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# LCA OF A MASS HOUSING AREA FROM AN ENERGY BASED ECONOMY PERSPECTIVE

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**Abstract**

As a technique that covers a system or environment from cradle-to-grave, Life-Cycle Assessment (LCA) assesses an environment-economy associated evaluation considering all the stages of a product's life. Buildings and settlement zones are known to be major energy consumption areas that lead to emission of significant amounts of greenhouse gases and to economic losses. In this study, the efficiency analysis of the YYÜ TOKİ Lodgments is conducted through the energy based economic LCA analysis. A comprehensive energy analysis is made to evaluate the economic LCA of the energy system in this settlement area, utilizing year-long temperature measurements for outside and indoors. The results of the study indicate a large potential of economic benefit conservation for the case area despite the fact that energy performances of sample site are relatively high compared to the current building stock averages of Turkey.

**Keywords:** Energy Efficiency, Life Cycle Assessment, Economy

**Jel Codes:** O18, O21, P18

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## Introduction

The global climate change taking place in our century implies a strong connection between environmental problems -like the shortage of non-renewable energy sources and global warming- and the environment itself. When the relationship between a residential area and energy is inspected closely, it is evident that the climactic properties of the residence directly affect the energy efficiency (Giovagnoria, 2011). From regional to local scales, all spatial solutions influence the energy consumption of the settlements (Owens 1986). There are many studies inspecting what kind of effects a settlement's properties might have over its energy consumption. One of the purposes of this study is to bring together the variables of this direct relationship and to quantify and qualify their scopes, and to prepare a guide to help reach optimum settlement plans in that regard.

Global climate change represents the negative effects of the poisonous gasses ($H_2O$(b), $CO_2$, $CH_4$, $O_3$, $N_2O$, CFC–11, HFC, PFC, $SF_6$) released to the atmosphere as a result of burning of fossil fuels. This, in turn, causes the greenhouse effect, resulting in the temperature increase and adverse effects over the climate. In order to solve these problems and to find spatial and design solutions, integration of renewable energy sources in the buildings, and in a larger scope, in all urban venues, has become imperative. In that regard, it is important to prepare an environment that considers the local climate –from the scope of sustainable structures to city blocks- and the renewable energy sources, supports a cleaner mass transit system, and has an accessible environment for all users, including handicapped individuals. Planning for energy-integrated venues that utilize renewable energy sources with an efficient spatial organization results in an urban macroform, and has become inevitable for solution of urban and environmental problems. Researchers conducted in Turkey indicate that when solar power is utilized in urban planning models that are focused on renewable energy, it may yield to a staggering 30-40% efficiency increase (Göksu, 1995).

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Some researches claim that energy consumption in the last 20 years was 57% more than the expected value (Koç and Senel, 2013). These figures are a clear display that energy requirements of our civilization are rapidly increasing. The non-renewable energy sources are estimated deplete in a near future. Meanwhile, our country is dependent on other countries in terms of energy sources, and imports for approximately 70% of its energy demand (Bayraç, 2010). 90% of this energy income is generated through consumption of fossil fuels. As is well known, consumption of fossil fuels causes emission of harmful materials, which pollute the soil, water and air, and degrade human health.

Life cycle analysis is an approach where a product or a process system is evaluated in terms of utilization of natural resources, and identification of emissions caused, for all the stages related to it, including the stages of obtainment of the raw materials, production, utilization, and disposal (Figures 1 and 2). For these reasons, it is also considered an essential tool that will enable sustainable growth ( Demirer 2011.).

Life cycle analysis consists of 4 stages;

1. Purpose and Scope: The purpose, scope and the limits of the analysis are defined.
2. Inventor Analysis: The utilization of energy, water, and raw materials related to the inspected product or system will be identified, along with the resulting environmental emissions.
3. Impact Analysis: The effects of utilization of the energy, water and raw materials, and the emissions identified in the inventor analysis stage, are evaluated in terms of their potential effects on the human health.
4. Evaluation: The findings of inventor and impact analysis stages are evaluated and appropriate processes or products are chosen. The evaluations and uncertainties made during the choice are chosen by the life cycle analysis (USEPA 2006, Demirer 2011).

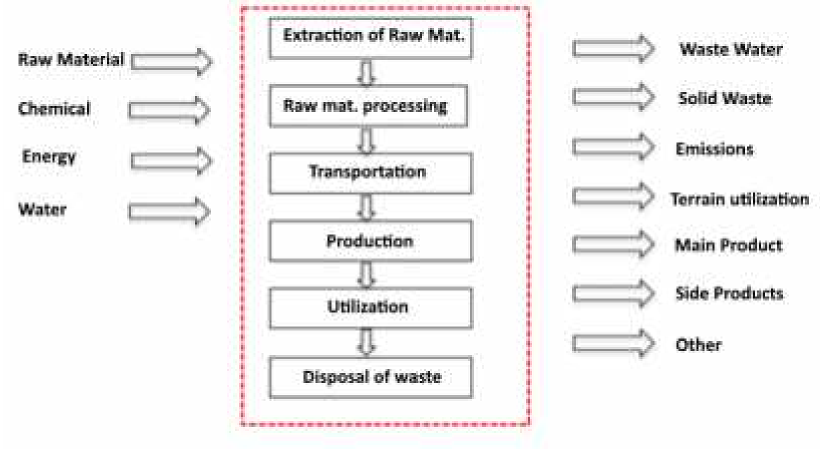


**Figure 1.** LCA Stages (Mammadov and Cılız 2017)

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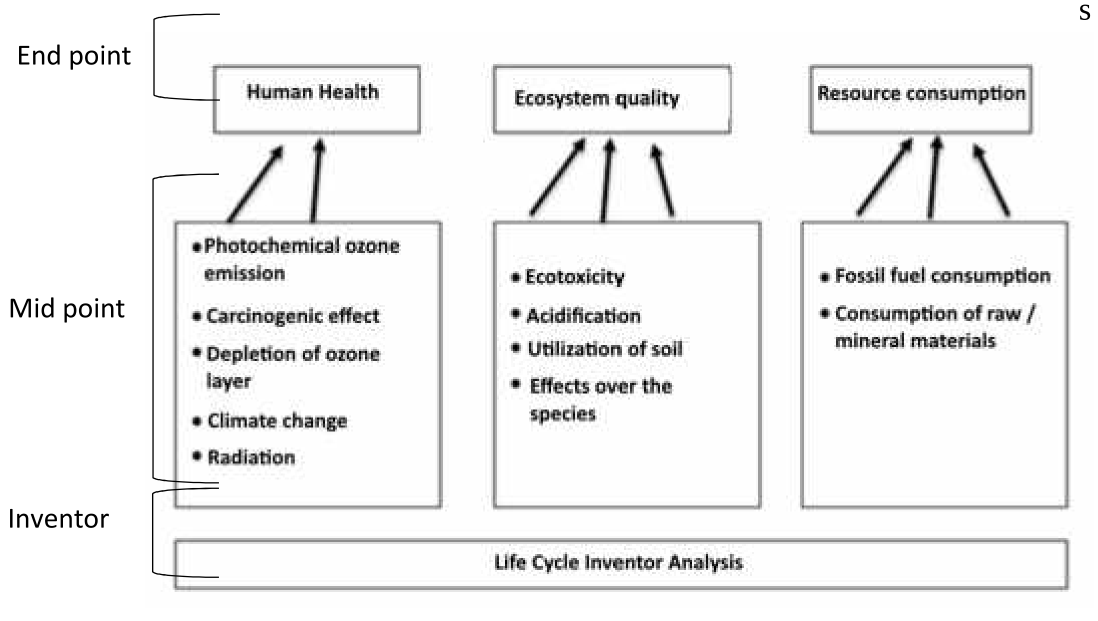


**Figure 2.** Mid-point end-point relationship in LCA impact analysis (Mammadov ve Cılız 2017)

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**Case Area**

The city of Van is located 38029′39″ North latitude 43022′48″ longitude, which places it into the Eastern Anatolia of Turkey. It is neighboured by Iran in the east, and the cities of Hakkari in the south, Bitlis in west and Ağrı in north. The city has a surface area of 19.069 $km^2$, and spans about 21.823 $km^2$ together with the Van Lake (Van İli Gelişme Raporu 2002). The winters are cold, and the summers are relatively cool in the city, which is under the influence of terrestrial climate. The city centre has a population of 427.069, and a total population of 1.100.190, according to the civil records of 2016 (TUIK, 2017).

When the solar path of the city of Van is inspected as given in Figure, the green curve towards the upper part of the graph represents the path sun followed in $21^{st}$ of June in the east-west orientation. The blue curve towards to bottom of the graph represents the path taken by the sun in the $21^{st}$ of December. The lowest solar angle in a given year is $28^o$, while the highest angle is $71^o$.

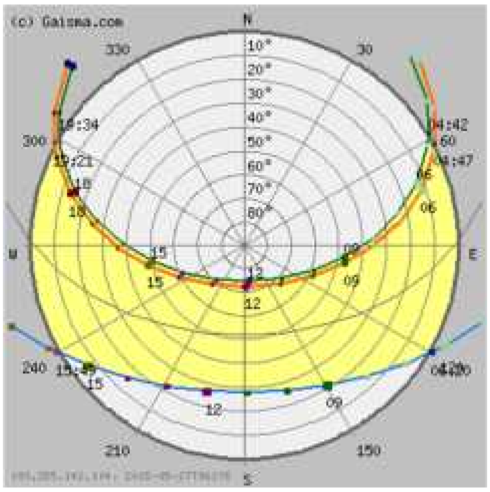


**Figure 3:** Solar path diagram for the city of Van (Gaisma, http://www.gaisma.com/en/location/van.html, access date 27.05.2015)

After earthquakes that took place in the city in 2012, a total of 496 residences in the form of 31 blocks were constructed by TOKI (Mass Housing Administration) in the Zeve Campus of the Yuzuncu Yil University (Figure 4 and Figure 5). 25 of these blocks are of K2 type (consisting of 3 rooms and a kitchen) while 6 are of type E (2 rooms and a kitchen). K2 type residences (Figure 6) are the samples inspected in the scope of this study.

The apartments have 4 flats in a floor and have 4 floors each.


**Figure 4.** Van Yüzüncü Yıl University TOKI Lodgments Layout Sheet (Van Yüzüncü Yıl University General Directorate of Construction).

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**Figure 5:** Van Yüzüncü Yıl University TOKI Lodgments top view (June 2017) (Taken by a drone cam).

**Figure 6:** TOKI K2 Type Normal Floor Plan (Van Yüzüncü Yıl University General Directorate of Construction).

## LCA Analysis

A life cycle analysis was conducted for this study on the selected TOKI lodgment residences considering their energy aspects. The energy used to heat the buildings and the costs for this heating were evaluated, and the fuel supply and greenhouse gas emissions were considered as waste.

In the inventor analysis, the natural gas consumed in the residences for heating and the isolation costs were evaluated. Table 1 represents the natural gas consumption, while Table 2 represents the isolation costs. The heating system used in the Lodgement apartments can be seen in Figure 7.

**Table 1.** Natural gas consumption amounts in the apartments of the study area (Van YYU Rectorate, Department for Administrative and Financial Affairs, 2017)

| Apartment / $m^3$ Natural Gas | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10-11 | 11-12 | 12-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **E1-01** | 10,35 | 5,84 | 5,58 | 3,10 | 0,00 | 0,00 | 0,00 | 0,00 | 2,79 | 4,33 | 7,21 | 8,65 |
| **E1-02** | 8,59 | 6,23 | 7,20 | 3,41 | 0,00 | 0,00 | 0,00 | 0,00 | 2,28 | 3,94 | 6,57 | 7,89 |
| **E1-03** | 8,30 | 5,54 | 4,96 | 2,45 | 0,00 | 0,00 | 0,00 | 0,00 | 2,65 | 3,96 | 6,59 | 7,91 |
| **E1-04** | 9,87 | 7,33 | 6,39 | 3,96 | 0,00 | 0,00 | 0,00 | 0,00 | 3,02 | 5,21 | 8,69 | 10,42 |
| **E1-05** | 9,58 | 7,18 | 6,64 | 3,04 | 0,00 | 0,00 | 0,00 | 0,00 | 2,75 | 5,01 | 8,34 | 10,01 |
| **E1-06** | 9,07 | 6,26 | 5,91 | 3,02 | 0,00 | 0,00 | 0,00 | 0,00 | 2,22 | 4,39 | 7,31 | 8,78 |
| **K2-01** | 11,58 | 7,37 | 6,69 | 3,25 | 0,00 | 0,00 | 0,00 | 0,00 | 2,96 | 5,31 | 8,86 | 10,63 |
| **K2-02** | 12,59 | 7,70 | 7,57 | 3,69 | 0,00 | 0,00 | 0,00 | 0,00 | 3,68 | 6,63 | 11,06 | 13,27 |
| **K2-03** | 14,64 | 7,34 | 6,28 | 3,91 | 0,00 | 0,00 | 0,00 | 0,00 | 3,14 | 5,84 | 9,73 | 11,67 |
| **K2-04** | 13,67 | 8,61 | 8,12 | 4,52 | 0,00 | 0,00 | 0,00 | 0,00 | 3,26 | 6,32 | 10,53 | 12,64 |
| **K2-05** | 13,07 | 9,27 | 8,45 | 4,77 | 0,00 | 0,00 | 0,00 | 0,00 | 3,48 | 5,67 | 9,46 | 11,35 |
| **K2-06** | 11,96 | 8,01 | 7,71 | 3,65 | 0,00 | 0,00 | 0,00 | 0,00 | 3,13 | 6,48 | 10,81 | 12,97 |
| **K2-07** | 13,35 | 9,96 | 8,17 | 3,52 | 0,00 | 0,00 | 0,00 | 0,00 | 3,59 | 5,97 | 9,95 | 11,94 |
| **K2-08** | 13,59 | 10,17 | 10,02 | 5,34 | 0,00 | 0,00 | 0,00 | 0,00 | 5,48 | 7,04 | 11,74 | 14,09 |
| **K2-09** | 11,33 | 7,75 | 7,17 | 3,31 | 0,00 | 0,00 | 0,00 | 0,00 | 4,20 | 7,77 | 12,95 | 15,54 |
| **K2-10** | 11,65 | 7,64 | 7,17 | 3,20 | 0,00 | 0,00 | 0,00 | 0,00 | 3,30 | 5,82 | 9,70 | 11,64 |
| **K2-11** | 12,98 | 8,14 | 8,30 | 4,86 | 0,00 | 0,00 | 0,00 | 0,00 | 4,95 | 6,32 | 10,54 | 12,65 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K2-12** | 11,42 | 8,43 | 7,34 | 4,09 | 0,00 | 0,00 | 0,00 | 0,00 | 3,02 | 5,04 | 8,39 | 10,07 |
| **K2-13** | 12,25 | 7,84 | 7,48 | 4,37 | 0,00 | 0,00 | 0,00 | 0,00 | 3,43 | 5,84 | 9,74 | 11,69 |
| **K2-14** | 11,98 | 8,06 | 8,80 | 4,01 | 0,00 | 0,00 | 0,00 | 0,00 | 3,30 | 6,01 | 10,02 | 12,02 |
| **K2-15** | 13,22 | 7,58 | 7,41 | 3,72 | 0,00 | 0,00 | 0,00 | 0,00 | 4,42 | 5,92 | 9,86 | 11,83 |
| **K2-16** | 11,31 | 8,14 | 8,31 | 5,66 | 0,00 | 0,00 | 0,00 | 0,00 | 3,25 | 5,85 | 9,75 | 11,70 |
| **K2-17** | 11,99 | 8,36 | 8,85 | 4,78 | 0,00 | 0,00 | 0,00 | 0,00 | 4,25 | 6,21 | 10,36 | 12,43 |
| **K2-18** | 15,56 | 7,67 | 7,66 | 3,90 | 0,00 | 0,00 | 0,00 | 0,00 | 5,53 | 6,90 | 11,50 | 13,80 |
| **K2-19** | 11,59 | 7,40 | 6,63 | 3,06 | 0,00 | 0,00 | 0,00 | 0,00 | 2,58 | 5,32 | 8,87 | 10,64 |
| **K2-20** | 13,67 | 8,51 | 7,23 | 4,15 | 0,00 | 0,00 | 0,00 | 0,00 | 3,43 | 6,76 | 11,26 | 13,51 |
| **K2-21** | 14,04 | 7,20 | 6,82 | 3,19 | 0,00 | 0,00 | 0,00 | 0,00 | 3,69 | 6,85 | 11,42 | 13,70 |
| **K2-22** | 14,01 | 11,35 | 9,23 | 4,34 | 0,00 | 0,00 | 0,00 | 0,00 | 3,79 | 7,42 | 12,36 | 14,83 |
| **K2-23** | 11,24 | 7,88 | 6,93 | 3,78 | 0,00 | 0,00 | 0,00 | 0,00 | 4,20 | 5,38 | 8,97 | 10,76 |
| **K2-24** | 14,31 | 9,60 | 8,27 | 2,97 | 0,00 | 0,00 | 0,00 | 0,00 | 4,12 | 6,87 | 11,45 | 13,75 |
| **K2-25** | 14,59 | 9,90 | 9,24 | 5,09 | 0,00 | 0,00 | 0,00 | 0,00 | 3,70 | 6,42 | 10,70 | 12,84 |

The consumed natural gas amounts obtained from Van YYU Rectorship, Department for Administrative and Financial Affairs is given in Table 1.

**Table 2. Structure facade materials and their thermal performance properties**

| **Material** | **Thickness** | **K** (W/mK) |
|---|---|---|
| XPS | 5 cm | 0.045 W/mK |
| BIMS | 20 cm | 0.150 W/mK |
| Inner Coating | 2 mm | 0.700 W/mK |
| Outer Coating | 2 mm | 1.000 W/mK |

***Impact Analysis***

As part of the impact analysis part of the energy based life cycle analysis, the energy-exergy and exergy efficiency, and the greenhouse emission rates, were calculated. Table 3 displays the greenhouse emission rates as a result of fuel consumption.

**Figure 7:** The natural gas heating system used in the lodgment apartments

**Table 3. Calculated monthly greenhouse gas emissions for the flats**

| Device No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 17,5 | 11,9 | 11,1 | 6,1 | 0,0 | 0,0 | 0,0 | 0,0 | 4,4 | 7,7 | 12,8 | 15,4 | Greenhouse gas emission ($m^3$) |
| 1 | 13,9 | 8,8 | 8,0 | 3,9 | 0,0 | 0,0 | 0,0 | 0,0 | 3,6 | 6,4 | 10,6 | 12,8 | |
| 4 | 16,4 | 10,3 | 9,7 | 5,4 | 0,0 | 0,0 | 0,0 | 0,0 | 3,9 | 7,6 | 12,6 | 15,2 | |
| 7 | 14,3 | 9,6 | 9,2 | 4,4 | 0,0 | 0,0 | 0,0 | 0,0 | 3,8 | 7,8 | 13,0 | 15,6 | |
| 9 | 14,3 | 9,6 | 9,2 | 4,4 | 0,0 | 0,0 | 0,0 | 0,0 | 3,8 | 7,8 | 13,0 | 15,6 | |
| 10 | 16,3 | 12,2 | 12,0 | 6,4 | 0,0 | 0,0 | 0,0 | 0,0 | 6,6 | 8,5 | 14,1 | 16,9 | |
| 11 | 16,3 | 12,2 | 12,0 | 6,4 | 0,0 | 0,0 | 0,0 | 0,0 | 6,6 | 8,5 | 14,1 | 16,9 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 13,6 | 9,3 | 8,6 | 4,0 | 0,0 | 0,0 | 0,0 | 0,0 | 5,0 | 9,3 | 15,5 | 18,6 | |
| 13 | 14,0 | 9,2 | 8,6 | 3,8 | 0,0 | 0,0 | 0,0 | 0,0 | 4,0 | 7,0 | 11,6 | 14,0 | |
| 2 | 15,6 | 9,8 | 10,0 | 5,8 | 0,0 | 0,0 | 0,0 | 0,0 | 5,9 | 7,6 | 12,6 | 15,2 | |
| 21 | 15,6 | 9,8 | 10,0 | 5,8 | 0,0 | 0,0 | 0,0 | 0,0 | 5,9 | 7,6 | 12,6 | 15,2 | |
| 36 | 14,7 | 9,4 | 9,0 | 5,2 | 0,0 | 0,0 | 0,0 | 0,0 | 4,1 | 7,0 | 11,7 | 14,0 | |
| 39 | 14,7 | 9,4 | 9,0 | 5,2 | 0,0 | 0,0 | 0,0 | 0,0 | 4,1 | 7,0 | 11,7 | 14,0 | |
| 16 | 14,4 | 9,7 | 10,6 | 4,8 | 0,0 | 0,0 | 0,0 | 0,0 | 4,0 | 7,2 | 12,0 | 14,4 | |
| 19 | 15,9 | 9,1 | 8,9 | 4,5 | 0,0 | 0,0 | 0,0 | 0,0 | 5,3 | 7,1 | 11,8 | 14,2 | |
| 22 | 14,4 | 10,0 | 10,6 | 5,7 | 0,0 | 0,0 | 0,0 | 0,0 | 5,1 | 7,5 | 12,4 | 14,9 | |
| 24 | 18,7 | 9,2 | 9,2 | 4,7 | 0,0 | 0,0 | 0,0 | 0,0 | 6,6 | 8,3 | 13,8 | 16,6 | |
| 25 | 18,7 | 9,2 | 9,2 | 4,7 | 0,0 | 0,0 | 0,0 | 0,0 | 6,6 | 8,3 | 13,8 | 16,6 | |
| 27 | 13,9 | 8,9 | 8,0 | 3,7 | 0,0 | 0,0 | 0,0 | 0,0 | 3,1 | 6,4 | 10,6 | 12,8 | |
| 29 | 13,9 | 8,9 | 8,0 | 3,7 | 0,0 | 0,0 | 0,0 | 0,0 | 3,1 | 6,4 | 10,6 | 12,8 | |
| 31 | 13,9 | 8,9 | 8,0 | 3,7 | 0,0 | 0,0 | 0,0 | 0,0 | 3,1 | 6,4 | 10,6 | 12,8 | |
| 33 | 13,9 | 8,9 | 8,0 | 3,7 | 0,0 | 0,0 | 0,0 | 0,0 | 3,1 | 6,4 | 10,6 | 12,8 | |
| 37 | 13,9 | 8,9 | 8,0 | 3,7 | 0,0 | 0,0 | 0,0 | 0,0 | 3,1 | 6,4 | 10,6 | 12,8 | |
| 34 | 16,4 | 10,2 | 8,7 | 5,0 | 0,0 | 0,0 | 0,0 | 0,0 | 4,1 | 8,1 | 13,5 | 16,2 | |
| 14 | 16,8 | 13,6 | 11,1 | 5,2 | 0,0 | 0,0 | 0,0 | 0,0 | 4,5 | 8,9 | 14,8 | 17,8 | |
| 40 | 17,5 | 11,9 | 11,1 | 6,1 | 0,0 | 0,0 | 0,0 | 0,0 | 4,4 | 7,7 | 12,8 | 15,4 | |

Exergy efficiency values for each month were calculated for each of the residences, using the study values, and using the suggested method by Mert (2014). The monthly heat loss for each residence was calculated first, and the results can be seen in Table 4. As can be seen, heat loss increases in the winter months due to increased inner temperature. Even though the coating system reduces the coefficient of the heat transfer, the high amount of heat difference still indicates significant heat loss.

## Table 4. Monthly Heat Loss for each of the Residences

| **Device No** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | -481,6 | -415,4 | -380,9 | -280,3 | -181,6 | -88,7 | -46,0 | -45,9 | -108,1 | -205,4 | -357,9 | -482,4 | Heat Loss W / per one day per residence |
| 1 | -499,2 | -425,9 | -359,1 | -250,5 | -162,8 | -71,1 | -35,6 | -27,1 | -82,4 | -208,8 | -361,6 | -476,1 | |
| 4 | -523,3 | -426,6 | -373,1 | -267,8 | -168,1 | -48,2 | -30,3 | -34,6 | -129,4 | -243,8 | -381,6 | -485,9 | |
| 7 | -508,6 | -450,4 | -366,4 | -263,9 | -158,4 | -65,5 | -47,4 | -55,1 | -129,8 | -238,4 | -377,3 | -489,1 | |
| 9 | -448,8 | -410,2 | -375,2 | -272,1 | -175,6 | -87,3 | -64,9 | -58,3 | -140,2 | -234,2 | -349,9 | -452,1 | |
| 10 | -503,2 | -419,4 | -384,9 | -281,9 | -177,7 | -92,2 | -56,0 | -69,2 | -149,7 | -255,6 | -393,3 | -501,4 | |
| 11 | -500,9 | -418,0 | -373,5 | -267,4 | -163,3 | -72,4 | -36,2 | -33,9 | -103,8 | -217,7 | -369,0 | -466,1 | |
| 12 | -493,5 | -427,1 | -377,4 | -262,0 | -166,6 | -74,0 | -45,7 | -46,0 | -110,4 | -211,9 | -356,8 | -472,1 | |
| 13 | -454,0 | -413,9 | -371,9 | -255,9 | -164,7 | -88,4 | -64,8 | -73,5 | -146,5 | -231,0 | -352,8 | -463,1 | |
| 2 | -463,7 | -402,1 | -355,2 | -256,7 | -173,7 | -71,3 | -36,2 | -31,3 | -93,5 | -207,7 | -354,3 | -446,4 | |
| 21 | -476,1 | -423,8 | -378,0 | -281,8 | -199,9 | -100,1 | -64,1 | -59,1 | -131,6 | -245,2 | -384,6 | -495,7 | |
| 36 | -446,0 | -370,7 | -323,4 | -229,1 | -167,0 | -85,3 | -78,4 | -61,1 | -113,0 | -203,7 | -319,6 | -432,8 | |
| 39 | -500,9 | -396,9 | -358,3 | -256,9 | -155,0 | -60,4 | -39,4 | -21,5 | -98,3 | -149,3 | -288,7 | -460,5 | |
| 16 | -476,0 | -422,8 | -364,7 | -261,5 | -170,5 | -83,5 | -61,5 | -73,2 | -149,7 | -242,3 | -381,6 | -479,9 | |
| 19 | -501,9 | -424,6 | -371,2 | -262,4 | -172,3 | -85,2 | -65,6 | -76,0 | -146,5 | -247,2 | -373,3 | -493,2 | |
| 22 | -507,3 | -435,0 | -379,6 | -276,5 | -184,2 | -67,0 | -43,6 | -53,5 | -118,5 | -218,1 | -361,1 | -502,6 | |
| 24 | -446,4 | -405,2 | -351,0 | -255,5 | -164,8 | -74,8 | -57,3 | -62,0 | -139,1 | -188,6 | -358,3 | -470,0 | |
| 25 | -481,7 | -401,9 | -345,7 | -253,6 | -164,4 | -75,0 | -62,9 | -70,5 | -141,3 | -195,4 | -353,2 | -462,1 | |
| 27 | -491,5 | -394,1 | -347,6 | -239,3 | -156,5 | -82,4 | -50,6 | -40,9 | -119,4 | -219,3 | -359,9 | -475,0 | |
| 29 | -490,6 | -395,5 | -344,2 | -249,3 | -173,3 | -100,2 | -66,0 | -55,4 | -119,9 | -221,3 | -362,4 | -480,1 | |
| 31 | -491,7 | -393,1 | -323,6 | -213,3 | -133,2 | -51,1 | -22,6 | -18,5 | -91,5 | -196,0 | -340,2 | -464,0 | |
| 33 | -492,8 | -391,0 | -351,7 | -251,2 | -162,1 | -89,1 | -66,0 | -60,6 | -117,9 | -204,8 | -348,5 | -472,0 | |
| 37 | -497,3 | -414,1 | -357,2 | -258,6 | -180,7 | -104,7 | -62,6 | -52,5 | -120,1 | -230,1 | -376,4 | -489,8 | |
| 34 | -476,0 | -410,1 | -336,1 | -226,8 | -153,5 | -52,0 | -39,8 | -46,2 | -129,7 | -226,4 | -347,7 | -453,8 | |
| 14 | -433,9 | -381,2 | -336,4 | -227,3 | -145,1 | -55,2 | -20,9 | -25,7 | -119,9 | -212,9 | -346,7 | -445,6 | |
| 40 | -485,6 | -424,8 | -359,1 | -250,2 | -167,0 | -70,7 | -41,3 | -37,0 | -106,5 | -209,5 | -357,1 | -481,1 | |

The cost of this inefficiency as a result of the LCA analysis is tabulated in Table 5.

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**Table 5. Monthly heating costs for each of the Residences**

| Apartment TL/ Building Daily | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10-11 | 11-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **E1-01** | 11,64 | 6,56 | 6,28 | 3,48 | 0,00 | 0,00 | 0,00 | 0,00 | 3,14 | 4,86 | 8,11 |
| **E1-02** | 9,66 | 7,00 | 8,10 | 3,84 | 0,00 | 0,00 | 0,00 | 0,00 | 2,56 | 4,43 | 7,39 |
| **E1-03** | 9,34 | 6,23 | 5,58 | 2,76 | 0,00 | 0,00 | 0,00 | 0,00 | 2,98 | 4,45 | 7,42 |
| **E1-04** | 11,10 | 8,25 | 7,19 | 4,45 | 0,00 | 0,00 | 0,00 | 0,00 | 3,40 | 5,86 | 9,77 |
| **E1-05** | 10,78 | 8,08 | 7,47 | 3,42 | 0,00 | 0,00 | 0,00 | 0,00 | 3,09 | 5,63 | 9,38 |
| **E1-06** | 10,21 | 7,04 | 6,65 | 3,40 | 0,00 | 0,00 | 0,00 | 0,00 | 2,50 | 4,94 | 8,23 |
| **K2-01** | 13,02 | 8,28 | 7,52 | 3,66 | 0,00 | 0,00 | 0,00 | 0,00 | 3,33 | 5,98 | 9,96 |
| **K2-02** | 14,16 | 8,66 | 8,52 | 4,15 | 0,00 | 0,00 | 0,00 | 0,00 | 4,14 | 7,46 | 12,44 |
| **K2-03** | 16,47 | 8,26 | 7,06 | 4,40 | 0,00 | 0,00 | 0,00 | 0,00 | 3,53 | 6,56 | 10,94 |
| **K2-04** | 15,37 | 9,68 | 9,13 | 5,08 | 0,00 | 0,00 | 0,00 | 0,00 | 3,66 | 7,11 | 11,84 |
| **K2-05** | 14,70 | 10,43 | 9,50 | 5,36 | 0,00 | 0,00 | 0,00 | 0,00 | 3,91 | 6,38 | 10,64 |
| **K2-06** | 13,45 | 9,01 | 8,67 | 4,10 | 0,00 | 0,00 | 0,00 | 0,00 | 3,52 | 7,29 | 12,16 |
| **K2-07** | 15,02 | 11,20 | 9,18 | 3,95 | 0,00 | 0,00 | 0,00 | 0,00 | 4,03 | 6,71 | 11,19 |
| **K2-08** | 15,29 | 11,44 | 11,27 | 6,01 | 0,00 | 0,00 | 0,00 | 0,00 | 6,17 | 7,92 | 13,20 |
| **K2-09** | 12,75 | 8,71 | 8,07 | 3,72 | 0,00 | 0,00 | 0,00 | 0,00 | 4,72 | 8,74 | 14,56 |
| **K2-10** | 13,10 | 8,59 | 8,07 | 3,59 | 0,00 | 0,00 | 0,00 | 0,00 | 3,71 | 6,55 | 10,91 |
| **K2-11** | 14,60 | 9,16 | 9,34 | 5,47 | 0,00 | 0,00 | 0,00 | 0,00 | 5,57 | 7,11 | 11,85 |
| **K2-12** | 12,84 | 9,49 | 8,25 | 4,60 | 0,00 | 0,00 | 0,00 | 0,00 | 3,39 | 5,66 | 9,44 |
| **K2-13** | 13,78 | 8,82 | 8,41 | 4,91 | 0,00 | 0,00 | 0,00 | 0,00 | 3,85 | 6,57 | 10,95 |
| **K2-14** | 13,47 | 9,06 | 9,90 | 4,51 | 0,00 | 0,00 | 0,00 | 0,00 | 3,72 | 6,76 | 11,27 |
| **K2-15** | 14,87 | 8,53 | 8,33 | 4,19 | 0,00 | 0,00 | 0,00 | 0,00 | 4,97 | 6,66 | 11,09 |
| **K2-16** | 12,72 | 9,16 | 9,35 | 6,36 | 0,00 | 0,00 | 0,00 | 0,00 | 3,66 | 6,58 | 10,97 |
| **K2-17** | 13,48 | 9,40 | 9,96 | 5,37 | 0,00 | 0,00 | 0,00 | 0,00 | 4,78 | 6,99 | 11,65 |
| **K2-18** | 17,51 | 8,62 | 8,61 | 4,38 | 0,00 | 0,00 | 0,00 | 0,00 | 6,22 | 7,76 | 12,93 |
| **K2-19** | 13,04 | 8,32 | 7,45 | 3,44 | 0,00 | 0,00 | 0,00 | 0,00 | 2,91 | 5,99 | 9,98 |
| **K2-20** | 15,37 | 9,57 | 8,13 | 4,66 | 0,00 | 0,00 | 0,00 | 0,00 | 3,86 | 7,60 | 12,66 |
| **K2-21** | 15,80 | 8,09 | 7,67 | 3,59 | 0,00 | 0,00 | 0,00 | 0,00 | 4,15 | 7,71 | 12,84 |
| **K2-22** | 15,75 | 12,76 | 10,38 | 4,88 | 0,00 | 0,00 | 0,00 | 0,00 | 4,26 | 8,34 | 13,90 |
| **K2-23** | 12,64 | 8,86 | 7,79 | 4,25 | 0,00 | 0,00 | 0,00 | 0,00 | 4,72 | 6,05 | 10,09 |
| **K2-24** | 16,10 | 10,80 | 9,30 | 3,34 | 0,00 | 0,00 | 0,00 | 0,00 | 4,64 | 7,73 | 12,88 |
| **K2-25** | 16,41 | 11,13 | 10,40 | 5,73 | 0,00 | 0,00 | 0,00 | 0,00 | 4,16 | 7,22 | 12,03 |

It is seen that the economic impact of the area is considerable high as the potential maximum efficiency is considered. It is known that by an energy efficient planning exergetic efficiency can be increased more than 15 %. So this can be led to a 30% economic improvement for each housing unit.

**Conclusion**

The alarming rate of global warming makes appropriate measures a necessity for the future of the world. The increase in the greenhouse gas emissions caused by the haphazardly growing towns accelerates the global warming. It is imperative to engage in planning and design principles that take the local climate conditions into consideration, while also focusing on spatial solutions that utilize renewable energy sources. Such an approach is further complimented if it can also preserve underground and surface natural resources, designs a mass transit system and accessible areas, and preserves the local identities and landscapes. All things considered, climate-friendly/climate-appropriate/climate sensitive and environment sensitive/energy efficient settlements that are oriented ecologically are essential for a sustainable future for our world. In that regard, it is of paramount importance to start adhering to the laws and regulations about the settlements. A significant step to such a solution would be the establishment of urban and rural design guidelines that contain spatial principles/suggestions ranging from the structure scale to macro form scale, for each region of the country. Such desing guidelines should be specific in scope and details to the region/city they apply to.

Since TOKI is building residences all around the country with a very fast pace, it is quite important for it to employ such principles and guidelines. TOKI already aims to complete numerous neighborhood units consisting of such structures in all around the country (Şanlıurfa, Denizli, Gaziantep, Hatay, İstanbul, Manisa) as part of their “New Settlements and Renewed Cities” project. This project is significant as it pays attention to horizontal and localized architecture, and aims to build healthy buildings. This project gives hope that the concerns mentioned in our study will be taken into consideration in medium and long terms at the very least.

Upon the evaluation of TOKI Van Yuzuncu Yil University lodgements that consist of 31 blocks and 496 residences where approximately 1900 individuals reside in terms of heating energy efficiency, planning, project, application and utilization aspects, some conclusions were reached. Some of these conclusions are problems that can be solved with improvement labors, while others are problems inherited from planning and design phases and thus cannot be fixed.

The analysis results indicate a relatively low exergy efficiency, which leads to more greenhouse gas emissions than an achievable lower amount. Considering that inefficient fossil fuel consumption is the single most affective factor in the global warming, it is clear that every responsible mechanism –from individuals to governments- should undertake their fair share of the work for the solution. In that regard, utilization of more efficient energy transformation systems for heating is essential, along with more efficient structuring to preserve existing heat. In the end, the relatively low exergy efficiency of the study area was attributed to the inefficiencies of the heat transformation and distribution network and the isolation system. Improving these aspects will help reduce the environmental impact value of the TOKI lodgment.

The traditional LCA analysis conducted in this study was applied only considering the energy used for heating. The reason for this approach was to evaluate the energy performances of the buildings in the cold climate and their interaction between each other and the lodgment in this regard, rather than the performances of the materials used in the construction. Future studies may focus on more detail LCA analyses that consider other factors for the structures as well.

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