately draw, it could result in the shading of solar features on a neighbouring lot and would prohibit the construction of a 4 in 12 (18.5°) sloped roof at the peak of the development ceiling. An angle of 18.5° would, perhaps, be more practical.

It is not desirable to protect the solar access of the whole solar envelope; it would be too restrictive on surrounding development. The south-facing plane and the development ceiling are the two prime sites for

the collection of solar energy (areas B and A in Figure 6.2.2 and also levels 1 and 2 in Figure 4.5.5). Passive solar features are best located on the south facing wall and roof of the dwelling. The various types of active space, DHW and swimming pool solar heating systems, can be located in any position on the lot or dwelling. In most cases, however, the best location, from a cost and efficiency point of view (Buchan, 1984) is on the roof of the dwelling.

The inclusions of a metre-wide strip across the top of the side planes of the solar envelope and the protected garden, would not generally contribute significantly towards the goal of energy conservation.

Although the voluntary by-law does not specifically identify energy conservation as its ultimate goal, the original intention of the funding to support the study was to investigate the feasibility of solar access protection in built-up areas so that solar energy could be a significant source for future energy needs (Anonymous, 1984a).

The public participation process was responsible for the inclusion of the protected garden in the voluntary by-law. The concept was originally proposed by the Westboro Committee on Solar Access (ibid:10), a diverse group of people with a common interest in solar access and in gardening (ibid:11). Perhaps their motives were as much to protect solar access for gardening as to protect solar access for energy conservation.

It can be argued that gardens could be, in themselves, a form of energy conservation. The impact, however, of home gardening on the global energy picture would be very slight indeed. The additional energy penalties associated with providing the solar access for gardening (reduced housing densities and therefore increased travel distances) would more than offset the energy savings provided by home gardens.

The City of Brampton approached the concept of solar access protection in a similar fashion. A building envelope was defined which would result in reasonable solar access for dwellings to the north and, because the by-law related to a new subdivision, the streets could be laid out in an appropriate east-west orientation. Figure 6.3.1 illustrates the solar building envelope. The angle 71.5° was chosen as the maximum angle which permitted reasonable development and at the same time provided reasonable solar access for the size of lot chosen. No protected garden has been incorporated in the by-law.

Albuquerque, New Mexico, is another community using solar envelope zoning. Basically, the zoning is designed to protect direct sunlight falling on the rooftops of shorter buildings in medium and high density areas (Erley, 1980:20). Most urban areas are focusing their endeavours on the broader land use and energy relationship. The use of solar energy has been acknowledged as one energy conserving technique; however, it has been given low priority and few planning departments have addressed the

Figure 6.3.1
CITY OF BRAMPTON
SOLAR BUILDING ENVELOPE
(City of Brampton, 1979:3)

technical aspects of protecting solar access (Erley, 1980; Lang and Armour, 1980, 1982a; Hemphill, 1980).

The concept of the protected garden may have limited usefulness for those landowners whose dwellings are already shaded by existing structures, however, it is unjustified to protect gardens as well as the other surfaces indicated in Figure 6.2.2. It is important to examine solar access protection from the broader perspective of energy conservation in general. As mentioned earlier, solar energy is most applicable to low density development; development which conflicts directly with energy efficient (from a transportation, heating, and servicing point of view) medium and high density housing. A fine balance is required between providing adequate solar access, but not too much.

The Solar Design Guidelines developed by the Community Development Department of the City of Ottawa have contributed significantly towards the identification of a potential mechanism for protecting solar access in the urban environment. Although the guidelines can be questioned on several technical grounds, the concepts presented in them have considerable merit.

The original intention of the Ottawa project was not to develop a voluntary by-law, but rather a binding regulation for certain districts in the urban area. The voluntary by-law should not be considered an end

product but rather as an interim step towards a final document which would truly be able to protect solar access for those wishing to use it.

The final section of this chapter presents the basis of a zoning regulation for protecting solar access in the urban area.

6.4 A Solar Zoning Proposal

The examination of the various potential mechanisms, which have been proposed to protect solar access, identified solar zoning as the most promising mechanism for use in the developed areas of the city (Chapter 5). Solar zoning involves the creation of a solar zoning by-law imposing a height and coverage restriction on an urban lot in order to permit as much sunlight as possible to reach the surrounding neighbours.

Maximum access for one landowner would be achieved by totally restricting development on all his southern, eastern, and western exposures. Of course, such a restriction would be politically unacceptable. A politically acceptable solar zoning by-law would be required to protect the solar access of the neighbouring landowners without placing an undue restriction on the landowner's use of his property. As well, the solar zoning regulations would have to be compatible with existing zoning

regulations, perhaps marginally increasing the development restrictions on a property but not dramatically altering the development potential.

The protection of solar access, clearly, is not desirable in all sections of an urban area. Along rapid transit routes and in central business districts or any areas where medium and high density development predominates, the widespread use of solar energy has limited feasibility and restrictions on development would generally be viewed as unacceptable. A solar zoning by-law should apply only to those sections of an urban area containing relatively homogeneous, predominantly low and medium density housing for which the by-law would provide protection for the majority of landowners.

Based on the research undertaken during the course of preparing this thesis paper, the examination in some detail of the proposed City of Ottawa solar access protection guidelines (City of Ottawa, 1984) and consideration of the City of Brampton Solar By-Law Number 139-79 (Corporation of the City of Brampton, 1979) the following model solar access by-law is proposed.

6.4.1 Proposed Solar By-Law

A proposed by-law to regulate the use of land in certain designated sections of an urban area to provide protection for solar access.

The lands designated for solar access, as well as being subject to existing zoning requirements, will also be subject to the following requirements:

- a) that the shape, volume and lot coverage of proposed development be designed to fall within the solar envelope.

The solar envelope is defined as the envelope containing the maximum development permissible on a lot. The following features define the solar envelope:

- i The front, sides and rear setbacks of the lot form the vertical planes of the envelope.
- ii The maximum eaves height of the north facing plane is 8.0 metres above the average ground level.
- iii The ceiling of development is to be sloped at an angle of 18.5° up from the horizontal and is to extend to the south facing vertical plane.
- iv The east, west, and south facing vertical planes are to extend upwards to meet the sloped ceiling of development (see Figure 6.4.1).

- b) that the orientation of the south face of any new building construction be to within 20° north or south of an axis running directly east-west, where possible. See Figure 6.4.2.

- c) that the orientation of the face of any active solar system collectors be to within 20° north or south of axis running directly east-west.
- d) that new planting of vegetation and new construction of structures and fences, which are opaque or translucent, shall at no point exceed the plane which determines the maximum ceiling of development. See Figure 6.4.3. No differentiation is made between deciduous and coniferous trees since the summer shading of solar DHW collectors can significantly reduce the collectors' effectiveness.
- e) that for existing dwellings for which more than 15% of the protected surface is shaded on January 21st between the hours of 9:00am and 3:00pm, the landowner can apply to have part of his yard (up to 10%) designated as a protected garden.

The protected surfaces of the solar envelope are the south facing vertical plane and the ceiling of development indicated on Figure 6.4.1.

A protected garden would be a portion of the lot, for example, the rear of a east or west facing lot, for which solar access is protected between 9:00am and 3:00pm throughout the growing season.

- f) that all existing vegetation, structures and fences be exempt from the regulation.

Figure 6.4.1
SOLAR ENVELOPE OF PROPOSED BY-LAW

Figure 6.4.2

ORIENTATION OF MAIN SOUTH FACE OF BUILDING

(Adapted from: Corporation of the City of Brampton, 1979)

Figure 6.4.3
HEIGHT LIMITATION FOR NEW VEGETATION
AND NEW CONSTRUCTION OF OPAQUE OR TRANSLUCENT
STRUCTURES AND FENCES

It is intended that this by-law be a regulation adopted by Council and enforced by a by-law officer. It may be politically desirable, however, to implement the by-law as a voluntary conformance instrument for a preliminary period as a means to educate the public about the benefits of solar energy utilization and to assess its viability. To be successful in the long-term, the by-law must be an enforceable regulation.

It is hoped that this proposed solar zoning by-law provides adequate protection for those urban dwellers, at present and in the foreseeable future, who wish to utilize available solar radiation. It is also hoped that the by-law does not place an unrealistic restriction on the development potential of the affected urban lots. If the by-law is perceived by the general public as benefitting a privileged few while the majority suffers, it is unlikely to be instituted. Without some form of solar access protection, it is doubtful that solar energy will be exploited to its full potential.

In addition to a municipality making the proper zoning by-law modifications to protect solar access, the municipality should ensure the incorporation of appropriate restrictive covenants for new subdivision development (Ross, 1979a). Through the development approval process, a municipality could ensure that the title of each parcel of property in a new development includes a restrictive covenant limiting the height of vegetation and structures to a specified ceiling of development.

Through the use of solar zoning, restrictive covenants and, under limited circumstances, site certification, it is considered that a municipality could provide solar access protection.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The patterns of land use in the urban and rural environment are of prime interest to the social geographer. Those factors which affect land use patterns are also of interest to geographers. The residential use of solar energy has an impact on land use in the urban area. The requirements of a southern exposure free from obstructions necessitates an area of relatively low height, low and medium density dwellings. It follows, therefore, that a social geographer has a mandate to study the land use implications of solar energy systems.

Three prime objectives were addressed in this paper. The land use constraints associated with each of four potentially viable techniques of solar capture for residential use were identified. The land use factors which need to be considered today to make solar energy use viable in the future were identified, and a set of preliminary planning guidelines were outlined which would accommodate the use of solar energy at present and in the future.

A survey of Canadian, American, and other sources was conducted to collect information on what is currently being done with respect to the use of solar energy for residential applications and in the area of legislation protecting solar access. A wealth of information is available pertaining to the field of solar energy. It was easy to get sidetracked, delving into such related fields as energy conservation. In retrospect, it seems that only the surface has been scratched in conducting the literature review for this thesis. In particular, the American and foreign sources were only given a very cursory assessment. Such a broad selection of existing and proposed legislation exists that an entire thesis could be devoted to assessing energy conservation legislation.

Based on the research undertaken and a growing understanding of solar energy use, the various current solar capture techniques were identified. Of the six distinct methods of solar capture identified, two were considered economically unfeasible for use in the urban environment, now, or in the foreseeable future.

The four most viable methods of solar capture -- domestic hot water heating, passive solar space heating, active solar space heating and swimming pool heating -- were further examined to identify their impact on land use in the urban area. Passive solar space heating was found to have the greatest solar access requirement and, therefore, the greatest

probable impact on development in the urban area. With its reduced requirement of solar access only during the summer months, swimming pool heating would have the least impact.

It was the relationship between solar energy utilization and surrounding land uses which has been addressed in this paper. How will a shift towards the greater use of solar energy affect land use in the urban area? It was determined that not all sections of the urban area are suitable for the widespread use of solar energy, but for those sections that are, height restrictions would require low rise, low and medium density developments. Where possible, streets would have to be oriented on an east-west axis to maximize the southern exposure of dwellings and vegetation restricted from shading solar collectors.

Having identified what and why solar access requires protection, the focus then shifted to how. The various mechanisms available at present, and a selection of potential mechanisms for protecting solar access, were examined. At present, no adequate mechanism exists for protecting solar access in built-up areas. Although restrictive covenants are an appropriate mechanism for solar access protection in new solar subdivision developments, they are not feasible for established residential areas. The creation of a solar zoning by-law identifying zones in an urban area where the utilization of solar energy is to be encouraged and zoning restrictions are imposed on all properties, appears to offer the best

approach for protecting solar access in built-up urban areas. Solar site certification is a third potentially useful option for individual sites.

It involves a municipal council creating transferable development rights to be given to a landowner as compensation for giving up development rights for his own property.

Solar zoning by-laws have been proposed and, in some cases, implemented in various American and Canadian cities in recent years. The City of Ottawa has recently developed voluntary solar design guidelines (still in limbo as of September 1984 (Lawton, 1984)), and these were examined in detail in Chapter 6. Although a valuable preliminary effort, it is considered that the guidelines lack the technical foundation and the political feasibility to be implemented as a solar zoning by-law.

Using the City of Ottawa solar design guidelines and the City of Brampton solar subdivision by-law as references, a proposed model solar zoning by-law was drafted. Applicable to the southern Ontario planning milieu, it is felt that the proposed by-law should be politically acceptable -- providing adequate solar access protection for those who desire it without creating undue restrictions on surrounding landowners.

In the last section of Chapter 3, Hoare's four sequential tests of feasibility, which he feels all alternate energy systems are required to pass, was briefly introduced (Hoare, 1979). It is his opinion that solar

energy technology was, in 1979, positioned between the level of technical and economic feasibility. That appears to be the current situation in Canada, as well.

The Federal and provincial governments have supported the development of a viable solar manufacturing industry. In some areas of Canada, passive solar and solar domestic hot water heating systems are approaching the realm of economic feasibility. The public, however, is still not educated to the benefits of utilizing solar energy. Solar energy systems do not appear to have passed the test among the ultimate decision-makers.

Further breakthroughs are required to bring the cost of most solar options down to the level of economic feasibility and, as well, some solar systems require considerable technological development. Before solar energy can achieve the last level of institutional and political feasibility, however, a concerted effort to educate the public is required.

Without an educated public requesting the necessary revisions to the existing infrastructure, institutions and politicians are unlikely to institute the changes.

We have the technical capability to develop a solar zoning by-law. The major impediment to the successful implementation of such a by-law rests with the public. Until it is perceived that the citizens of an urban

area want solar access protection, it is doubtful whether such legislation will be introduced.

The first step the geographer, the planner and others interested in energy conservation must take towards preserving for the potential for solar energy systems is to educate the general public to the benefits of such preservation.

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