論 文 の 内 容 の 要 旨

論 文 題 目　　Research on Estimation Methods for Household Energy Demand in Developing　Countries – The Case of Tanzania
（開発途上国における住宅セクターからのエネルギー需要評価に関する研究－タンザニアにおけるケーススタディ）

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1.　Introduction

1.1.　Background and motivation of research

There is a direct relationship between energy use and social development. Some researchers have concluded that energy is a prerequisite condition for development and emphasized on electricity consumption by saying that it is directly linked to development. Rapid population increase and urbanization in developing countries is the main cause of rapid increase in energy demand and is expected that out of the total energy consumed in the world in the next 20 years, about 60 percent of this consumed demand will be from these countries. Developing countries are facing a crisis on how to satisfy their energy demand. Abrupt changes in energy demand between urban and rural areas are part of the problem but unplanned energy supplying and management systems contribute to the problem to a larger part. Planned preparations for meeting future demand or regulations for efficient energy use are unheard of in most developing countries and detailed drivers for these rapid changes are not known due to a severe lack of energy data in these countries. End-use/bottom-up models that require detailed data for their applications are not applicable in most cases.

1.2.　Purpose of research

Due to adverse differences in the energy demand intensity, demand growth rate, available energy resources together with the technological and social infrastructure between different regions in developing countries-especially between urban and rural areas, a tool that can work on a localized area data to predict energy demand trend for that area is of utmost important. This research aims at developing a method to collect localized area data to enable bottom-up/end-use models that can be used specifically in developing countries that have limited available data to understand the energy use outlook in order to facilitate energy supply and demand planning and management focusing on the effect of different drivers in future demand.

2.　Methodology

From the literature review and direct interviews with energy managers and policy makers, it was

found that the developing countries are facing a huge problem in energy management and appropriate policy mechanism due to a lack of detailed data on energy consumption. As a consequence, energy policies in these countries concentrates on the national or sectoral energy demand management and ignores locality based management and end-use management. In developing countries where the household sector contributes a high percentage of the total energy demand, understanding the drivers in the household sector is important in making informative decisions on energy management and policy making. To overcome the limitation a new methodology to estimate energy demand in developing countries was proposed.

Firstly, a new method to collect regional/locality data was introduced. The basic hypothesis behind this method is the assumption that households form or are segregated in zones of similar income and consequently similar energy consumption intensity since energy use is directly related to income. Using this theory, the total energy consumption intensity in each zone is aggregated to calculate the total energy consumption intensity of the whole area.

Since the methodology requires the establishment of energy consumption intensity zones, land use analysis involving regional planning and Master plan analysis was proposed. From the land use analysis, zones having similar household income and consequently similar household energy demand were established. Satellite pictures taken from samples within these zones were analyzed and the total number of houses in each zone was computed. The average house and compound size in each zone can also be calculated using this method and the distribution of housing type can also be understood.

From then onwards, a simple household energy use survey from a sample in each zone is conducted in order to understand the appliances penetration level in each income zone, the number of hours they are used per day, and the quantity of appliances per household in each income zone. The survey also looks on the appliances energy consumption (power ratings) to understand the difference – if any – of appliances' efficiency in each income zone. This information together with the data collected by land-use analysis is then inputted in the end-use model to predict the future energy demand of that locality.

2.1. Model simulation

To analyze and test the model, Dar es Salaam city in Tanzania was chosen as a case study. This city is chosen because it is among the top ten rapid expanding cities in the world and experiences acute energy shortages. Three master plans of 1954, 1969 and 1979 were analyzed together with current infrastructure and land use reports to establish zones of household zones per income. It was found that the northern area of the central business district along the Indian Ocean coast is a prime housing area with the plot value decreasing the further from the coastal area. Satellite image

analysis confirmed that the housing density is the lowest from the coastal area inwards establishing the zones for high, middle and lower income households in the unplanned settlement areas in the hinterland.

Household Energy Use Survey conducted was divided into two parts; questionnaire and interview via three different media; Word file though emails that got 48 responses, paper handouts that got 52 responses, and an online version that got 57 responses; 157 in total. This survey was conducted between March to September 2012.

The questionnaire asked on the location of the household, the type of dwelling, the number of rooms and the household size. It also asks on the fuel used for cooking and lighting together with the number of appliances and their average time of use per day. The interview on the other hand, questions the reasons leading to the household choice of cooking and lighting fuel together with appliances use. Another survey on the lifestyle characteristic was conducted on-site on 53 households between February and March of 2013, in order to understand the living style related to energy use as well as to measure appliances power and efficiency. This information is inputted in an end-use model proposed to simulate the energy demand for Dar es Salaam for the year 2012.

When the results are compared with real consumption energy [Source: Tanzania Electricity Supply Company - TANESCO] they show a close similarity at 0.4 percent difference. The simulations for year 2007 was also conducted using Africa Development Bank standards for income group categorization (baseline was set at $4 Dollars PPP per person equivalent to above $500 per family of 4.2 people) under World Bank database composition. The simulated energy consumption results show a 20 percent difference to the real values.

To validate the data, Malaysia's appliances use characteristics was used because of the geographical, climatic and cultural similarities between Malaysia and Dar es Salaam, Tanzania. The simulated results using Malaysia's information differs to when Dar es Salaam's data is used by 3.01 percent for year 2012 and 13.46 percent for year 2007. A sensitivity analysis was then used to understand the effect of changes of parameters to the model. It was found that appliances time of use and appliances power has the highest influence to the model and there is a potential in energy conservation through their control.

2.2. Model application

The model was used to enable end-use model to estimate energy use for Dar es Salaam region for circa 2020 and circa 2030. The estimated demand shows a huge difference to the demand under Business As Usual scenarios, showing the need of understanding the demand pattern since it is not possible to be seen under normal conditions. Using the model, energy demand drivers were possible

to be understood, and this information can be a basic tool for energy planners and managers to prepare policies and control schemes on the end-use level. The model was shown to be applicable to understand demand pattern on a more localized area and can be consequently used to control and design policies that can be used by local governments instead on the central government scale as the present case in developing countries. It was also shown that, by using this method policy makers can make informed decisions in energy supply investments and efficiency control investments from end-use and locality scale to national scale.

3. Conclusion and discussions

By using this methodology, the regional/locality energy use characteristics were shown to be possible to capture to be used in the energy demand prediction model. This information can then be used to enable bottom-up models that are important in understanding the energy demand drivers behind the demand growth. This means that, current and future energy demand drivers in the household sector in a locality can be easily understood and appropriate action can then be used to meet the demand. The advantage of this method compared to the current methodologies used in developing countries is that it can produce different localized trends for different parts of the country using basic energy data. Moreover, the energy demand and the fuel type demand distribution can be understood for different areas within a locality. Hence, by using this methodology, energy demand intensity maps can be established and energy demand prediction could be conducted zone wise, urban locality wise and at the top, national wise.

This methodology can be a useful tool for energy planners and managers to allocate and manage the supply of energy in a smaller scale. The methodology gives planners a chance to make policies targeting smaller areas after understanding their specific energy use trend and growth. These policies can then replace policies that target the whole country homogeneously. Sources to meet demand can be localized and optimal use of resources can be achieved.

The model confidence level is affected by the very limited and basic data used in this study. It also has a limitation on its adaptability to all developing countries. Since this model did not consider the relationship on energy use between two adjacent households, it needs some modification to be applied to localities that have a high number of collective housing.