# Greening the Grow Home

AVI FRIEDMAN, VINCE CAMMALLERI, and JOHN ARCHER
McGill University

## THE GROW HOME

The Grow Home - a narrow front two-storey affordable design alternative for an urban dwelling - was developed in the Affordable Homes Program at McGill University. Following the erection of a full-scale prototype on the university campus, several local builders implemented the concept. With basic construction costs of $40,000, over 2000 units have been built to date in and around the Montreal area.

Development, construction and operating costs were minimized by using simple and effective design strategies. The narrow-front rowhouse configuration allowed significant reductions in land and infrastructure costs as well as operating costs since the heat losses were restricted to two exposed walls and a small roof area. For land costs of $20 per sq. ft., standard lot depths of 100 ft. and servicing costs of $400 per linear foot, every foot of frontage costs $2400. By reducing the frontage from 18 ft. (which is the minimum required by the City of Montreal) to 14 ft., a $9600 saving was incurred. The 14-foot dimension also represents the cut-off point for a floor structure consisting of 2"x10" joists at 16"c/c; adding one foot to the width requires upgrading to a structure which costs 25% more. The need for interior load bearing partitions was also eliminated, making the space very flexible. Construction costs were minimized by virtue of the house's small size, simple layout, and the efficient use of conventional construction materials. Assuming construction costs at $50/sq. ft., a savings of $15,000 could be achieved by simply reducing the size of the dwelling from 1300 sq. ft. (the size of an average house) to 1000 sq. ft.. With the shrinking size of the average North American household, a smaller dwelling would not necessarily compromise the occupants' living comfort.

Two main aspects of the project contributed to its popularity. First, it provided an affordable alternative to the housing problem without sacrificing building quality or occupants comfort. Second, it was attractive to the average builder, who viewed the product as a practical, feasible

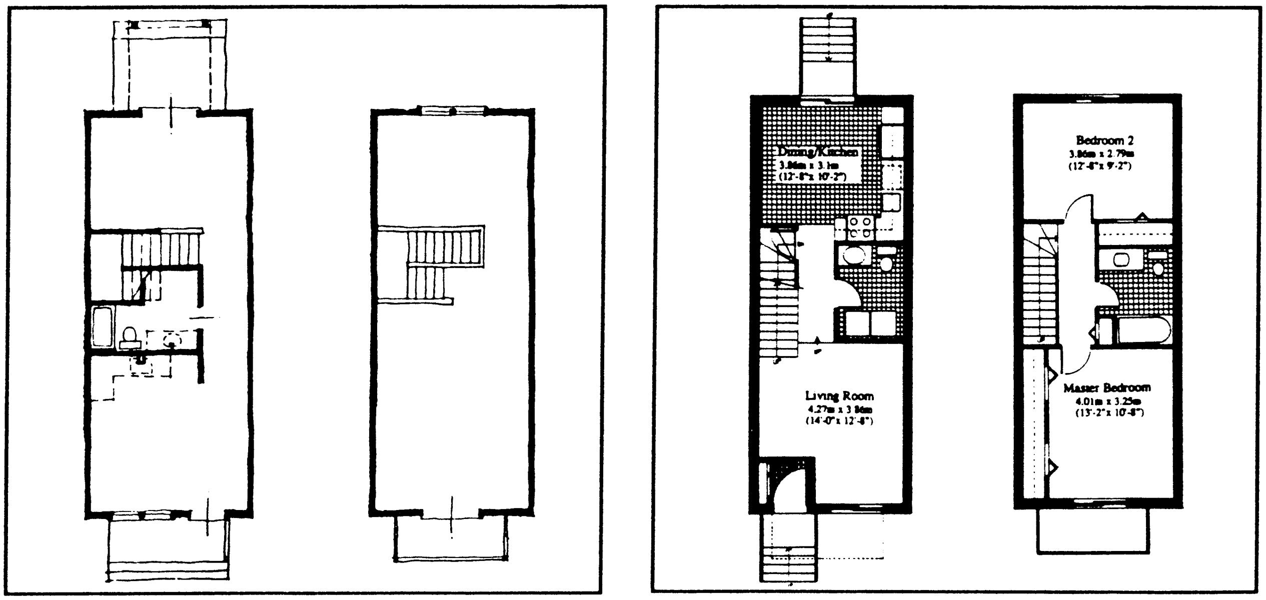

Figure 1: Plans of Conceptual (Built on Campus) and Modified (Built on Site) Grow Homes

opportunity for investment. The built projects revealed some interesting interpretations of the Grow Home concept. While the 14-foot width was retained in all cases, each of the builders modified the design to suit the tastes and budgets of his own particular market. The original plan, which subdivided the space with a central plumbing/stair core, was altered in most cases to accentuate the full depth of the space (Figure 1). The second floor was partitioned and finished in all but one project, some with "luxurious" bathrooms with seperate showers and whirlpool baths. Eleven of the builders provided brick veneer on the exterior to increase quality and project an image of permanence, while the remainder used a cement-based aggregate finish. All units were built with basements, adding 500 square feet to the floor area, and indoor garages were included in 15% of the homes. Vestibules and walk-in closets were added to the units in one of the projects, while separate garages were added to the sides in another.

What follows is a discussion of the strategies for reducing energy resources and construction waste through effective residential unit design using the Grow Home as a prototype.

## GENERAL BACKGROUND

Energy requirements for countries in cold climates are generally high, partly due to space heating requirements. Energy usage per capita in Canada is one of the highest in the world. Heating, cooling and operating housing accounts for approximately 20% of our total energy consumption. Furthermore, an additional 5-10% is used as indirect or embodied energy from construction, renovation and demolition of housing and its infrastructure (Robinson, 1991).

Construction is also responsible for some 16% of the total solid waste production, and approximately 20% of this is from new homes. Some 80% of this waste ends up in a landfill, much of which can be avoided. A study conducted in the Greater Toronto Area during the a period of high building activity found that construction of an average home produces 2.5 tons of waste, and 20 tons in cases where demolition is required (REIC, 1991). Approximately 25% of the waste is dimensional lumber, and another 15% is attributed to manufactured wood products. The situation is not only wasteful in terms of embodied energy, but also contributes to the problem of waste disposal. Despite Canada's vast terrain, most of its population is concentrated in a small number of urban centers, and waste disposal in landfills has become a serious crisis, with a growing problem of toxic leaching, resulting in contaminated soils and groundwater. It is evident that alternatives to current design, construction and operating standards for residential developments can play a major role in reducing our total energy consumption and alleviating the growing problem of waste disposal. The objective of this section is to examine how the basic design of a unit can be modified to provide a more economical and environmentally responsible product without compromising the occupant's living comfort.

## PLANNING GUIDELINES

There are several design factors which will help conserve resources by reducing the amount of building materials required and by improving the thermal efficiency of the building envelope. The modifications will also result in a more affordable and marketable product, since both selling price and operating costs will be lowered. There are five basic strategies which can be adopted, none of which will interfere with a builder's traditional working routines.

### 1. Building Configuration/Plan Simplification

One of the simplest ways of reducing material use and heat loss is by simplifying the unit's configuration. A more complex building form requires more corners and perimeter, which in turn requires more skin. This results in higher construction costs and increased heat loss. Generally, the ratio of floor area to perimeter should be maximized.

Figure 2 illustrates several possible building configurations having the same floor area. On one extreme, the "H" shaped plan has a ratio of floor area to perimeter of 0.87, requiring 160 sq. m. (1,722 sq.ft.) of exterior wall area for a 93 sq.m. (1000 sq.ft.) house. The required envelope decreases progressively as the plan is simplified to a "T" shape, an "L", a rectangle, square and circle. The latter makes the most efficient use of space, requiring close to 11% less wall than the square for the same floor area.

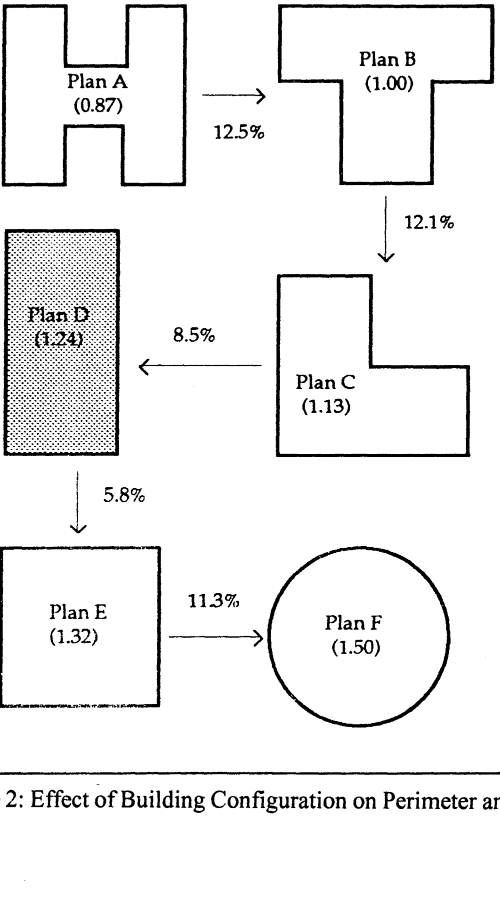

Figure 2: Effect of Building Configuration on Perimeter and Floor Area

| Plan Configuration | Wall Area (sq.m.) | Energy Required (KWh) | Associated Heating Cost |
|---|---|---|---|
| Plan A (H) | 160 | 2859 | $134 |
| Plan B (T) | 140 | 2501 | $117 |
| Plan C (L) | 123 | 2198 | $103 |
| Plan D (Rect) | 112 | 2001 | $94 |
| Plan E (Square) | 106 | 1894 | $89 |
| Plan F (Circle) | 94 | 1679 | $79 |

Table 1: Effect of Building Configuration on Energy Consumption

A simple plan costs less to build since there are fewer corners and, most likely, fewer windows. Envelope costs, from the basement to the roof, are reduced while simple configurations generally require less cutting and fitting of building materials. Consequently, the amount of material wasted is reduced, and the management task is simplified.

Reductions in the exposed wall area are accompanied by a proportional decrease in heat loss. When a plan is simplified from a "T" shape to a square, conductive heat losses from the walls alone can save $28 in heating costs annually for a small (93 sq.m.) house in Montreal (Table 1). These savings could easily be doubled if the additional heat losses from the basement and infiltration are accounted for.

While the circle provides the best area/perimeter ratio, its potential savings can be easily offset by the extra cost of building curved walls, and the interior plan may lead to layouts that are not functional. Similarly, the square provides a more efficient perimeter to floor area ratio when compared with a rectangle. This configuration, however, may be difficult to plan efficiently on the interior. The rectangle appears to be the most advantageous configuration in this regard. Furthermore, the rectangle would require less land, since it can be built on narrower lots, and can benefit more easily from being grouped into rowhouses, which in turn leads to additional savings in construction and energy costs.

## 2. Modular Design/Dimensioning and Efficient Framing Practices

Another simple and effective way of reducing material waste is through careful dimensioning of the building to accommodate the modular configuration of the building materials. At the most basic level, designing within standard dimensions for structural framing members such as studs, joists and plywood could result in substantial savings. It has been estimated that in a typical detached home, the use of general dimensions for stud spacing (i.e. 405 mm or 16" module) to eliminate the need for an extra stud at the end of the wall, placing and dimensioning windows accordingly and locating partitions to line up with the structural studs may save a ton of lumber in an average home. Designing for 2200 mm (4-foot) modules and 610 mm (24") stud spacing alone can reduce lumber use by 8%. Providing for efficient details at corners and intersections of exterior walls and interior partitions doubles these savings.

With more careful planning and material selection, the same principle could be implemented to accommodate interior finishes such as drywall and floor tiles. Cost savings are achieved not only through efficient use of material, but also through reduced labour requirements, since less cutting and fitting is required.

Figure 3 illustrates four simple plans which have approximately the same floor area and configuration, but are dimensioned for different modules. Theoretically, the amount of structural wood required to build these plans should be almost the same, since there is no significant difference in either floor area or perimeter between the alternatives. Table 2 shows the quantity of floor joists, wall studs and sheathing materials (walls and floors) required for a two-storey house as measured from the plans. The sheathing requirement is fairly consistent from one plan to another, with a difference of about 10 sq.m. (108 sq.ft.) between the highest and lowest estimates. This is equivalent to about 3.5 standard sheets of material. Similarly, the total length of wall framing components (including top and bottom plates) changes little between alternative floor

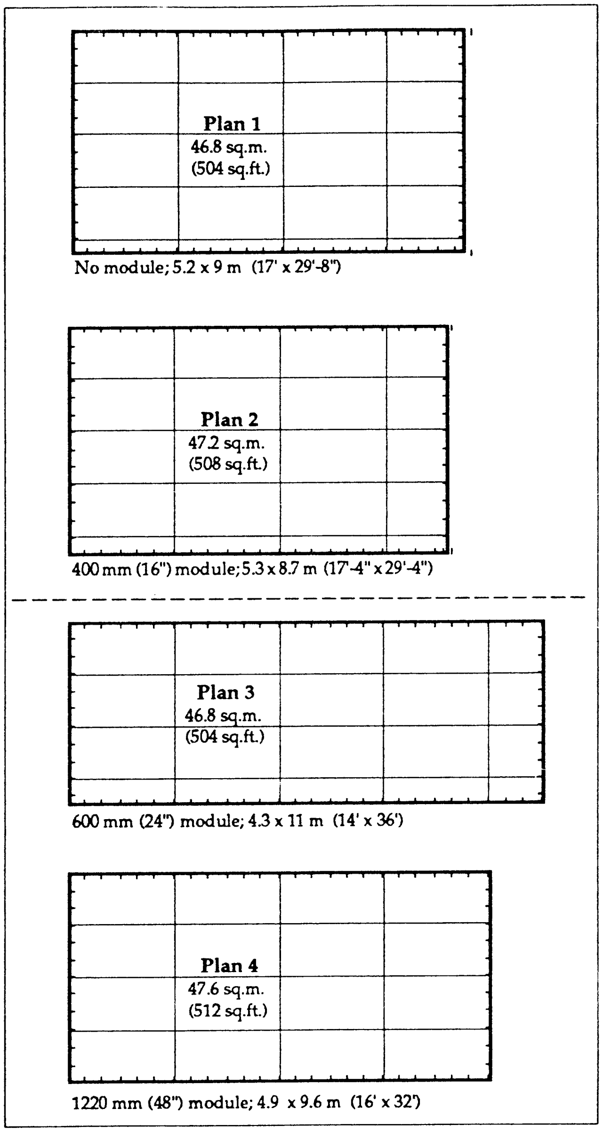

Figure 3: Alternative Modular Design/Dimension

| Plan Module | Joists (m) | Studs (m) | Sheathing (sq.m.) |
|---|---|---|---|
| Plan 1 (no module) | 378.2 | 561.1 | 232.5 |
| Plan 2; 406 mm (16") | 384.4 | 520.1 | 233.3 |
| Plan 3; 610 mm (24") | 299.9 | 559.2 | 242.4 |
| Plan 4; 1220 mm (48") | 302.4 | 534.0 | 237.9 |

Table 2: Measured Material Requirements

| Plan Module | Joists | | Sheathing | |
|---|---|---|---|---|
| | Ordered (m) | Wasted (m) | Ordered (sq. m.) | Wasted (sq.m.) |
| Plan 1 (no module) | 403.6 | 25.4 | 249.7 | 17.2 |
| Plan 2; 406 mm (16") | 408.4 | 24.0 | 249.7 | 16.4 |
| Plan 3; 610 mm (24") | 302.4 | 2.4 | 249.7 | 7.3 |
| Plan 4; 1220 mm (48") | 302.4 | 0.0 | 237.9 | 0.0 |

Table 3: Material Usage

plans except for Plan 2, which approaches a square and has less perimeter than the others. More floor joists are needed for the first two plans (Plan 1 and 2), which are wider and require tighter joist spacing (405 mm; 12").

Although the total measured material requirements vary little for plans which use different modules, the amount of waste generated in each design can vary significantly. The amount of waste produced is generally higher in those plans which are based on smaller modules or random dimensions (Table 3). Between 6% and 7% of the material bought for Plan 1 (random dimensions) is wasted on cut-offs that cannot be reused because they are too small. This wastage is reduced gradually as the plans are designed for larger modules. The structural frame based on a 2220 mm (4 ft) module needs very little cutting, and can be built producing little or no waste. Consequently, 5% less sheathing material needs to be purchased.

The amount of wasted material for each plan in Table 3 represents ideal conditions, assuming that all reasonably-sized material cut from a whole sheet or length of lumber is reused. In actual construction, it is probable that some, if not most of the "scrap" will not be recovered or reused. Lumber falling on wet ground, for instance, is not likely to be recovered, nor is that which is cut in a location which is distant from the area where it can be reused.

### Efficient framing

The amount of lumber required in the building frame can further be reduced in three ways: (1) by using wider spacing between components; (2) by removing any extra lumber whose main purpose is to provide nailing surface for interior finishes; and (3) by lining up the floor joists and wall studs, thereby eliminating the need for a double top plate.

| Framing Alternative | Lumber Savings (m) | Lumber Weight (kg) | Constr. Cost Savings | Embodied Energy [1] (MJ) |
|---|---|---|---|---|
| Lining up joists w/studs | 61.0 | 204 | $139 | 1502 |
| Stud spacing at 610 mm (24") | 68.3 | 228 | $156 | 1682 |
| Exterior Walls | 19.5 | 65 | $44 | 481 |
| Interior Partitions | 97.5 | 217 | $200 | 1597 |
| | **Total** | **713** | **$539** | **5262** |

[1] *Based on energy intensities and conversion factors taken from Sheltair, 1991.*

Table 4: Savings from Efficient Framing Practices

The savings that can be achieved in a rowhouse 4.3 m (14 ft.) wide and 11 m (36 ft.) deep by applying these principles are shown in Table 4. Lumber used for wall framing can be reduced by over 12% by spacing the studs at 610 mm (24") centers rather than at 405 mm (16"). Similar savings can result from aligning floor joists with wall studs, which eliminates 61 m (200 ft.) of wall studs. Using two studs at the corners rather than three can save an additional 19.5 m (64 ft.) of lumber, and the same techniques applied to interior partitions saves 97.5 m (320 ft.) of interior framing lumber. When all four techniques are applied, lumber savings can add up to 713 kg, with associated construction costs of $539 and an embodied energy content of approximately 5262 MJ, or 1,463 KWh. With every 4 houses built, enough lumber and energy can be saved to frame the walls of a fifth house and heat it for at least one year.

### 3. Area Distribution/Floor Stacking.

While the vertical distribution of a unit's floor area will have the greatest impact on land use efficiency and housing density, it can also have substantial effects on the use of building materials and, to some extent, energy efficiency. Vertical designs make most efficient use of space, since more stacking results in the need for less construction material. The cost of a two-storey square house, for instance, is less per square foot than a one-storey with equivalent area, since it has half the foundation and roof area. Floor to floor heights, which are affected by such factors as the floor thickness and the presence of suspended ceilings, will also have an impact on the amount of raw materials that go into construction, especially in the building envelope.

Generally, buildings with a smaller ratio of surface area to volume make the most efficient use of materials and require less energy to heat. Bungalows, which have an average surface-to-volume ratio of .38, are considered to be wasteful. Split-level-type plans, which accommodate the same floor area on 1.5 storeys, have a lower ratio, usually in the area of 0.25.

The effect of floor stacking on energy efficiency will depend on several factors, including unit size and grouping (Figure 4). For the model examined earlier, the energy benefit of moving from a one-storey, 93 sq. m. (1000 sq.ft.) bungalow to a two-storey cottage-type model with the same floor area is marginal.

Although the transition increases the total exposed wall area by more than 50%, the extra heat losses are compensated for by a reduction of basement and roof areas. Total heat

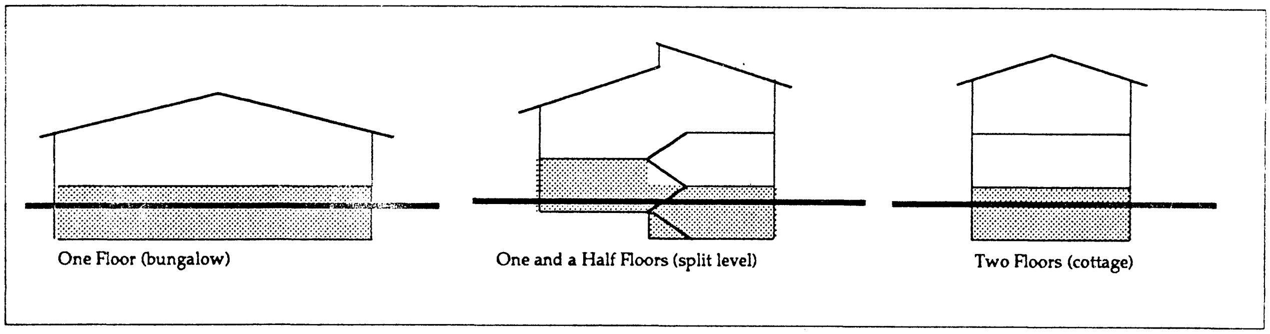

Figure 4: Possibilities for Floor Stacking

| Component | Heat Loss (Watts) | | | |
|---|---|---|---|---|
| | 1 Storey | 2 Storeys | | |
| | (bungalow) | Detached | Semi-det | Rowhouse |
| Roof | 558 | 279 | 279 | 279 |
| Walls | 1005 | 1643 | 1005 | 367 |
| Doors and Windows | 1598 | 1598 | 1598 | 1598 |
| Basement | 1560 | 1249 | 780 | 311 |
| Infiltration | 1547 | 1413 | 1250 | 1087 |
| **Total** | **6267** | **6182** | **4912** | **3642** |
| Annual Energy Consumed (KWh) | 9154 | 9029 | 7174 | 5320 |
| Associated Heating Costs (Montreal) | $429 | $423 | $336 | $249 |

Table 5: Combined Effect of Floor Stacking and Unit Grouping on Heat Loss

losses are therefore fairly balanced, resulting in a negligible savings in the order of 1% (Table 5). By reducing the footprint of the house, however, and consequently excavation and foundation requirements, substantial construction cost savings can be achieved.

For the narrow-front house, a major advantage of stacking floors is that it allows two or more units to be joined, leading to significant reductions in heat loss and improved land use efficiency.

## 4. Grouping/Joining Units.

One of the most effective ways of reducing energy consumption is by joining units into semi-detached or rowhouse configurations, since heat losses are limited to two walls (or three, for a semi-detached unit) and a small roof area. Grouping units is also an effective way of improving construction efficiency. The repetition of design in a set of rowhouses usually results in a shorter construction period per unit. The reduction in perimeter area can have a significant impact on the delivery time, since construction of the envelope is a labour-intensive operation.

The joining of units into groups of two or more can provide significant savings in both construction and energy. Joining four detached units into semi-detached, for instance, reduces the exposed wall area by 36%. Grouping all four units as rowhouses provides an additional 50% savings (Figure 5).

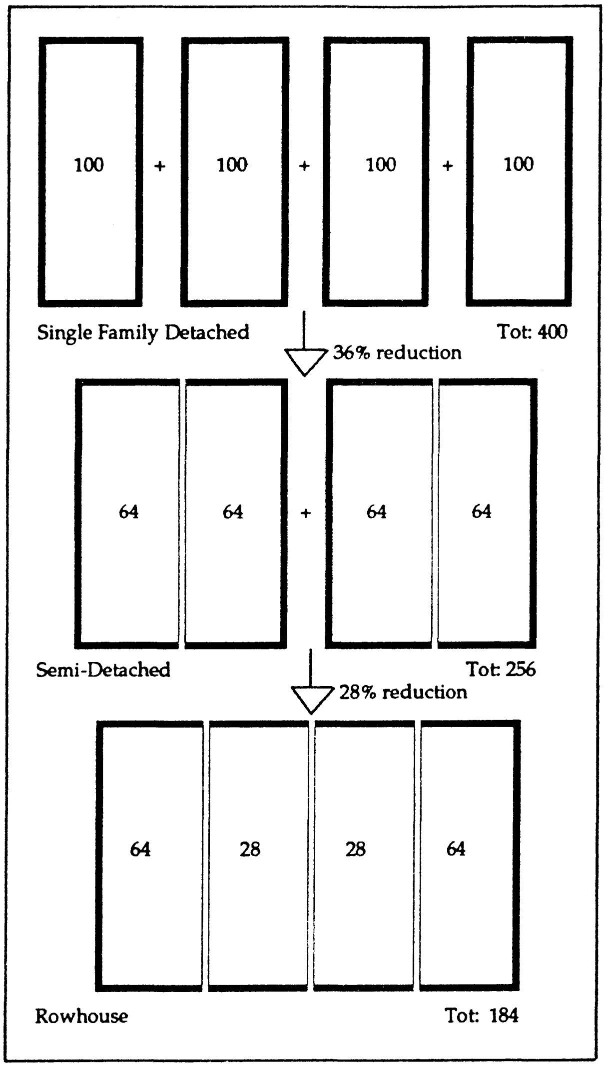

Figure 5: Effect of Unit Grouping on Exposed Wall Area

Heat-loss reductions of approximately 21% can be achieved when two dwellings are attached, and a further 26% savings for the middle unit when three or more dwellings are joined as rowhouses (Table 5). For Montreal, the transition from a detached unit to a rowhouse results in annual savings of $174. In addition to substantial reductions in energy consumption, the joining of units enables efficient use of land and infrastructure.

### 5. Size Reduction/Efficient Planning.

Efficient planning of the unit's interior layout can be instrumental in reducing both construction costs and energy consumption. By increasing the ratio of usable to gross floor area, the quantity of construction materials is reduced, as are the space heating requirements. 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. This can be achieved in several ways.

One possibility is to reclaim the attic, especially for small houses. Most types of prefabricated trusses can be wasteful where small spans are involved, particularly since they render the space unusable for living purposes. Using knee-type trusses or stick-build framing methods in the roof could increase the floor space without necessarily increasing construction costs. For a 4.3 x 11 m (14' x 36') area, for instance, a 2.4 m (8') clearance could be achieved with a roof slope of 6:12. Assuming that 40% of this space is usable for occupancy, an additional 19 square metres (200 sq.ft.) of floor space could be added to this home.

Eliminating the basement could also be beneficial where there is sufficient living space on the main and upper floors of a unit, or where accessible dwellings are desired. Slabs on grade, crawl spaces and pier foundations use less concrete, are less expensive to build and use less energy to heat. Where a basement is deemed necessary, the use of preserved wood foundations, particularly in the form of prefabricated panels, can provide dry, energy-efficient basements that are relatively easy to finish. The use of wood rather than concrete reduces the amount of embodied energy by about 30%. It also enables the buyer to participate in the construction process, since wood is easier to work with than most other alternatives. Interior finishes, for instance, are relatively labour intensive and can account for about 33% of the total cost of a house. By having the buyer finish the house independently, its selling price can be reduced substantially.

As far as the internal layout and space division are concerned, there are several factors which should be considered. The open interior plan, for instance, is most flexible, energy efficient and uses fewer materials. Local heat gains and losses are more easily equalized, and energy demand for mechanical ventilation is reduced, since there are no obstructions to the air flow. Circulation paths and hallways, which receive marginal use, should be reduced to a minimum. Design for concentric or circular movement patterns are generally most efficient.

It should also be kept in mind that the illusion of large spaces can be created without having to increase the size of the room by emphasizing horizontal lines, removing part of the wall between two adjacent spaces, using gently sloping ceilings and interior walls 6.5 feet tall.

Planning efficiency can also be increased by grouping spaces with similar functions and environmental control needs. Pipe, duct and conduit runs can be minimized by planning for close bathroom, kitchen and laundry areas, preferably with back-to-back sinks.

## CONCLUSION

Substantial savings in construction and operating costs can be achieved through efficient planning and framing techniques. By simplifying the building configuration, construction costs and heat loss can be significantly reduced, since there are fewer corners to build and less exposed wall area. Building on two floors and grouping the units into semi-detached or rowhouse configurations saves land and infrastructure, and reduces energy consumption by 42%. Careful dimensioning reduces the amount of waste generated, and simplifies the construction task. Efficient framing practices can reduce lumber requirements by 25% in a small, narrow-front rowhouse. Over a ton of lumber can be saved for every two units built, which translates into $1,200 worth of construction costs. While implementing such basic planning principles can lower operating expenses and make the unit more affordable, the usable floor area remains unchanged, and the occupants' living comfort is not affected. In addition, significant savings in material, energy and construction time can be achieved by following some basic planning principles:

- Do not overdesign the structure; stud spacings of 24" on center are usually sufficient for most two-storey houses; corners can be built with two studs, and intersections with interior partitions could be supported without using studs.
- Dimension units to accommodate modular dimensions of building materials.
- Dimension and locate openings to accommodate stud spacing.
- Simplify the unit's configuration and plan interiors efficiently.
- Stack floors; two-storey homes use less material and are less expensive to build.
- Group units as semi-detached or rowhouses to save on land, infrastructure, energy and material.

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