Investigating the Effect of Urban Compactness on Energy Efficiency in Recent Urban Communities in UAE

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Abstract. Studying the effect of urban compactness on energy consumption has been the locus of research for many Western researchers since the mid 1990s. In the last few years, the UAE federal and local governments have adopted agendas for energy efficiency in all sectors of development, especially in the building and urban development sectors. As a result, a shift from the conventional sprawl urban form to a more compact urban morphology has been attempted in some recently developed neighbourhoods in the UAE but with no scientific evidence about the effect of these new and more compact urban morphologies on energy efficiency in general, and the high cooling energy demand in specific. In a humble attempt to bridge this gap, this research adopted a comparative method for investigating the effect of urban morphology on energy efficiency through comparing the effect of the conventional sprawl vs. the effect of the recent more compact urban forms on operational and cooling energy demands. The main utilized tool in this comparative investigation was the UMI (Urban Modelling Interface) simulation conducted for Al Dhaher conventionally designed neighbourhood in Al Ain city, representing the conventional sprawl urban form, and Al Ghreiba, a recently developed more compact urban community in Al Ain city as well. The results revealed that the average operational and cooling Energy Use Intensities for Al Ghreiba were higher than those recorded Al Dhaher while the opposite was expected. To justify the results, the effects of increased building density, open space/street grid pattern, and building mass configurations on urban energy consumption, have been studied. It has been evident that simply compacting the urban form to some degree seems not only insufficient in saving operational and cooling energy, but it might also result in higher energy consumption if other influential measures are not appropriately considered.

1. Introduction
Sustainable urban morphology is claimed to be one of the most influential pillars of sustainable urbanism. It has been defined as the concept of realizing sustainable city and what it will look like, how it will function, and how it will change over time [1, 2]. Despite the common agreement on that the sustainable urban morphology requires increasing built up area and residential population densities in order to intensify urban economic, social and cultural activities, it has been asserted that there is no single ideal ‘model’ of a sustainable urban form [3,4,5]. This is simply because any sustainable urban morphology is a product that exploits the specific characteristics of an area and respects its local context. Accordingly, studying the effect of urban morphology on energy consumption and efficiency, as an approach for realizing sustainable urban neighbourhoods and cities, has attracted many researchers since the mid-1990s, or even before, especially in the West [6]. On the other hand, compact urban forms have been advocated as the optimal means of reducing energy consumption. A wide spectrum of studies has
concluded that the urban sprawl fabrics in many of existing neighbourhoods encourage car-oriented lifestyles which entail higher energy consumption rates and costs, accompanied by increased pollution levels and negative environmental effects [7]. Therefore, it would be more environmentally and economically sustainable to provide and maintain services like water, sewers, electricity, communications, and other amenities and utilities in more compact neighbourhoods than in dispersed communities [8]. Some recent research works proved that increasing urban density results in significant reduction in energy use. For example, the USA cities with low density of typically 10 persons per hectare or less, usually use about five times more energy per capita in gasoline than the cities of Europe, which are about five times denser on average. Accordingly, it is argued that a compact urbanism with good public transport, walkability, and a reduced need to drive long distances to reach destinations helps reduce energy consumption and thus positively contribute to environmental sustainability [9].

This global concern about studying the effect of urban morphology on energy efficiency has recently found its ground in the MENA (Middle East & North Africa) region by some of the international institutions and aid agencies where the recent study conducted by MED-ENE [10] entitled “Energy Efficiency Urban Planning Guidelines for MENA region” addressed how can neighbourhood’s urban morphology contribute to energy consumption and efficacy. This significant study has summarized the relationship between urban morphology and energy efficiency in three main aspects. First is Massing where the configuration of the building mass, within a specific climatic context, influences indoor and outdoor comfort conditions. Therefore, developing certain building morphologies can reduce the cooling load through, for example, increasing shading and natural ventilation. Second is Outdoor Space and Street Grid. The configuration of the outdoor space and the street grid should support the short distances while the pedestrian networks should provide comfortable access to services and amenities easily without depending on private automobiles. Third is Parcellation, which ensures that the plot fabric is resilient enough to accommodate courtyard and other building form types that enhance natural light and vegetation, with mid-block connections, and central open spaces. Locally in the UAE, buildings consume up to 70-80% of the country’s total electricity generation, with a big portion consumed in meeting the high cooling demand for buildings that reaches 3564 annual Cooling Degree Days (CDD) on average compared with only 31 Heating Degree Days (HDD). The reduction of building/urban energy consumption is now a priority for the UAE federal and local governments. In Dubai, for instance, 25% of the existing building stock has been identified as inefficient according to Dubai Supreme Council of Energy (DSCE) [11]. In response, achieving energy efficiency in all sectors of development, especially in the building and urban development ones has become a national priority in the last few years in the UAE. Several initiatives have been launched recently in the country including, but not exclusive to, Estidama Pearl Rating System for Buildings (PBRS) [12], Estidama Pearl Community Rating System (PCRS) [13], Dubai Green Building Code, Dubai’s Initiative for Creating Sustainable Communities [14], and Abu Dhabi National Housing Guidelines for Integrated Communities: Planning Guideline [15]. As a result, a shift from the widely spread conventional sprawl urban form to a more compact urban morphology has been attempted in some recently developed neighbourhoods in the UAE.

2. Research problem and objective
In all these above-mentioned initiatives it can be easily noticed that the efforts exerted so far to achieve energy efficiency on the building scale are prominent but unfortunately far exceeding those on the urban level. There are also different approaches for designing sustainable urban neighbourhoods that have been attempted recently in the UAE but there is no scientific and reliable evidence about the real effect of these new more compact urban morphologies on energy efficiency, in general, and on cooling energy demand in specific. In its wider scope, this research can also be perceived as a modest contribution to the UAE’s efforts on mitigating GHG emissions and reducing the carbon footprint, as part of the international efforts related to the United Nations Framework Convention on Climate Change [16]. More precisely, the research is focusing on studying the effect of urban morphology of the newly developed single-family housing urban patterns of social housing in UAE, as the most prevailing form.
of urban development, on the energy efficiency of these urban patterns. The ultimate aim is to define the shortcomings associated with the currently adopted urban morphologies. This is hoped to ultimately help develop alternative strategies and urban design/planning guidelines that could achieve better energy efficiency in the public urban housing sector in the UAE. Consequently, the two main objectives of the study can be phrased as follows: first, comparatively studying the effect of urban morphology on energy efficiency in two neighbourhoods, one representing the conventionally designed public housing neighbourhoods in the UAE with mostly a sprawl urban form, and the other representing the new more compact urban form trend in the design of public neighbourhoods. The second objective is to justify the results of this analysis to define the influential urban morphology factors affecting the energy consumption.

3. Research method
The research adopted a comparative analysis method for investigating the effect of the conventional sprawl urban form vs. the effect of the recent more compact urban form on energy efficiency. This comparison was conducted through defining the normalized EUI (Energy Use Intensity) for operational energy consumption, cooling energy demand and embodied energy for 50 years’ time span in two selected case studies. The selection of these case studies came after conducting field surveys for the urban morphology patterns of some of both the conventionally planned public housing neighbourhoods on the one hand, and the recently developed neighbourhoods, especially those associated with declared local sustainability agendas, on the other hand. The survey relied on examining satellite images to help define the status quo of the urban massing and outdoor spaces/street grid patterns, updated maps from the local municipality as well as conducting site visits to update the land use and building forms, types, and heights. Among the several public housing neighbourhoods that have been developed in Al Ain, the city mostly occupied by Emirati citizens, the conventionally designed Al Dhaher public housing neighbourhood was selected to represent the sprawl urban form. Al Dhaher obviously manifests the traits of the sprawl urban form in its planning theme. Additionally, Al Ghreiba neighbourhood in Al Ain city as well has been selected to represent the recently developed more compact urban form because it is the first Emirati housing project designed to achieve the 2nd level (2 pearls) in the Estidama building and community rating systems in Abu Dhabi Emirate [17].

The 2014 developed Urban Modelling Interface (UMI) V.2 tool was utilized for the EUI simulations. UMI is a Rhino-based design environment for modelling the environmental performance of neighbourhoods and cities with respect to operational and embodied energy use [18]. In this research, the UMI simulation tool was used first in identifying the Floor Area Ratio (FAR) for each of the two studied neighbourhoods. FAR represents the degree of physical compactness as it is calculated through dividing the total area of the built-up floors over the total area of the neighbourhood lot itself. Then, the UMI was used to measure both the normalized EUI of the operational, cooling and the embodied energy for each of the two neighbourhoods. The operational energy represents the yearly use of energy for operating the whole buildings in the neighbourhood expressed in kWh/m². The calculation of the operational energy is influenced by the building’s geographical location, physical properties, window-wall ratio (WWR), geometry, used material, orientation, and operating hours (usually determined through the building use). All these measures were customized in the UMI software tool before conducting the energy simulations. Meanwhile, the embodied energy represents all non-renewable fuel consumption which happened through the lifetime of the whole buildings in the studied neighbourhood, expressed in kWh/m² and is measured over 50 years of the buildings’ life time span.

4. Selected case studies

4.1. Al Dhaher neighbourhood: A conventional sprawl urban form
Al Dhaher neighbourhood is an Emirati citizens neighbourhood located to the south east of Al Ain city (figure 1a). It occupies a rectangular shaped lot of about 1230m x 2280m with a gross area of about 285
hectares. Developed in 2002, the neighbourhood has 460 single-family housing plots. The plot area is either a 45m x 60m or 45m x 45m. The neighbourhood has some planned services and amenities including mosques, schools, a clinic and retail shops. The urban form of the neighbourhood was conceptualized as clusters of 10, 12, 14 and 16 housing plots grouped around open common spaces. Meanwhile, the main services and amenities were located on both the longitudinal centre of the neighbourhood and on its outer edges. Despite the fact that the neighbourhood was conventionally developed as a ‘self-contained’ community with the envisaged needed services and amenities locally provided for residents, apparently not all of the planned amenities have been actually provided most likely due to the low population density.

Figure 1. (a) Land use of Al Dhaher neighbourhood. (b) Land use of Al Ghreiba neighbourhood.

4.2. Al Ghreiba neighbourhood: A more compact urban form
Al Ghreiba is an Emirati citizen neighbourhood consisting of 1,022 single-family housing plots on a 155 Hectare site located approximately 10 km west-south of Al Ain city centre (figure 1b). The site is zoned as “Low Density Villa Residential” under the future Plan Al Ain 2030 [19]. In response to the desire for achieving a more compact urban form, the housing plot area has significantly decreased from 45m x 45m and 45m x 60m in Al Dhaher conventionally designed neighbourhood to only 30m x 36m with a ground floor area of 430m2. Besides the residential use, the master plan land uses include a mosque, local and district retail shops, KG + Cycle 1 school, 2 large community parks, pocket parks in a form of small parks considered to be baraha (traditional small open space), linear park, sikka (traditional name for a 2m to 6m wide linear pedestrian access). The neighbourhood centre contains retail, community services and a *Jum'a* prayer mosque. Infrastructure was developed under the surface leaving the ground level as a habitat reserve. There is also a buffer zone in a form of undevelopable land setback for the protection of the community. A waste area was allocated for waste recycling with municipality pick up, as per Estidama requirements.

5. Pre-analysis stage
The first step before undertaking the analysis of the two neighbourhoods was developing digital models for the housing clusters, groupings of housing clusters and the overall neighbourhood, showing the building masses and the open space/street grid of each case study. At the beginning, the two neighbourhoods were modelled in a 2D format on AutoCAD 2018. In this phase, each building type (and height) was assigned a separate layer to ease the analysis and separate layers have been assigned as well to the street network, the neighbourhood parks, and the neighbourhood boundaries. In addition, the footprint of every building in each neighbourhood, that is going to appear later as a solid mass in the Rhinoceros 5 software environment and the UMI Bundle, was represented by a single boundary object (or enclosed polyline) in the AutoCAD environment. In this 2D modelling phase, the shape of the whole neighbourhood lot and the neighbourhood parks were converted into a combination of enclosed
triangular/quadrilateral polylines in order to easily facilitate converting the parks and the neighbourhood land into meshes (surfaces) when developing the 3D model in the Rhinoceros 5 software. More complex neighbourhood and park land shapes were created through the combination of multiple meshes constituting the desired shape. Afterwards, the completed 2D model of each neighbourhood was exported, with its overall appropriately drawn and layered elements including building outlines, street networks, and parks and neighbourhood land boundary, to Rhinoceros 5 software, the tool for developing the 3D format of the two neighbourhoods and thus converting them into the UMI bundle. Within this bundle, a customized building template was assigned to each single service building or house in each of the two analysed neighbourhoods including the building use, floor-to-floor height, material, and window-wall ratio on every side. While the FAR calculation is a straightforward process, the operational, cooling and embodied energy simulations required the definition of the geographical location of the analysed neighbourhood. The weather information file of Al Ain (in epw format) was upload in the UMI bundle for both neighbourhoods. Parameters related to cooling, heating, domestic hot water, air conditioning energy loads, lighting were considered.

6. Analysis of the EUI for operational, cooling and embodied energy

6.1. Al Dhaher neighbourhood
The FAR of Al Dhaher neighbourhood was 0.11. This is apparently a low urban compactness ratio reflecting the low density that results from the adopted sprawl urban form of the neighbourhood. On the other hand, and for the sake of comparison, the EUI were calculated as normalized values measured in kWh/m² for all energy relevant measured parameters including operational, cooling and embodied energy. The yearly operational energy use for all the neighbourhood’s buildings was 153 kWh/m² (figure 2a) and the cooling energy consumption reached about 103 kWh/m². The cooling EUI for only houses reached about 120 kWh/m². On the other hand, the calculated embodied energy, measured for the 50 years’ time span, reached 1426.67 kWh/m² for the whole buildings in the neighbourhood (figure 2b).

(a) (b)
Figure 2. (a) Yearly operational EUI Al Dhaher, (b) Embodied energy for 50 year in Al Dhaher.

6.2. Al Ghreiba neighbourhood
As for Al Ghreiba, the adopted trend towards a more compact urban form resulted in a higher FAR of 0.24. The calculated yearly operational energy use for Al Ghreiba reached about 154 kWh/m² for the whole neighbourhood’s buildings (figure 3a), while the average yearly cooling EUI reached about 113 kWh/m² for all buildings and 121 kWh/m² for the houses only. In addition, the calculated embodied energy, measured for 50 years’ time span, reached about 1351.5 kWh/m² for the whole buildings in the neighbourhood (figure 3b).
6.3. Comparing the conventional sprawl with the more recent compact urban forms

The above results surprisingly revealed that the operational and cooling EUI in Al Dhaher neighbourhood, with its conventionally designed sprawl urban form, was less than those calculated for Al Ghreiba with its more significantly compact urban form where the FAR for Al Ghreiba neighbourhood is almost the double of that of Al Dhaher. The cooling energy demand for houses was noticeably higher in Al Ghreiba (113 kWh/m²) than of it in Al Dhaher (103 kWh/m²) while the opposite was expected. This applies also to the results of the cooling energy use for the whole buildings. The operational EUI showed the same tendency. Table 1 summarizes this comparison between the two neighbourhoods. These results explicitly indicate that the degree of compactness of the recent ‘claimed-to-be’ sustainable neighbourhoods has not been sufficient in lowering the operational, the cooling or the embodied energy consumption despite adopting more compact urban form with much higher FAR. Therefore, it could be claimed that simply compacting what used to be a sprawl urban form to some degree seems not only insufficient in saving cooling energy, but it might also result in higher energy consumption. In an attempt to justify these results and to define the urban morphology measures that influentially affect EUIs, the effect of urban space/street grid pattern and the building mass geometry were investigated in the following Section.

| Neighbourhood | FAR   | Total Operational Energy/m² [kWh/m²] | Cooling Energy/m² [kWh/m²] | Embodied Energy/m² for 50 Years [kWh/m²] |
|---------------|-------|-----------------------------------|---------------------------|----------------------------------------|
|               |       | Avg.: 153 Housing: ≈ 157           | Avg.: 103 Housing: ≈ 120  | Avg.: 1426.67 Housing: ≈ 1527.67       |
| Al Dhaher     | 0.11  | 88-261                            | 31-173                    | 1025-2051                              |
|               |       | Avg.: 153 Housing: ≈ 157           | Avg.: 103 Housing: ≈ 120  | Avg.: 1426.67 Housing: ≈ 1527.67       |
| Al Ghreiba    | 0.24  | 98-229                            | 41-161                    | 1045-1712                              |
|               |       | Avg.: 154 Housing: ≈ 158           | Avg.: 113 Housing: ≈ 121  | Avg.: 1351.5 Housing: ≈ 1390.74        |

7. Factors affecting EUIs in the two studied neighbourhoods

7.1. Investigating the effect of the urban space/street grid pattern

In order to evaluate the effect of the configuration of the urban space/street grid on the EUI, the two neighbourhoods were reanalysed after unifying the configuration of the houses’ masses to eliminate their possible effect on energy performance. Masses for the houses in both cases were converted to simplified foursquare shaped forms with a Build Out Area equals the maximum allowable size for house mass on the house plot, i.e. the ground floor built-up area after leaving the setbacks of 6m in the front, 4m in the back and 3m from each side, as per the applied building regulation in Al Ain city. Thus, the only variable affecting measured energy use would be the urban space/street grid. The rerun of the UMI simulation showed a significant increase in FAR and a drop in the operational and cooling EUIs in both cases. For Al Dhaher conventionally designed sprawl neighbourhood, the average yearly operational
EUI dropped to about 77 kWh/m² for the whole buildings in the neighbourhood and to 74 kWh/m² for the houses. Meanwhile, the cooling EUI dropped to an average of 38 kWh/m² for the whole buildings in the neighbourhood and to 37 kWh/m² for the houses (figure 4 and table 2).

For Al Ghreiba recently developed more compact urban form, the average yearly operational EUI dropped to about 95 kWh/m² for the whole buildings in the neighbourhood and to about 92 kWh/m² for the houses. As for the cooling EUI, it dropped to an average of 56 kWh/m² for both the whole buildings and the houses in the neighbourhood (figure 5 and table 2). These figures indicate that Al Ghreiba urban compact case is still achieving higher EUI than Al Dhaher conventional case. The main outcome of this simulation is that there are three important factors that significantly affect the EUI in urban neighbourhoods. First, is the Build-Out Area which is defined as the development of the housing plot to its full potential or theoretical capacity as permitted under current planning or zoning designations [20]. In the simulation, building on the total housing plot area after leaving setbacks has led to a significant increase in the urban form compactness represented in the FAR that increased from 0.11 to 0.53 in Al Dhaher, and from 0.24 to 0.51 in Al Ghreiba. This was associated with remarkable reductions in the operational and cooling energy use for the whole buildings. The cooling EUI in Al Dhaher significantly decreased from 103 kWh/m² to 38 kWh/m² and form 111 kWh/m² to 56 kWh/m² for Al Ghreiba. Normally, when the built-up area increases, the chance for buildings mutually cast shades on one another increases causing less energy demand for cooling.

Table 2. Compared EUI results for the neighbourhoods after unifying the houses configuration.

| Neighbourhood | FAR | Total Operational Energy/m² [kWh/m²] | Cooling Energy/m² [kWh/m²] | Embodied Energy/m² for 50 Years [kWh/m²] |
|---------------|-----|-------------------------------------|-----------------------------|------------------------------------------|
| Al Dhaher     | 0.53 | 71-262                              | 29-161                      | 1025-1719                                |
|               | Avg.: 77 | Housing: ≈ 74                  | Avg.: 38                   | Avg.: 1210.24                           |
|               | Housing: ≈ 92 |                      | Housing: ≈ 37              | Housing: ≈ 1214.72                      |
| Al Ghreiba    | 0.51 | 90-216                              | 39-148                      | 1045-1712                                |
|               | Avg.: 95 | Housing: ≈ 92                  | Avg.: 56                   | Avg.: 1257.26                           |
|               | Housing: ≈ 92 |                      | Housing: ≈ 56              | Housing: ≈ 1259.3                        |
Second, the shorter the block length, the more EUI would be in the neighbourhood. In Al Ghreiba, housing blocks are composed of juxtaposed 2, 3, 4, or 5 housing plots of total lengths ranges between 60m, 90m, 120m, and 150m. Meanwhile, in Al Dhaher housing blocks are mostly composed of juxtaposed 4, 5, or 6 housing plots of total lengths range between 180m, 225m, and 270m. The linear spaces between the housing blocks (pedestrian pathway, street, etc.), decrease the chance for mutual shading of housing masses. Third, it seems that the curvilinear urban space/street grid form, as noticed in Al Ghreiba neighbourhood, results in more EUI plausibly due to the more buildings/houses exposure to sun rays. This increased exposure results from the winder space shapes of the plots and the vacant ‘triangles’ spaces left with no apparent use (figure 9). These unidentified land shapes, especially by the end of the housing blocks, reduce the impact of compactness and make several housing masses unshaded. Therefore, it might be claimed here that the orthogonal grid of the streets of Al Dhaher, along with the longer block length, have resulted in better EUIs.

7.2. Investigating the effect of the building mass geometry
As for clarifying the effect of the building mass geometry on the EUIs, a rerun of the UMI simulation was done for two cases in Al Ghreiba after eliminating the effect of the change in the street pattern. While using the same original urban space/street grid of the neighbourhood, two shapes of building mass geometries were compared; the original one and a simplified foursquare shape but both with exactly the same built-up area and the same height (figure 6). The comparative UMI simulation for these two cases of Al Ghreiba neighbourhood showed that the building mass morphology has an effect on the EUIs (figure 8). In the simplified form case, the calculated yearly average operational EUI for the whole buildings reached about 126 kWh/m² (figure 7a) and the yearly average cooling EUI reached about 85 kWh/m² for the whole buildings in the neighbourhood and about 88 kWh/m² for houses, compared with 154 kWh/m², 113 kWh/m² and 121 kWh/m² respectively for the original building mass morphology case. On the other hand, the calculated embodied energy for 50 years dropped from about 1351.5 kWh/m² for the original case to 1300.48 kWh/m² for the simplified building mass morphology case (figure 7b). Table 3 summarizes these results.

Figure 6. Al Ghreiba; comparing between two shapes of building geometry; the original one (right) and a simplified foursquare shape (left).

Figure 7. Simplified building mass morphology; (a) Al Ghreiba operational energy use, (b) Al Ghreiba embodied energy for 50 years.
This simulation has proved that the more simplified the shape of a building/house mass is, the less energy use it would need. This is apparently due to the fact that the simplified building shape would have less outer perimeter (in case of same built-up area) and therefore would have less exposure to the outside environment and the direct sun rays it would receive.

8. Conclusions
In accordance with the recent tendency in UAE to achieve more sustainable urban forms in urban neighbourhoods, a shift has been witnessed from the conventional urban sprawl design paradigm to a more compact urban form but without sufficient evidence on the resulting EUIs. Two case studies were selected for investigation, one represented the conventional urban sprawl design and the other represented the more recent compact design. Both cases were prepared for simulation utilizing the UMI software to reveal the effect of their sprawl vs. compact urban forms on the EUIs. Surprisingly the results of the research investigations indicated less EUIs in the sprawl urban form case than in the conventional urban form one. This proves that having more compaction is not enough for decreasing the EUIs, and even in some cases it might lead to higher EUIs. Studying the factors that might affect the EUI in both neighbourhoods revealed four measures that seem to help achieve higher energy efficiency in the urban forms of the neighbourhoods in UAE. First is the ‘Build-Out Area’ where building on the total plot area after leaving setbacks led to significant increase in the urban form compactness causing remarkable reductions in the operational and cooling EUIs for the whole buildings. Second, the longer block length is doing better in terms of energy use performance. Third, the orthogonal grid of the streets and urban spaces is better than curvilinear spaces in reducing EUIs. This might be referred to that it avoids the winder shapes of the plots and the urban spaces that usually reduce the impact of compactness thus reducing mutual shading and increasing exposure to ambient harsh weather conditions. Finally, the simplified building mass geometry results in less EUIs apparently because it has less outer perimeter and thus less exposure to the outside environmental conditions. Finally, it should be noted that the research did not take into account the energy consumed in car movement in both neighbourhoods which might affect the urban form related energy consumption. Further and more elaborated research would ultimately help depict a roadmap for the appropriate urban forms and morphologies that cater for realizing sustainable urban communities in UAE and other MENA region countries. It is recommended also to continue testing new urban morphologies for not only the single-family housing typology but to extend it further to housing apartment blocks that have been developed very recently in some of the UAE cities to accommodate social housing for the first time.

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Table 3. Compared EUIs results between original and simplified building morphology for Al Ghreiba.

| Neighbourhood | FAR | Total Operational Energy/m² [kWh/m²] | Cooling Energy/m² [kWh/m²] | Embodied Energy/m² for 50 Years [kWh/m²] |
|---------------|-----|--------------------------------------|-----------------------------|-----------------------------------------|
| Al Ghreiba (Original form buildings) | 0.24 | 98-229 | 41-161 | 1045-1712 |
| | | Avg.: 154 | Avg.: 113 | Avg.: 1351.5 |
| | | Housing: 153-162 | Housing: 117-125 | Housing: ≈ 1390.74 |
| | | Avg.: 158 | Avg.: 121 | |
| Al Ghreiba (Simplified form buildings w/same built-up area & height) | 0.25 | 98-229 | 41-161 | 1045-1712 |
| | | Avg.: 126 | Avg.: 85 | Avg.: 1300.48 |
| | | Housing: 121-132 | Housing: 84-95 | Housing: ≈ 1310.27 |
| | | Avg.: 125 | Avg.: 88 | |
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