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Future Housing Energy Efficiency Associated with the Auckland Unitary Plan

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Abstract**—**The draft Auckland Unitary Plan outlines the future land used for new housing and businesses with Auckland population growth over the next thirty years. According to Auckland Unitary Plan, over the next 30 years, the population of Auckland is projected to increase by one million, and up to 70% of total new dwellings occur within the existing urban area. Intensification will not only increase the number of median or higher density houses such as terrace house, apartment building, etc. within the existing urban area but also change mean housing design data that can impact building thermal performance under the local climate. Based on mean energy consumption and building design data, and their relationships of a number of Auckland sample houses, this study is to estimate the future mean housing energy consumption associated with the change of mean housing design data and evaluate housing energy efficiency with the Auckland Unitary Plan.

Keywords**—**Auckland Unitary Plan, Building thermal design, Housing design, Housing energy efficiency.

I. Introduction

As Auckland continues to grow, intensification will occur in the existing urban area and quality higher density residential development is needed to meet the future population growth. According to the draft Auckland Unitary Plan, there are five residential zones: Single House, Mixed Housing, Terrace Housing and Apartment Buildings, Large Lot, and Rural and Coastal Settlement. In future, the Mixed Housing zone can be the most common residential zone in Auckland urban area. It enabled two storey housing in a variety of sizes and forms including detached dwellings, semi-detached dwellings, town houses and terraced housing and low-rise apartments. The unitary plan not only increases urban housing density but also changes conventional housing types and their thermal performance under the local climate. Those changes can also impact housing energy consumption. There are a number of previous studies on the impact of different building design factors on energy efficiency. These design factors are mainly related to building orientation, geometry and envelope.

Some studies focus on building orientation, which is one of most important design factors for building energy efficiency, impacting on solar radiation received [1], [2] and shading [3]. Other studies focus on the impact of building shape [4]–[7] with different orientations [5]–[8]; or on energy consumptions under different climates [9]. All heat exchanges between indoor space and outdoor space are through the building envelope, which has the greatest impact on building energy consumption [10], [11].Those studies based on mathematical models and computer simulations can be used to compare different building designs for energy efficiency. For energy efficient house design, computer simulations are becoming available as design tools [12]–[14], and some studies combine computer simulations with field study data for energy efficient house design or improved housing thermal performance [15]–[18]. The study suggests that better design of new buildings could result in a 40-70% reduction in their energy consumption relative to 2000 levels [19]. This study is to use actual monthly energy consumption data and design data of a number of different Auckland houses and their relationships as bench marks to estimate variation of mean Auckland housing energy consumption in the future associated with Auckland Unitary Plan.

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II. Method

Previous study collected the actual energy consumption data and design data of 200 different sample houses with insulation in their wall and roof [20] in the Auckland urban area. The 200 sample houses include 90 one-storey houses, 104 two-storey houses and 6 three-storey houses. The range of floor areas is 31 – 446m2 with a mean floor area of 182m2. The range of occupancy per dwelling is 1 – 7 persons with a mean number of occupants per dwelling of 3.4 persons. The range of floor areas per occupant is 20 – 180m2 with a mean floor area per occupant of 65m2. There are 69 houses with metal roofs (15 houses with brick walls and 54 houses with weatherboard and other walls), 116 houses with concrete tile roofs (78 houses with brick veneer walls and 38 houses with weatherboard and other walls) and 15 houses with cedar shingle roofs or other roofing materials. There are 158 houses with internal garages and 42 houses without. According to the local climate, an Auckland house normally does not use energy for space cooling during the comfort and dry summer and only use some energy for temporary space heating during the mild and wet winter. An Auckland house uses more energy during the winter than other seasons. Extra winter energy of a house mainly comprises space heating energy and extra energy for hot water and all appliances during the winter, which is closely related to building thermal design and thermal performance under the local climate. Mean extra winter energy is a large portion (28.4%) of mean winter energy of Auckland sample houses. Mean total winter energy consumption is also a large portion (32.3%) of mean total annual energy consumption of the sample houses [21], [22].

Building thermal design for energy efficiency of Auckland housing should focus on building thermal performance under the winter climate conditions. The study uses the mean daily energy usage per unit volume (m3) of house indoor space (kWh/m3day) as the basic energy consumption unit because winter extra energy consumption is mainly related to indoor thermal conditions. Based on design and winter energy data of the 200 Auckland sample houses, this study is to mainly estimate the future Auckland mean winter housing energy consumption with changing mean building design data for evaluating housing energy efficiency associated impacted by Auckland Unitary Plan. Housing enveloper, roof, wall and window design data are used for this study.

III. Housing Design Data

A. Ratio of Building Surface to Volume

Winter energy consumptions of the 200 Auckland sample houses used for this study are in the ranges of 0.02103 to 0.16304kWh/m3day with the mean of 0.07544kWh/m3day. Ratios of building surface to volume of the 200 sample houses used for this study are in the ranges of 0.4401 to 0.9869 with the mean of 0.6337. A house with a high ratio of building surface to volume has a large external surface area per unit of indoor space from which to lose heat to the outdoors, and uses more energy for space heating, hot water and other appliances that can be affected by indoor thermal conditions during the winter. An increase in winter energy consumption is associated with an upward trend in the ratios of building surface to volume of the sample houses (see Fig. 1). The unitary plan not only increases mean urban housing density but also changes conventional housing types and their thermal performance under the local climate. As more mixed house, terrace housing and apartment buildings are allocated in the existing urban areas, Auckland current mean housing design data, that can impact building thermal performance, will be changed in the future. Those changes can also impact future mean housing energy consumption under the local climate. Median density or higher density housing such as Attached house, terrace house and apartment building have lower ratio of building surface to volume than single house. In the future, the mean ratio of building surface to volume in Auckland residential area will decrease with the Auckland Unitary Plan. According to mean winter energy, mean ratio of building surface to volume of the 200 Auckland sample houses, their relationship and the gradient of trend line in Fig. 1, the reduction of mean winter energy can be estimated associated with decreasing mean ratio of building surface to volume. Table I shows that relationships between reduction of mean winter energy and decrease of mean ratio of building surface to volume of the Auckland sample houses. Decreasing mean ratio of building surface to volume in the Auckland residential areas can positively impact on reducing housing winter energy.

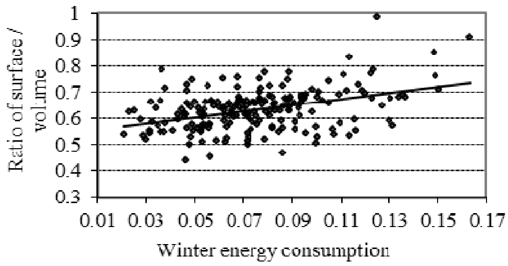

Fig. 1 Winter energy consumptions and ratios of building surface to volume of sample schools

TABLE I
REDUCTION OF WINTER ENERGY (KWH/M^3/DAY)WITH DECREASING RATIO OF BUILDING SURFACE TO VOLUME

Winter Energy	Reduction	Surface/Volume	Decreasing
0.0755	Mean	0.6337	Mean
0.0717	5%	0.6293	0.7%
0.0646	10%	0.6210	2.0%
0.0549	15%	0.6098	3.8%
0.0439	20%	0.5972	5.8%

B. Ratio of Roof Surface Area to Indoor Space Volume

Ratios of roof area to indoor space volume of the 200 Auckland sample houses used for this study are in the range of 0.1172 to 0.5719 with the mean of 0.3545. A low rise building such as a house loses more heat through roof than wall. An Auckland house with one to two stories loses about 40% heat through roof and about 20% heat though wall during the winter. A house with a high ratio of roof area to indoor space volume has a large roof area per unit of indoor space from which to lose heat to the sky by long wave radiation during the winter night, which results using more energy for temporary space heating. An increase in winter energy consumption is associated with an upward trend in the ratios of roof area to indoor space volume of the 200 Auckland sample houses (see Fig. 2). As more two or three storey terrace houses and higher apartment buildings will be built in the existing residential area, mean ratio of roof area to building indoor space in Auckland residential areas will be decreased in the future, and multi-floors can also supply more protection from heat loss through the roof. According to mean winter energy, mean ratio of roof area to indoor space volume of the 200 Auckland sample houses, their relationship and the gradient of trend line in Fig. 2, the reduction of mean winter energy can be estimated associated with decreasing mean ratio of roof area to indoor space volume. Table II shows that relationships between reduction of mean winter energy and decrease of mean ratio of roof area to indoor space volume of the Auckland sample houses. Decreasing mean ratio of roof area to indoor space volume in the Auckland residential areas can positively impact on reducing housing winter energy.

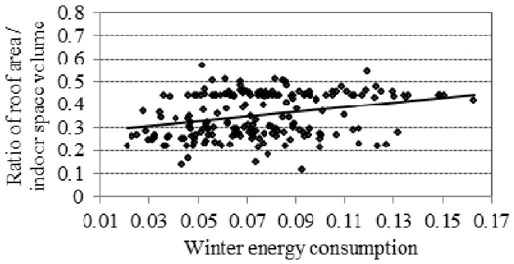

Fig. 2 Winter energy consumption and ratio of roof area to indoor space volume

TABLE II
REDUCTION OF WINTER ENERGY (KWH/M^3/DAY)WITH DECREASING RATIO OF ROOF AREAS TO INDOOR SPACE VOLUME

Winter Energy	Reduction	Roof/Volume	Decreasing
0.0755	Mean	0.3545	Mean
0.0717	5%	0.3507	1.1%
0.0646	10%	0.3433	3.2%
0.0549	15%	0.3333	6.0%
0.0439	20%	0.3219	9.2%

C. Ratio of Wall Area to Building Indoor Space Volume

Ratios of wall area to indoor space volume of the 200 Auckland sample houses used for this study are in the range of 0.2521 to 0.7753 with the mean of 0.4233. A house with a high ratio of wall area to indoor space volume has a larger external wall area per unit of indoor space from which to lose heat to outdoor during the winter. An increase in winter energy consumption is associated with an upward trend in the ratios of wall area to indoor space volume of the 200 Auckland sample houses (see Fig. 3). As more terrace houses and apartment buildings will be in the existing residential areas, there will be more partition walls between dwellings or apartments and less external walls per unit of indoor space of new residential buildings. Mean ratio of wall area to indoor space volume in Auckland residential areas will be decreased in the future. According to mean winter energy, mean ratio of wall area to indoor space volume of the 200 Auckland sample houses, their relationship and the gradient of trend line in Fig. 3, the reduction of mean winter energy can be estimated associated with decreasing mean ratio of wall area to indoor space volume. Table III shows that relationships between reduction of mean winter energy and decrease of mean ratio of wall area to indoor space volume of the Auckland sample houses. Decreasing mean ratio of wall area to indoor space volume in the Auckland residential areas can positively impact on reducing housing winter energy.

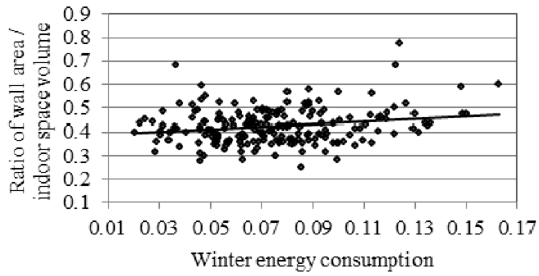

Fig. 3 Winter energy consumption and ratio of wall area to indoor space volume

TABLE III
REDUCTION OF WINTER ENERGY (KWH/M^3/DAY) WITH DECREASING RATIO OF WALL AREAS TO INDOOR SPACE VOLUME

Winter Energy	Decreasing	Wall/Volume	Decreasing
0.0755	Mean	0.4233	Mean
0.0717	5%	0.4212	0.5%
0.0646	10%	0.4171	1.5%
0.0549	15%	0.4116	2.8%
0.0439	20%	0.4053	4.2%

D. Ratio of Window Area to Indoor Space Volume

Ratios of window area to indoor space volume of the 200 Auckland sample houses used for this study are in the range of 0.0351 to 0.14876 with the mean of 0.0875. Most windows of the sample houses are single glazed windows. Windows are commonly weak elements of building thermal performance. Even using double glazed windows, the R-value 0.26 is still very low compared with wall (1-1.9 m2 °C/W) or roof (2.9-3.5 m2 °C/W). A house with a high ratio of window area to indoor space volume has a larger and lower R-value window area per unit of indoor space to lose heat to outdoor during the winter. Increasing the ratio of window area to indoor space volume can cause stronger negative impact on winter energy consumption than increasing the ratios of roof and wall to indoor space volume. An increase in winter energy consumption is associated with an upward trend in the ratios of window area to indoor space volume of the 200 Auckland sample houses (see Fig. 4). More terrace house and apartment building with more partition walls between dwellings or apartments and less external walls per unit of indoor space of new residential buildings can decrease ratio of wall area to indoor space volume and also can potentially reduce mean ratio of window area to indoor space volume in the residential areas. According to mean winter energy, mean ratio of window area to indoor space volume of the 200 Auckland sample houses, their relationship and the gradient of trend line in Fig. 4, the reduction of mean winter energy can be estimated associated with decreasing mean ratio of window area to indoor space volume. Table IV shows that relationships between reduction of mean winter energy and decrease of mean ratio of window area to indoor space volume of the Auckland sample houses. Decreasing mean ratio of window area to indoor space volume in the Auckland residential areas can positively impact on reducing housing winter energy.

According to a minimum requirement for day lighting of the compliance document for New Zealand building Code [23], vertical windows in external walls of a house shall have a window area of no less than 0.1 of the floor area. The ratios of window area to floor area in the sample houses are 0.08 to 0.37 and the mean ratio is 0.21. A house with high ratio of window area to floor area has good day lighting and positive thermal conditions during daytime but negative thermal conditions during night time, which results more heat loss during night time and using more heating energy. An increase in winter energy consumption is associated with an upward trend in the ratios of window area to floor area of the 200 Auckland sample houses (see Fig. 5). Window design should meet the minimum requirement of day lighting and also avoid the big ratio of window to floor area which can create major heat loss during the winter.

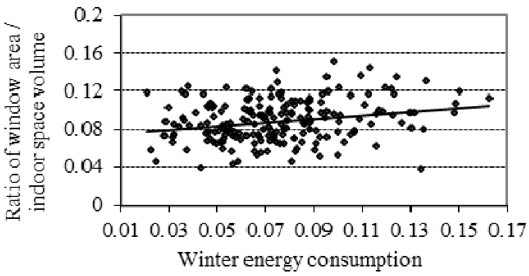

Fig. 4 Winter energy consumption and ratio of window area to indoor space volume

TABLE IV
REDUCTION OF WINTER ENERGY (KWH/M^3/DAY)WITH DECREASING RATIO OF WINDOW AREAS TO INDOOR SPACE VOLUME

Winter Energy	Decreasing	Window/Volume	Decreasing
0.0755	Mean	0.0875	Mean
0.0717	5%	0.0868	0.8%
0.0646	10%	0.0854	2.4%
0.0549	15%	0.0835	4.5%
0.0439	20%	0.0814	6.9%

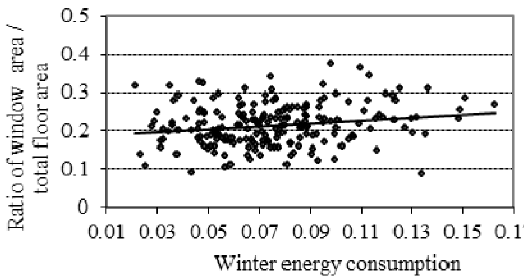

Fig. 5 Winter energy consumption and ratio of window area to floor area

IV. CONCLUSION

According to the draft Auckland Unitary Plan, increasing median or higher density housing such as terrace houses, apartment buildings, etc. in the existing residential areas can change mean building design data such as ratio of building surface to volume, ratios of roof, wall, and window to indoor space volume. Variations of those major building thermal design data can impact housing thermal performance under the local climate and mean housing winter energy consumption. Based on building design data and winter energy consumption data of the 200 Auckland sample houses, variations of those major building thermal design data are associated with the decrease of mean winter energy consumptions. An Auckland house normally uses much more energy than other seasons and winter energy is large portion of annual energy consumption. According to Auckland climate, residential building thermal design should more focus on the winter thermal performance. Decreasing winter energy can significantly reduce annual energy consumption of an Auckland house. The Auckland Unitary Plan can potentially reduce the future mean housing winter energy consumption in the residential areas and positively impact Auckland housing energy efficiency.

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