Designing Affordable Homes and Communities with Passive Solar Considerations in Regina, Saskatchewan, Canada

Avi Friedman¹ and Adrian Sheppard²

¹School of Architecture, McGill University, Montreal, Canada
²School of Architecture, McGill University, Montreal, Canada

ABSTRACT: Energy saving measures and technologies are commonly left out during the design of North American affordable housing. The prevailing assumption is that they are costly and, as a result, builders and homebuyers will not be willing to pay for them.

In their research and design of low-rise, wood-frame, market sector housing, the authors demonstrated that when simple design measures are taken, substantial energy savings can be achieved with a marginal cost increase. The thrust of their conceptual approach is the argument that design for passive solar gain in community planning and dwelling design are compatible with cost reduction design strategies.

By simplifying the dwelling shape (i.e. eliminating corners) energy savings were achieved. Reducing the unit's area also contributed to energy reduction. Since heat rises, floor stacking helped with lowering energy consumption in upper floors. Creating an open plan enabled the air to circulate freely between levels. The joining of units to form a row reduced the façade area. Orienting a large number of blocks of units towards the south, minimizing opening on the North elevation helped with passive solar gain. The above measures contributed to the reduction of consumption by 28%.

The authors demonstrated these design strategies in seven private sector housing projects in the city of Regina, the province of Saskatchewan's capital. Considered the sunniest city in Canada, the authors implemented these principles on large new developments, as well as single units.

In their paper the authors will outline these principles and demonstrate their application in particular projects and designs.

Conference Topic: Built environments and environmental buildings
Keywords: energy, comfort

INTRODUCTION

Two main objectives have been set for the housing projects in Regina: affordability and passive solar gain. The first aimed at incorporating design and construction principles that lowered the cost of a home and made it accessible to households with modest income. The second objective required the designers to follow another set of design criteria that was meant to lower the occupants’ utility expenses through passive solar gain and increase the level of comfort in their homes.

Review and analysis of these two sets of principles demonstrate that at times they compliment each other. That is when a common goal of lowering cost and increasing solar gain can be achieved. In other times achieving the objective in one area will compromise success in another. The task of designing affordable passive solar homes therefore becomes a balancing act. The mind-set that one needs to bring to the process is that of finding a middle ground between different sets of considerations. The process needs to begin by establishing a set of priorities regarding which of the two objectives might be more important at each chosen site. Within the realm of passive solar design there are challenges as well. Strategies that will maximize gain in wintertime, the installation of a large window for example, will also contribute to the overheating of the house in summertime. The need to consider both conditions becomes essential. A method commonly used to strike a balance between all these factors is known as the Optimal Value Engineering (OVE). OVE is a comparison and selection process of alternative materials and methods to determine the least costly combination that will result in a product acceptable to its users.
The need to find this balance is rewarding. Whereas some tend to believe that the affordability challenge ends when a would-be homebuyer finally purchases a home and moves in, others suggest that affordability begins upon moving in. The need to pay household expenses such as maintenance and upkeep in addition to monthly mortgage payments put a financial strain on the family budget. Reducing utility costs will make a contribution towards alleviating that financial burden.

There are, of course, other reasons for the need to take advantage of the sun as an energy source. The environmental benefits of solar gain are obvious. It is a non-polluting source. When strategies for passive solar gain are used, the financial investment, dependant on work done, is relatively small compared to the potential gain throughout the building lifecycle. Passive solar gain bears other advantages as well. Incorporating and letting in the sun increases the homeowner’s sense of personal comfort primarily in Canada’s long winters. The link between sunny spaces and people’s moods, primarily in the case of the elderly, has been demonstrated repeatedly. At the same time one needs to take into account the fact that our summer months can be hot and introduce all the necessary devices to protect the home against overheating and excessive use of air conditioning.

It is therefore worthwhile to consider these advantages and reach both affordability and passive solar gain while conducting a “balancing act”.

2. DESIGN PRINCIPLES

Cost reduction in housing is achieved by implementing large or small measures. A large measure can be the increase in the housing density for a given site or altering the way the infrastructure is constructed or simplifying the overall shape of a home. A small measure can be the use of a lower cost product, or leaving some interior spaces unpartitioned. The very same approach can be applied to the design of a community and homes with regard to passive solar gain. Fenestrating south elevations of the homes with large windows and building a high performance thermal wall will yield more gain. Alternatively, orienting part of the home’s façades towards the south and having smaller windows will yield small gain. Designers need to identify and list their possible strategies when they approach both designs for affordability and passive solar gain from the outset.

Listed below are a range of approaches that make an attempt at achieving a balance between affordability and passive solar gain. Some can be considered large scale measure and some small scale.

3. SITE PLANNING

The sites that were given to the students in the city of Regina ranged in size from a narrow front lot for a single dwelling in the city’s core to a 1.62 hectare site in a new development. Each of the sites required a unique approach to planning, yet, common strategies were used in all the projects in order to lower the cost of each unit. The principles embedded in these strategies can be used by builders to lower the cost of housing in other sites as well.

4. INCREASED DENSITY

Lowering the cost of land and infrastructure was achieved by increasing the sites’ density. That is, more units have been built on each site to better make use of the land and the services. Several strategies were used to this end. The first was to propose homes on smaller lots and the second to incorporate buildings with multi-family units. An additional approach was to group the units together and form rowhousing. These strategies were evident in the St. Joseph’s School site where townhouses and an apartment building were proposed (Fig. 1). The design contributed to the efficient use of land and the reduction of service cost for each unit.

The challenge when choosing a higher density planning strategy is to make sure that the appearance of the development will not be compromised. The single family home and lot did not lose its appeal and will likely continue to be a popular housing form in Regina. It is therefore necessary to design for higher density while keeping in mind basic amenities like public and private outdoor spaces. In the St. Joseph’s School site two green open spaces have been created around which the homes were placed. Wherever possible the parking was placed at the periphery of the site. Increasing density from the current 18-25 units per hectare to 35-60 units will reduce land and infrastructure costs by half and therefore can be considered as a large scale measure with a strong effect on cost.

Figure 1: Site plan for the St. Joseph’s School site.
Increasing density and placing the homes next to each other does not contribute to maximizing solar exposure since the buildings will cast shadows on each other. If rowhouses are proposed, only front and back elevations of the row’s middle unit have potential for sun exposure. The need is therefore to resort to several additional measures. The first is to place as many units or rows of them as possible on a north-south axis when the layout of the streets is conceived. Given the site dimensions, proportion and orientation it is not always possible, yet, an attempt must be made.

Figure 2: Shadow studies for the St. Joseph’s School site.

If parallel rows of homes are used they have to be placed at a distance from each other. This approach will help with achieving greater privacy in the project as well as preventing blocks of homes from casting shadows on each other. Each design needs to be followed with careful shadow studies of the site (Fig. 2).

Another strategy is to stagger the units on the lot. As was pointed out above the need to find a middle ground between affordability and passive solar gain requires that studies of shadow-casting for a variety of alternatives will be done parallel to the site planning and decisions have to be made accordingly. Such an approach was proposed in several projects and was implemented in the Angus Street and the Garden Ridge projects. In the Rothwell Crescent site the units were staggered and had their main elevations oriented towards the south (Fig. 3).

Figure 3: Staggering and orienting units towards south in Rothwell Crescent.

5. UNIT PLANNING

The need to balance between affordability and passive solar gain is well reflected in the planning of the home itself. Several strategies are known to contribute to cost reduction. Their effect on the energy performance of the house is also well-documented and will be outlined below.

6. BUILDING CONFIGURATIONS

One of the most effective ways of reducing housing cost is by simplifying the configuration and the plan of a dwelling. Savings will be achieved by reducing the number of corners, perimeter walls, and as a result, the number of windows. The required envelope decreases progressively as a plan is simplified to a “T” shape, to an “L”, or a rectangular square and a circle. In addition a simpler shape will require less cutting and fitting of building materials. An intricate house configuration will also require a complex roof which is costly and generally poses a construction challenge.

The tendency is often to believe that a complex shape makes the home architecturally attractive which is often not the case. In order to make the Regina projects affordable, homes with simple shapes have been proposed. Yet, the designs were further articulated by using porches and features like window sills and shutters (Fig. 4).
7. SIZE REDUCTION AND EFFICIENT LAYOUT

Reducing the unit’s size and as a consequence using interior space efficiently is a highly effective cost reduction measure. This strategy coincides with the need to increase density in the site planning stage which reduces cost of land and services. The design objective would be to “trim the fat” and provide a smaller house with the same usable floor area so as not to disrupt the occupants’ living comfort.

One possibility of using interior space efficiently is to reclaim the attic, especially for smaller houses. Using knee-type trusses or stick-built framing methods in the roof could increase the floor space without necessarily increasing construction cost. Taking advantage of the basement space by raising it up and letting in more light is another way to reclaim space in a small home and use it efficiently.

Once the configuration of a small building envelope was determined, attention can be focussed on the home’s interior layout. An appropriate design strategy for the unit’s public spaces (e.g. living room, dining room) is to encourage an open concept in order to alleviate the effect of a small space. It is a more flexible design approach that uses less material at the same time. It also has benefits with passive solar gain since the heat can travel easily from area to area. The open concept approach can be expanded to upper floors through central location of open stairs configuration which helps warm air from lower floors heat the upper ones. Efficient use of small space was attempted in most of the students’ projects. The location of the function and their proportions was carefully determined and the basement was made habitable in many of the designs (Fig. 5).

In order to keep the cost down unconventional forms of walls (e.g. curved, angled) must also be avoided. Contractors tend to base their pricing on how simple or elaborate the interior layout is. Another measure that will contribute to cost reduction through planning efficiency is the increased grouping of spaces with similar functions and environmental control needs. Pipe, duct and conduit runs can be minimized by planning for closed bathroom, kitchen and laundry areas preferably with back-to-back plumbing fixtures (Fig. 6).

The placement of the rooms themselves is an important consideration in the interior design of a home. Room functions are often divided into day and night areas. The kitchen is likely to be used during daytime and the bedrooms during night time. As far as passive solar gain is concerned, it is common to place day functions in the southern part of the house and to provide appropriate window size in these rooms. Window area in the range of 6% to 8% of the room size and 1.2 meters tall is recommended. Night functions are often placed against the northern façades of the home. This simple practice will benefit the comfort of the home’s occupants and improve the unit’s energy management.
8. FLOOR STACKING

A strategy that contributes to increased density and as a result to cost reduction and to improve energy management is to stack floors. Construction cost will be reduced since the home will not be spread out and smaller plots of land will be used and the very same foundation will be used for more floors. Energy management in such a house is also advantageous since heat rises and warm air from lower floors will heat the upper.

Installing a simple fan at the top of the stairs of a tall home with open plan can contribute by improving circulation of warmer air.

Tall buildings are advantageous when passive solar gain is considered since more faced area is exposed to the sun. The disadvantage of tall buildings, however, is that they cast shadows on adjacent buildings. The planning of a community made of such buildings will see them staggered or built apart from each other whenever possible (Fig. 7).

Figure 7: The shadow analyses help to prevent houses from casting shadows on each other and other buildings.

9. GROUPING UNITS

A design measure that can reduce the cost substantially and have a less desired effect on passive solar gain is the grouping of units. Grouping units contributes to increased density and the elimination of two of the middle units façades. Joining 4 detached units, into semi-detached for instance, reduces the exposed wall area by 36%. Grouping all four units as rowhouses provides an additional 28% savings. Heat loss reduction of approximately 21% can be achieved when two dwellings are attached and a further 26% savings for the middle unit when 3 or more dwellings are joined as rowhouses (Fig. 8).

Figure 8: Grouping of units in the St. Joseph’s School site.

Grouping units will not advantageous for passive solar gain since less façade area implies less exposure. It is therefore necessary to place rowhouses with their long façades towards south and to ensure that the southern façade will have more openings than the rear. Also, the designer needs to see to it that daytime functions will also face south.

10. CONSTRUCTION PRACTICES

A common objective for designers of affordable homes and those that are designed for passive solar gain alike should be quality construction. Cost reduction should not be attained by using poor construction practices or products. The mindset that needs to guide the architect and the builder of affordable housing is that of Optimal Value Engineering which refers to identifying the least costly product with the highest value for the occupant. The key parameter for such an approach needs to be that the home’s basic construction features be of high quality. No compromise should be made during building the home’s frame or insulating it. In general, elements whose replacement or upgrading will be costly and disruptive should be well chosen and well built. It makes sense, for example, to use vinyl floor covering for the kitchen since it can be easily removed and replaced with ceramic tiles when means become available.

The same approach should be used when decisions affecting passive solar gain or the house’s energy performance are going to be made. Windows, for example, need to be of high quality. Triple-glazed windows filled with Argon gas and low-e coatings have dropped in price in recent years and should be considered. Affordable homes are already small in size and therefore it is likely that they will have a reduced number of openings which justifies investment in good windows.

A high efficient and relatively inexpensive wall that has now become common in the construction of affordable housing is one of 38m x 140m (2’ x 6’) at 620mm (24”) on centre. The wider spacing between the studs reduces lumber consumption, and the additional thickness (compared to the conventional (2’ x 4’) increases the thermal performance of the home.

CONCLUSION

The selection of a construction method and practice in affordable housing and the design for passive solar gain must be made in parallel to unit design itself and not in the aftermath of such a
process in order to ensure that gains made as a result of design will not be lost.

What sets this research apart from other work in the field is the combination of solar energy and affordability. Past projects that dwell on reducing cost avoided including strategies to reduce energy consumption. Passive and active solar approaches have been ignored. This research demonstrates that by implementing simple design measures, affordable housing can also become energy efficient.

ACKNOWLEDGEMENT

The authors wish to thank Changhua Wei, Ping Yan, Xu Yang and Jian Zhang for the designs shown in this paper, as well as contributions made by Louis Pretty, Robert Bjerke and Thomas Green to the project.