ENG Transactions

Journal homepage: http://www.engtransactions.com

ENG Transactions, vol. 2, pp. 1-6, July 2021
ID: ENGT-2107152112373

Research Article

Correlation Between Energy Consumption and Building Size

Mohammad Ali Malakoutian[1*], Yas Malakoutian[2], Pooria Mostafapoor[3], Mohammadbagher Amjadi[4]

[1]*Department of Architecture and the Built Environment, University of the West of England, Bristol, United Kingdom*
[2]*Department of Art and Architecture, University of Guilan, Rasht, Iran*
[3]*Department of Business, The University of Texas at Arlington, Arlington, USA*
[4]*Department of Electronic Engineering, Royal Holloway University of London, London, United Kingdom*

Keywords

Electricity consumption,
gas consumption,
simple linear regression.

Abstract

In this paper, relationship between energy consumption and the size of the building has been presented. Electricity and fuel gases as two essential energies in the world have also been investigated by considering that the relationship is linear. The energy waste of different buildings with different sizes has been surveyed. This can broaden people's horizon in order to find the ways of reducing the amount of energy consuming which have significant effects on reducing energy crises. It is possible to conserve energy for future generations and increase total life cycle energy use and associated environmental effects.

1. Introduction

During last few decades, the world is dealing with varies problem. Energy consumption is one of the most significant crises. Therefore, the deep studies in the field of energy consumption have been conducted to reduce energy consumption [1]. Meysam [2-4] has been conducted a research about reduce energy consumption in a supply chain system by optimizing of a delivery system. In addition, his studies have a significant impact to reduce air pollution and global warming.

Over the recent decades, house sizes have significantly increased [5]. People prefer to stay in larger houses since it provides them more comfort. As people's income increase, residents' energy consumption will increase, it is brilliant that larger houses require higher life cycle energy installing and using more materials and devices which require incredibly energy consumption. The size of a building is symmetric to the amount of material used for the construction as well as the area required heating and cooling.

U.S. households require energy to power various home equipment and devices, however on average, more than half (51% in 2015) of an annual energy consumption of the households is just related to two energy end uses: air conditioning and space heating [6]. The usage of these has seasonal pattern and also it varies considerably by geographic location, home size and

* Corresponding Author: Mohammad Ali Malakoutian
E-mail address: mir2.malakoutian@live.uwe.ac.uk, m.malakoutian8@gmail.com

Received: 18 June 2021; Revised: 9 July 2021; Accepted: 15 July 2021

Please cite this article as: M. A. Malakoutian et al., "Correlation between energy consumption and building size", *ENG Transactions*, vol. 2, pp. 1-6, 2021.

structure. Water heating, lighting, and refrigeration are the other forms of home energy uses. In 2015, these three accounted for 27% of total annual home energy use in 2015 [6].

Developed countries are investing in reducing the carbon dioxide emissions in response to climate change. It goes without saying that industrial demands play a significant role in the energy consumption. However, according to the research done by International Energy Agency (IEA) in 2019 [6], more than 20% of the total energy consumption of various OECD countries was consumed by households, of which developed countries such as Britain reached more than 30%. Also, based on the China Household Energy Report in 2016, total energy consumption of the living energy consumption of residents in United States increased from 17.5% in 1949 to 21.7% in 2013, while industrial energy consumption increased from 46% in 1949 and fell to 32.3% in 2013 [13-20].

There are a few existing researches that have focused on operational energy [7-9]. However, there are many significant analyses about the effect of house size on the life cycle energy demand [10] [21-27]. This research is also trying to focus on the energy consuming by construction and figure out the correlation between house size and energy consumption by analyzing the data of several buildings in Arlington County in Virginia State in the US. The method we used in this study is simple linear regression.

2. Problem

To clarify the concept of Heat wasting on building surfaces, this article will survey Basics of heat transfer from surfaces. In general, if there is a temperature difference on both sides of a surface, energy is transferred from the higher temperature environment to the lower temperature environment. This energy transfer is created by directing energy from higher-energy molecules to lower-energy side molecules.

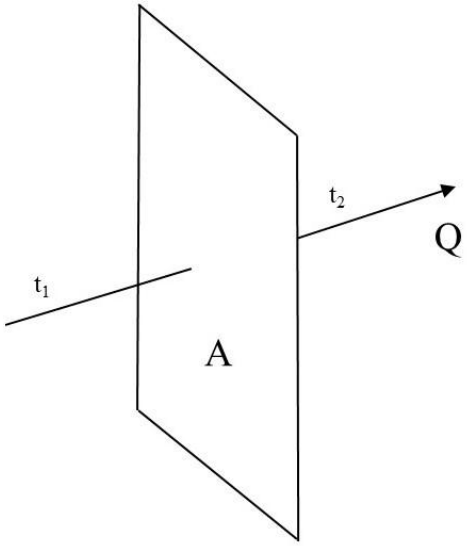

Figure 1. Heat transfer through a surface or wall

Figure 1 shows that if the temperature on one side of the surface (t1) is higher than the other side of the surface (t2), heat is transferred from one side of the surface to the other. Also, it is brilliant that different surfaces of a building such as walls, windows, and roof would follow this fact. Therefore, transferred heat in summer would be transferred from outside the building to the inside due to the warmer environment outside the building than inside the building. The amount of heat transferred from different levels of a building will be calculated by Eq. (1).

$$Q = (k / s) A dt \quad (1)$$

where Q = heat transfer (Btu/hr), k = Thermal Conductivity of material (Btu / (hr .°F .ft)), s = material thickness (ft), A = heat transfer area (ft^2), dt = t_1–t_2 = temperature gradient - difference - over the material (°F).

3. Implementation and Uniform Distribution:

To further investigate the correlation between building area and energy consumption, it is necessary to calculate a practical example. The proposed example is the consumption of electricity and natural gas in 40 different buildings that are available between 2015 and 2018 [11]. These 40 buildings are all located in Arlington County, Virginia and are considered to be the same in terms of weather conditions.

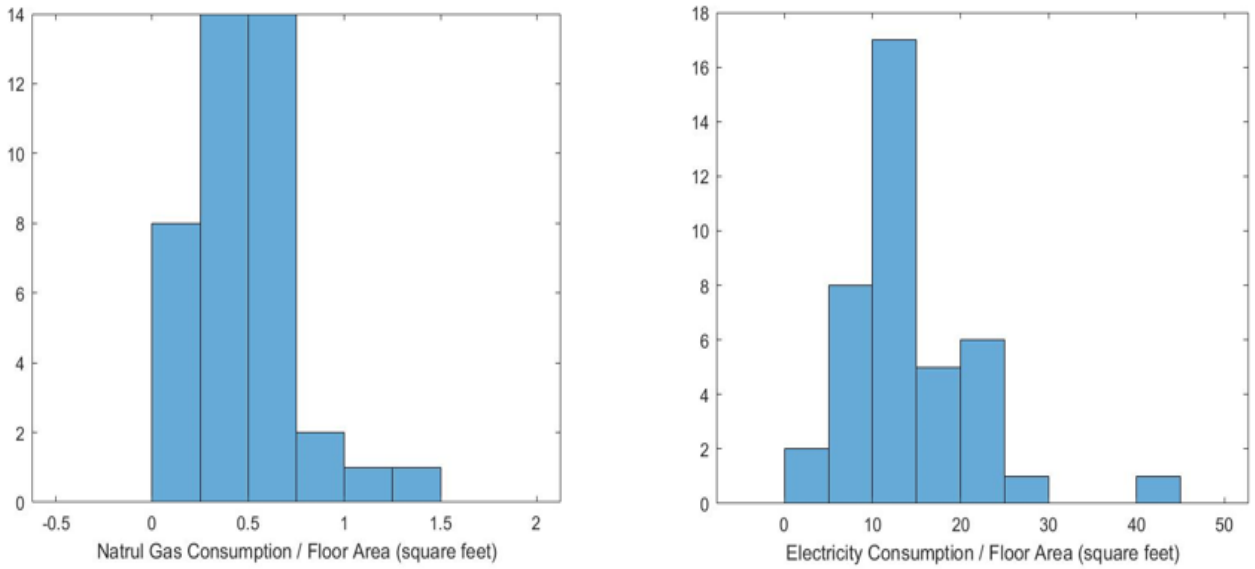

Figure 2. Histogram of Data

3.1 Test of uniform distribution for Natural Gas consumption with 95% level of confidence

H_o: Distribution is uniform, H_A: Distribution is not uniform, $\sum \frac{(O_i - E_i)^2}{E_i}$ = 6.02283514341213, Degree of freedom: 40-2-1=37

Rejection area is more than 44.97 and Conclusion: Do not Reject.

3.2 Test of uniform distribution for Electricity consumption with 95% level of confidence

H_o: Distribution is uniform, H_A: Distribution is not uniform, $\sum \frac{(O_i - E_i)^2}{E_i}$ = 143.454431145427, Degree of freedom: 40-2-1=37

Rejection area is more than 44.97 and Conclusion: Reject.

4. Regression Model and Results:

Two regression calculation have been done for this problem as below.

The correlation between gas consumption and building area is considered linear. It means by increasing building area, the amount of natural gas consumption will increase by same ratio.

$$b_1 = x/y \quad (2)$$

$$yCalc_1 = b_1 * x \quad (3)$$

$R^2 = 1 – \text{sum}((y - yCalc1)^2) / \text{sum}((y - \text{mean}(y))^2)$ (4)

and $R^2=0.389636$ (5)

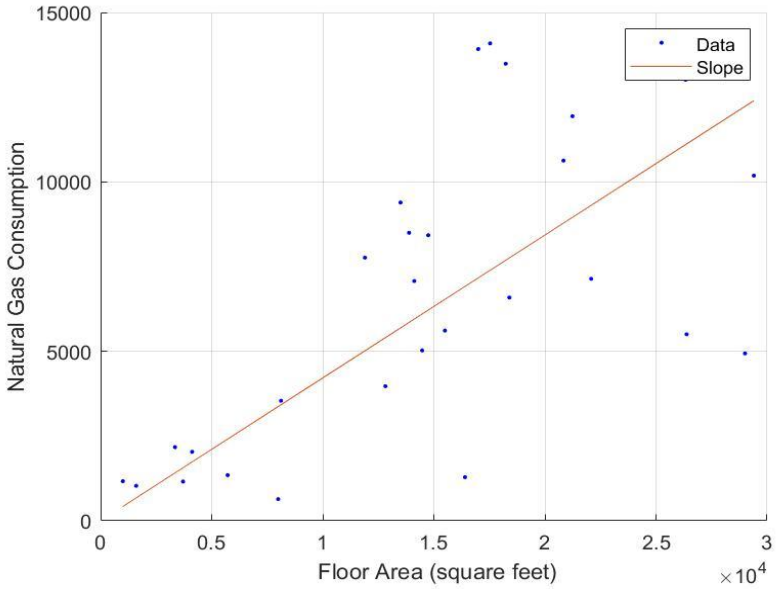

Figure 3. Linear Regression Relation Floor Area & Natural Gas Consumption [12]

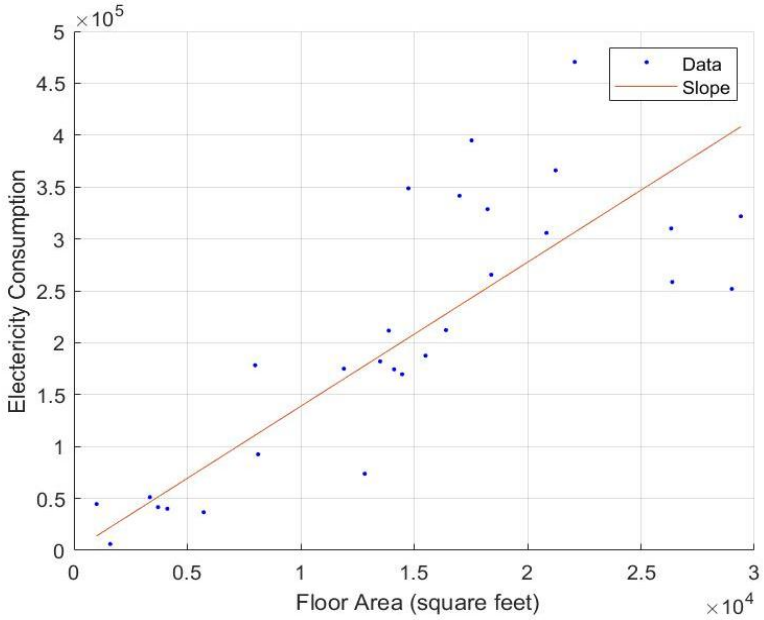

Figure 4. Linear Regression Relation Floor Area & Electricity Consumption [12]

The correlation between electricity consumption and building area is considered linear as well. It means by increasing building area, the amount of electricity consumption will increase by same ratio.

$B_2 = x/y$ (6)

$yCalc_2 = b_2*x$ (7)

$$R^2 = 1 - \text{sum}((y - yCalc2)^2) / \text{sum}((y - \text{mean}(y))^2) \quad (8)$$

$$R^2=0.633149 \quad (9)$$

If the energy consumption in a building with a very small area (close to zero square feet) is considered zero, then in the above calculations the start of the regression line will be from the origin of coordinates and intercept in both relations above are considered zero.

5. Conclusion

This article has invested on the relationship between energy consumption and the size of the building. To survey the study, we invested on electricity and fuel gases as two essential energies in the world. However, in order to make the concept clearer, we have considered that the relationship is linear. Everyone knows that during recent decades, world is dealing with varies problem. Energy consumption as one of the significant crises has been argued in this article. In fact, deep studies in the field of energy consumption and ways of reducing the amount of energy consuming will have important effects on reducing energy crises. As a matter of fact, by studying in this field, we can conserve energy for future generations and increase total life cycle energy use and associated environmental effects.

Conflict of interest: Authors declare no conflict of interest.

Reference

[1] M. Yazdani, K. Kabirifar, B. E. Frimpong, M. Shariati, M. Mirmozaffari, A. Boskabadi, "Improving construction and demolition waste collection service in an urban area using a simheuristic approach: A case study in Sydney, Australia,"*Journal of Cleaner Production*, vol. 280, pp. 124138, 2021.

[2] M. Mahjoob, S. S. Fazeli, S. Milanlouei, L. S. Tavassoli, "A Modified Adaptive Genetic Algorithm for Multi-product Multi-period Inventory Routing Problem,"*arXiv preprint arXiv:2104.09031*, 2021.

[3] M. Mahjoob, S. S. Fazeli, L. S. Tavassoli, M. Mirmozaffari, S. Milanlouei, "A green multi-period inventory routing problem with pickup and split delivery: A case study in flour industry,"*Sustainable Operations and Computers*, vol. 2, pp. 64-70, 2021.

[4] M. Mahjoob, S. S. Fazeli, S. Milanlouei, A. K. Mohammadzadeh, L. S. Tavassoli, "Green supply chain network design with emphasis on inventory decisions, "arXiv preprint arXiv:2104.05924, 2021.

[5] Y. Yuan, J. Lu, "Demanding energy from carbon," *Carbon Energy*, vol. 1, no. 1, pp. 8-12, 2019.

[6] S. M. Hosseinian and V. Najafi Moghaddam Gilani, "Analysis of factors affecting urban road accidents in rasht metropolis," *ENG Transactions*, vol. 1, no. 1, pp. 1–4, 2020.

[7] M. Mirmozaffari, et al., " Machine learning clustering algorithms based on the DEA optimization approach for banking system in developing countries," *European Journal of Engineering and Technology Research*, vol. *5*, no. 6, pp. 651-658, 2020.

[8] D. Gielen et al., " The role of renewable energy in the global energy transformation," *Energy Strategy Reviews*, vol. 24, pp. 38-50, 2019.

[9] S. Chu, Y. Cui, N. Liu , "The path towards sustainable energy," *Nature materials*, vol. 16, no. 1, 16-22, 2017.

[10] A. Rahiminejad, A. Aranizadeh, B. Vahidi, " Simultaneous distributed generation and capacitor placement and sizing in radial distribution system considering reactive power market,"*Journal of renewable and sustainable energy*, vol. *6*, no. 4, 2014.

[11] M. Khaksar and M. M. A. Malakoutian, "Productivity evaluation for banking system in developing countries: DEA malmquist productivity index based on CCR, BCC, CCR-BCC (a case study)," *ENG Transactions*, vol. 1, no. 1, 2020.

[12] M. Feizbahr, C. Kok Keong, F. Rostami, and M. Shahrokhi, "Wave energy dissipation using perforated and non perforated piles," *International Journal of Engineering*, vol. 31, no. 2, pp. 212–219, 2018.

[13] M. Mirmozaffari, R. Yazdani et al., "VCS and CVS: New combined parametric and non-parametric operation research models," *Sustainable Operations and Computers*, vol. 2, pp. 36-56, 2021.

[14]] F. J. Golrokh, Gohar Azeem, and A. Hasan, "Eco-efficiency evaluation in cement industries: DEA malmquist productivity index using optimization models," *ENG Transactions*, vol. 1, pp. 1–8, 2020.

[15] N. A. Golilarz, M. Mirmozaffari, T. A. Gashteroodkhani, L. Ali, H. A. Dolatsara, A. Boskabadi, M. Yazdi, "Optimized wavelet-based satellite image de-noising with multi-population differential evolution-assisted harris hawks optimization algorithm,"*IEEE Access*, vol. 8, pp. 133076-133085, 2020.

[16] M. Mirmozaffari, M. Yazdani, A. Boskabadi et al., "A novel machine learning approach combined with optimization models for eco-efficiency evaluation,"*Applied Sciences*, vol. 10, no. 15, pp. 5210, 2020.

[17] F. J. Golrokh and A. Hasan, "A comparison of machine learning clustering algorithms based on the DEA optimization approach for pharmaceutical companies in developing countries," *ENG Transactions*, vol. 1, pp. 1–8, 2020.

[18] A. Aranizadeh, M. Kazemi, H. Barahmandpour, M. Mirmozaffari, "MULTIMOORA Decision Making Algorithm for Expansion of HVDC and EHVAC in Developing Countries (A Case Study),"*Iranian Journal of Optimization*, vol. 12, no. 1, pp. 63-71, 2020.

[19] M. Taleghani and A. Taleghani, "Identification and ranking of factors affecting the implementation of knowledge management engineering based on TOPSIS technique," *ENG Transactions*, vol. 1, no. 1, 2020.

[20] M. Mirmozaffari, A. Alinezhad, "Ranking of Heart Hospitals Using cross-efficiency and two-stage DEA,"in *proc. 7th IEEE International Conference on Computer and Knowledge Engineering (ICCKE)*, pp. 217-222, Oct. 2017.

[21] M. Mirmozaffari, "Filtering in Image Processing," *ENG Transactions*, vol.1, 2020.

[22] M. Mirmozaffari, "Eco-Efficiency Evaluation in Two-Stage Network Structure: Case Study: Cement Companies, "*Iranian Journal of Optimization*, vol. 11, no. 2, pp. 125-135, 2019.

[23] L.S. Tavassoli et al., "A New Multiobjective Time-Cost Trade-Off for Scheduling Maintenance Problem in a Series-Parallel System," *Mathematical Problems in Engineering*, Article ID 5583125, pp. 1-13, 2021.

[24] A. Addeh, M. Iri, "Brain tumor type classification using deep features of MRI images and optimized RBFNN," *ENG Transactions*, vol. 2, no. 1, pp. 1–7, 2021.

[25] G. Azeem,M. Mirmozaffari et al., " Exploring the impacts of COVID-19 pandemic on risks faced by infrastructure projects in Pakistan," *International Journal of Applied Decision Sciences*, 2021.

[26] M. Mirmozaffari et al., "A novel artificial intelligent approach: comparison of machine learning tools and algorithms based on optimization DEA Malmquist productivity index for eco-efficiency evaluation,"*International Journal of Energy Sector Management*, vol. 15 no. 3, pp. 523-550, 2021.

[27] A. Alinezhad, M. Mirmozaffari, "Malmquist Productivity Index Using Two-Stage DEA Model in Heart Hospitals," *Iranian Journal of Optimization*, vol. 10, no. 2, pp.81-92, 2021.