Energy Poverty Map: Online Survey System of the Indoor Environmental Quality for Energy Poverty in South Korea

Lee, Jong-Won

ABSTRACT

As the energy poverty cannot afford the energy expenditure, their indoor environmental quality (IEQ) was affected by diverse problems from low energy efficient residential buildings. Thus, it is important to identify IEQ of energy poverty`s residential buildings to improve their well-being. However, there is no specific and diverse data on the IEQ of energy poverty in low-income housing in South Korea due to the difficulty of reaching many households and managing an amount of survey data. This study aims to establish an online survey system that provides the IEQ questionnaires and analyzes the IEQ data of energy poverty in low-income housing. In this study, we developed a web-based survey system and an energy poverty map. By using the system, a pilot survey was conducted in five cities in South Korea during the summer and winter seasons in 2020. Due to the difficulty to have easy access to the low-income village during the Covid-19, researchers have collaborated with Korean Non-Governmental Organizations (NGOs) who could be access to energy poverty dwellings. Through a pilot case study, NGO`s members have collected 600 dwellings data and descriptive statistical analysis was performed. The following analysis will be conducted through the accumulated database. First, future study will conduct a correlation analysis between the econometric and demographic characteristics of energy poverty using this database. In addition, future study measures should include expanding household data to identify a large enough number of user patterns that can be considered representative of energy poverty. Second, the energy poverty map can be used to identify neighborhoods with low income, social weakness, and poor buildings in the policy decision-making process.

INTRODUCTION

The Korean government recently announced that "energy poverty" is one of the 41 major social problems through the "Comprehensive plan for solving the social life problem based on science and technology". The definition of energy-poor households is interpreted in various ways according to standards, but generally, energy-poverty is that households that spend more than 10% of their income on energy use, such as electricity, fuel, and heating (Boardman, 1991). Energy poverty also can be explained by low-income people living in inappropriate and inefficient housing (Lampietti and Meyer, 2002). The causes of energy poverty are largely divided into low income, high energy prices, and low energy efficient houses. Among them, the improvement of energy efficiency in a building is significantly efficient for the goal of reducing energy poverty. In the low energy efficiency village without energy supply infrastructure such as city gas or district heating, the burden of heating costs is higher than income (Lee and Ryu, 2013). Even though the residential welfare policy with subsidies and goods (fans, briquettes, etc.) for energy poverty helps alleviate urgent poverty for a while during hot summer and cold winter, a fundamental and long-term solution to reduce energy poverty is needed by improving the indoor environmental quality (IEQ) and energy efficiency in the residential environment.

As the energy poverty generally cannot afford the energy expenditure, their IEQ was affected by diverse factors from low energy efficient residential building. Thus, it is important to identify the IEQ of energy poverty`s residential buildings to improve their well-being (Lin and Wang, 2020). However, it is difficult to analyze their IEQ without a systematic database related to the residential buildings where energy poverty resides. In addition, the existing paper questionnaire survey method was not web-based, so it is difficult to monitor and visualize data results. Thus, this study aims to establish an online survey system and energy poverty map for energy poverty data.

Jong-Won Lee is a senior researcher in the Department of Building Energy Research, Korea Institute of Civil Engineering and Building Technology, Goyang-si, Gyeonggi-do, South Korea.

THE SURVEY DESIGN AND ENERGY POVERTY MAP

Questionnaire design

This study has focused on the qualitative information collected in occupant`s surveys instead of the qualitative measurements (temperature, CO2, electric consumption, etc.) due to the difficulty to set up and monitor measurements regularly during the Covid-19 pandemic. The survey method is a fast and cost-effective way to collect and analyze responses (Graham, Parkinson and Schiavon, 2020). In addition, online surveys have overcome the technical challenges of paper surveys. Thus, we developed a web-based survey system to collect data directly from the field site in real time.

This research has collaborated with Korean Non-Governmental Organizations (NGOs) who have visited energy poverty villages over 10 years. Although it was hard for the researchers to reach the low-income village due to the rejection from the local governments during the Covid-19, NGO members could be access to their dwellings because they have volunteered for them for a long time. The volunteers mainly had conducted a survey instead of the researchers.

Energy poverty is caused by various factors like socio-economic aspects, geographical characteristics, physiological characteristics, housing characteristics (Kolokotsa and Santamouris, 2015; Raúl et al, 2019). In this study, socio-economic aspects and housing characteristics are considered for IEQ and divided into five categories; environment, households, building, appliances and usage pattern, and energy welfare. The details are shown in Table 1.

Table 1. Summary table of the questionnaires

Category	Variables
Environment	Survey time, Weather, Temperature (indoor/outdoor), Humidity(indoor/outdoor)
Households	Family number, Age, Gender, Income, Family Relationship,
Building	Address, Area, Construction year, Renovation record, Building orientation, Building floor
Appliances and Usage Pattern	Heating, Cooling, Lighting, Electric appliances, Cooking, **Window/Door condition**
Energy Welfare	Eligibility, Benefited government support, Energy consumption differences after Covid-19

In particular, the survey included the 5-point scale of window condition satisfaction and window information. It is expected that the collected window data can be used to identify the poor window condition based on the scores. The details are as follows: Window condition satisfaction (air permeability/ventilation, lighting, airtightness, condensation, corrosion/crack, distortion/skewness, decreased opening and closing), Window information (orientation, window glazing, window frame bacterial, glass coating)

A pilot survey and result

Total 600 energy poverty household's data were collected with the system in five cities in South Korea. During the summer and winter seasons, the survey was conducted for the same households. The survey result shows that most households were aged 65 years or older (82%), and the average age of households was 73.7 years old. Around 63% of households were not engaged in economic activity, and full-time workers among households who have worked are only 26%. In addition, the average monthly income of the households was around 500 dollars. 63% of the total energy poverty households lived in houses built before 1980 that were over 30 years old. In addition, the average occupant`s satisfaction of the window condition was generally low as follows with a scale of 5 points: air permeability/ventilation (2.9 points), lighting (2.7 points), airtightness (2.8 points), condensation (2.9 points), and corrosion/crack (3.0 points), distortion/skewness (3.0 points), and decreased opening and closing (2.9 points). The system shows automatically statistical results.

Energy poverty map: visualization of window condition

These collected data were used to create an energy poverty map based on GIS (Geographic Information System) as shown in Figure 1. All quantitative responses can be shown with diverse colors on the map. For example, the window condition satisfaction mentioned above is displayed in multilevel colors such as red, orange, and yellow in Figure 1. The satisfaction is displayed in red if the occupants are not satisfied, yellow if the satisfaction is moderate, and green if the occupants are satisfied. The map was developed based on the open sources (Leaflet and Openlayers) and liked with various Korean government open data like building age, floor information, and energy use information. The main reason for using open data is to reduce implementation costs (Lee et al, 2020). Data visualization on the map can help survey volunteers to be easily accessible to dwellings and to monitor the survey response.

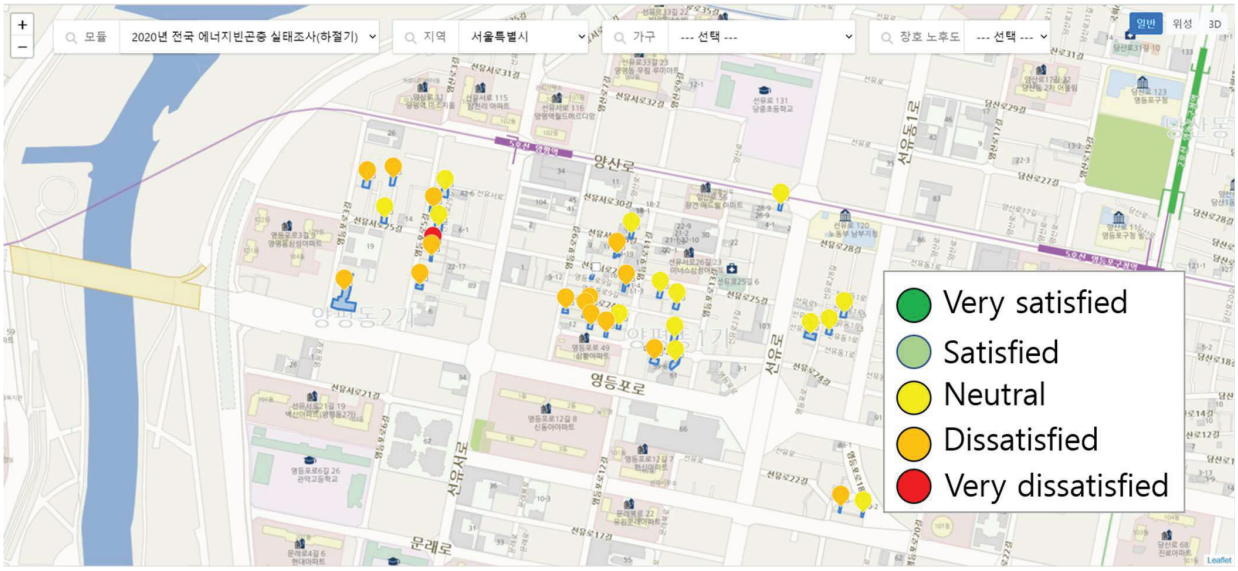

Figure 1 GIS mapping with IEQ satisfaction score (e.g. window condition) in Seoul. The window condition satisfaction is displayed in multilevel colors such as red (very dissatisfied, 1 point), orange (dissatisfied, 2 points), yellow (neutral, 3 points), light green (satisfied, 4 points), and green (very satisfied, 5 points).

CONCLUSION

This research represents the first step to develop an online survey system that can accumulate scattered and unsystematic data related to IEQ and energy use of energy poverty in low-income housing. Due to the Covid-19 pandemic, the survey process, data collection, and result analysis have been delayed. Thus, the following analysis will be conducted through the accumulated database. First, future study will conduct a correlation analysis between the econometric and demographic characteristics of energy poverty using this database. In addition, future study measures should include expanding household data to identify a large enough number of user patterns that can be considered representative of energy poverty (Guerra-Santín and Silvester, 2017). Second, the energy poverty map can be used to identify neighborhoods with low income, social weakness, and poor buildings and support policy decision-making in monitoring the energy poverty risk and addressing suitable strategies at the urban level (Fabbri and Gaspari, 2021). The future study will find a way to adapt this energy poverty map in the policy decision-making process.

ACKNOWLEDGMENTS

We would like to thank the Korea NGO`s Energy Network for their initial support for providing valuable information and access to some low-income dwellings to monitor them, and especially, to the families who voluntarily participated in this study. This work was supported by the Major Project of the Korea Institute of Civil Engineering and Building Technology (KICT) [grant number 20210204-001].

REFERENCES

Boardman, B. 1991. Fuel Poverty: from Cold Homes to Affordable Warmth. Belhaven Press, London, United Kingdom. Charlier, D., and Kahouli, S. 2019. From residential energy demand to fuel poverty: income-induced non-linearities in the reactions of households to energy price fluctuations. Working Papers, FAERE - French Association of Environmental and Resource Economists.

D Kolokotsa, M., and Santamouris. 2015. Review of the indoor environmental quality and energy consumption studies for low income households in Europe, *Science of The Total Environment* 536: 316-330.

Guerra-Santín, O., and Silvester, S. 2017. Development of Dutch occupancy and heating profiles for building simulation. *Building Research & Information* 45: 6–413.

Graham, L. T., Parkinson, T., and Schiavon, S. 2021. Lessons learned from 20 years of CBE's occupant surveys. *Buildings and Cities* 2(1): 166–184.

K. Fabbri, J., and Gaspari. 2021. Mapping the energy poverty: a case study based on the Energy Performance Certificates in the city of Bologna. *Energy and Buildings* 234

Lampietti, J., and Meyer, A. 2002. When Heat is a Luxury: Helping the Urban Poor of Europe and Central Asia Cope with the Cold. Washington, D.C.: World Bank

Lee, J.S., and Ryu, K.H. 2013. A Legislative Study on Energy Poverty in United Kingdom and Australia. *Korea Legislation Research Institute,* 13-20-4.

Lee J.W., Kim D.W., Lee S.E., Jeong J.W. 2020. Development of a Building Occupant Survey System with 3D Spatial Information. *Sustainability* 12(23):9943.

Lin, B., and Wang, Y. 2020. Does energy poverty really exist in China? From the perspective of residential electricity consumption. *Energy policy* 132: 379–391.

Raúl C.R,, Jaime S.G., Carlos R. B., and Madelyn M. 2019. Towards a multiple-indicator approach to energy poverty in the European Union: A review. *Energy and Buildings* 193: 36-48.