DEVELOPMENT OF PREDICTIVE MODELS FOR ENERGY DEMAND AND CO_2 EMISSION TRENDS FOR HOUSEHOLDS IN MAKURDI METROPOLIS

ABSTRACT

Development of predictive models for energy demand and CO_2 emission trends for households in Makurdi metropolis was carried out. As part of the study, households were randomly selected. Four major emission sources: electricity; transportation; solid waste and cooking fuels were considered, and data on the sources were obtained using records from relevant departments as well as questionnaires, surveys, and interviews of the occupants. This data was analyzed and used to calculate the CO_2emissions of the households using IPCC standard guidelines and formulae. The CO_2 emission and energy demand predictive models were also developed using Design Expert 13. The ANOVA for the CO_2 emission and energy demand shows a significant model (Significance F value of ≤ 0.0001) and a high R-squared value of 0.9981 and 0.9802 respectively. This indicates the adequacy of the models, and they can therefore be used to predict the CO_2 and energy demand of households in Makurdi metropolis.

Keywords:Model, Emission, CO_2, Household, Energy

1.0 INTRODUCTION

Efficient planning of distributing energy needs accurate prediction of future demand to make the balance between the supply and demand of the energy [1]. In a residential building, underestimation of energy consumption can lead to power outage, which can be harmful both for economy and daily life of the society. On the other hand, overestimation of energy demand may lead to creating unused capacity that is equal to wasting the resources, mostly financial. Despite the increasing importance accorded to the demand for electricity to meet residential need in Nigeria, the current power situation is deplorably inadequate [2]. Factors responsible for this power situation in the country cut across social, political, climatic and even economic dimensions [3].

While proffering solutions to the power situation is pertinent, residential units are expected to evolve ways to mitigate the adverse effect of power outages to ensure continued survival. Such measures include the use of solar panels, private generating plants powered by fossil fuels such as Premium Motor Spirit (PMS) and Automated Gas Oil (AGO) as well as the efficient usage of energy given the objectives that households seek to achieve. However, as far as the latter is concerned, there is quite some doubt.

Studying energy consumption problems has become an important topic of research in recent decades. Energy problems are vital for the security and wellbeing of the societies. Long-term planning of energy supply-demand must satisfy the requirements of sustainable development of a country. Accurate forecasts or prediction can help the decision makers to know the volume and trend of the future energy consumption to better schedule and plan the operations of the supply system.

Prediction studies are important from the aspect of pricing as well. Energy price variation is a function of supply-demand balance. Energy price variations, climate change, increasing global energy demand, dependence to fossil fuels and less development of new energies threatens the energy supply security [4]. Environmental issues as global warming and emission are the other important aspects of energy consumption forecasting. More than 75% of the human made greenhouse gas is the result of burning fossil fuels[5]. Using fossil fuels is the most common way to produce electricity. Therefore, producing electricity both deplete the natural resources and make environmental pollution.

All in all, the importance of energy demand management has been more vital in recent decades as the resources are getting less, emission is getting more and developments in applying renewable and clean energies is not globally applied yet.

1.1 Energy Audit

Energy audit is the review of the total energy used and costs, normally performed in conjunction with a site investigation. It involves the classification of the energy sources and their contribution in running a residential buildings or a factory. It provides a structural review of how energy is being purchased, managed and used with the aim of identifying opportunities for energy cost saving through improved services.

Different energy inputs exist in different residential buildings, organizations or industries and various methods are used in evaluating these energy inputs.For instance, fossil fuel which is one of the mostly utilized energy sources in industries and households can be evaluated by employing equation 1 and 2 [6]; [7].

For Diesel:

$$E_{FLD} = 47.8D \quad (MJ) \quad (1)$$

Where,

E_{FLD} = liquid fuel energy input for diesel, MJ

47.8 = Unit energy value of diesel, MJL^{-1}

D = Amount of diesel fuel consumed, (liter)

For Petrol:

$$E_{LLP} = 42.3P \ (MJ)$$

Where,

E_{LLP} = liquid fuel energy input for petrol, MJ

42.3 = Unit value of petrol,

P = Amount of petrol consumed, (liter).

1.2 Intergovernmental Panel on Climate Change (IPCC) Guideline for GHG Emissions Inventory

The guidelines for emissions assessments stipulates that assessments can be done entirely in relation to CO_2 emission, hence emissions of all GHGs are quantified as CO_2 equivalents. Likewise, emissions inventories are done based on the sources of emissions, these sources are categorized according to the boundaries they are encapsulated in [8].

1.2.1 Organizational Boundaries

This refers to the activities that are within the physical boundaries of the organization being assessed.

1.2.2 Operational Boundaries

The operational boundaries deal with identification of emissions associated with the organization's operations and categorizing them as direct and indirect emissions. The IPCC standard identifies operational boundaries for institutions as 'scopes'. There are three scopes outlined thus:

Scope 1 (Direct GHG emissions): Includes all direct sources of GHG emissions that are owned or controlled by the institution/household and are within the physical boundaries of the institution/household, these include production of electricity, heat, or steam, transportation, waste incineration and fugitive emissions (from unintentional leaks).

Scope 2 (Indirect GHG emissions): This covers indirect emissions i.e. those that do not occur within the institution/household boundaries but can be controlled by the institution/household, e.g. GHG emissions from purchased electricity, heat or steam.

Scope 3 (Other indirect GHG emissions): These are indirect emissions outside the control of the operator (organization/household), such as emissions by suppliers.

However, to simplify data collection and processing, most inventories only consider Scopes 1 and 2.

There is therefore no known report of any work in literature on the development of predictive models for energy demand and CO_2 emission trends for households in Makurdi , Benue State, Nigeria. or elsewhere in the world.

The aim of this work is to develop a predictive models for energy demand and CO_2 emission trends for households in Makurdi , Benue State, Nigeria. The study will help to develop strategies for better control of CO_2 emission and energy consumption.

2.0 MATERIALS AND METHODS

The materials/equipment used for this study are a well-structured questionnaire, Weighing scale, Design Expert Version 13, Microsoft Excel Version 2016 and Computer system (hp Intel(R), Core(TM) i5, CPU M 480 @ 2.67GHz, 4 GB Ram).

The following methods were used to achieve the objectives of this research.

Twelve residential buildings (households) were selected within Makurdi, Benue State. The households that were used for this study are located in four locations (High level, Wurukum, Wadata, North bank) in Makurdi, Benue State. Three households were randomly selected from each of the locations, making a total of twelve households, and the data for the quantification of energy consumption were gathered with the aid of a well-structured questionnaire and oral interview of the occupants. The head of the households were majorly interviewed in order to get first-hand information about the energy consumption in the respective households.

Twelve months' data on energy consumption, both electricity from grid and fossil fuels for the respective households were collected. The fossil fuel consumption in liters was then converted to energy equivalent by employing equations 1.

2.1 Data Analysis in CO_2 Emissionsand Energy Consumption Assessment

Formulae and steps as provided and outlined by IPCC as guidelines for assessment of CO_2emissions were employed[8]. For the energy consumption in the respective households, a record for the monthly electricity consumption for the period of twelve months was obtained from Jos Electricity Distribution Company (JED) through the occupants for the respective households. Likewise, for electricity generated using diesel and petrol powered.

2.2 Development of CO_2 Emission and Energy Demand Predictive Models

CO_2 and energy demand predictive models were developed using Design Expert 13. Model relating the total CO_2 emission and the sources of the emissions was developed, and also, model relating total energy demand and the respective energy sources was developed by adopting the approach by [9]. The appropriateness of the models was determined by the F-statistic and their respective coefficient of determination (R^2) values.

3.0 RESULTS AND DISCUSSION

3.1 Distribution of Average Monthly Electricity Consumption of the Households

The distribution of the average monthly electricity consumption for the respective households is shown in Figure 1. This shows that electricity from power generator is responsible for more than half of the total monthly energy consumption of the households. This implies that electricity from power generator is mostly utilized by the respective households, and this contributes more to the GHG emission of the households as shown in Figure 2.

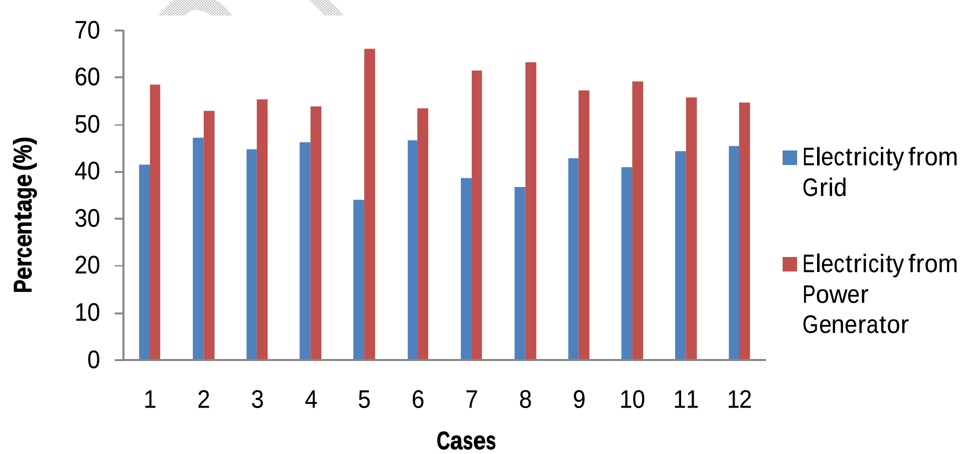

Figure 1: Distribution of Average Monthly Energy Consumption of Households

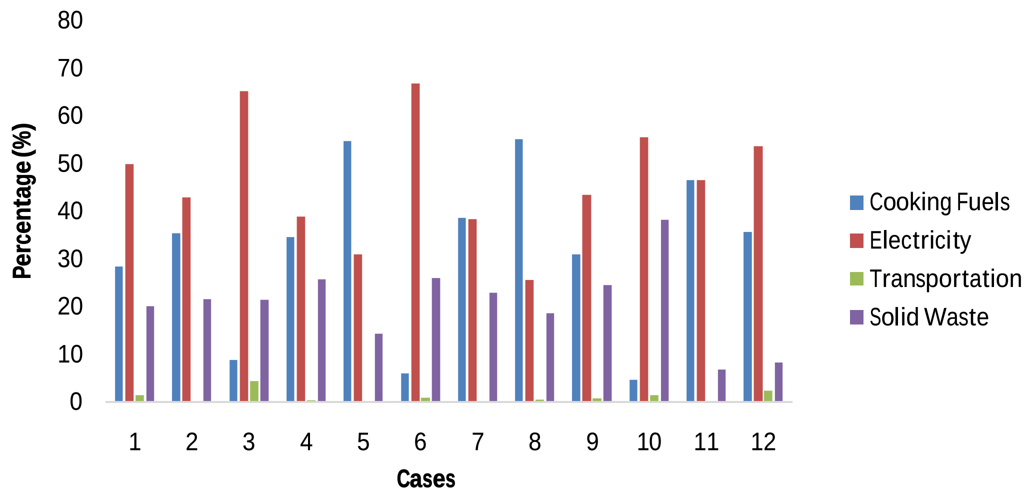

Figure 2: Distribution of the Respective Households GHG by Emission Source

3.2 Modelling of the CO_2 Emission and Energy Demand of Households

The ANOVA and the fit statistic of CO_2emission and the energy demand shows that the Significance F is very low (≤ 0.0001), which is a perfect fit for the models. This also shows the significance and the adequacy of the models [9]. The high R-Squared value obtained shows consistency and that the process parameters explained 99.8% and 98% of the variance of the CO_2emission and the energy demand models. Therefore, the linear models presented in Table 1 can be used to predict the CO_2emission and the energy demand of households in Makurdi, Benue State.

Table 1: Developed CO_2 Emission and Energy Demand Models

CO_2 Emission $= +2.30756E^{-}15 + (1.30100 * CF) + (0.95901 * E) + (0.02150 * T) + (1.02010 * \text{Solid Waste})$ ($\mathbf{R}^2 = 0.9981$)
Energy Demand $= +0.013702 + (0.795968 * GE) + (0.98905 * GRE)$ ($\mathbf{R}^2 = 0.9802$)

Significance F $\leq$ 0.0001

CF = Emission from Cooking Fuel

E = Emission from Electricity

T = Emission from Transportation

SW = Emission from Solid Waste

GE = Generated Electricity

GRE = Grid Electricity

3.3 Actual and Predicted CO_2 Emissions and Energy demand of Households

The experimental data were analysed to check the correlation between the values of the experimental and the predicted CO_2 emissions and energy consumption. The result of the plot is shown in Figure 3 and 4 respectively. The R^2 values of 0.9981 and 0.9802 shows that the data points are distributed reasonably near the straight line. This indicates a good relationship between the actual and the predicted CO_2 emissions and energy demand. The result suggests also that the selected models are adequate for predicting the CO_2emissions and energy demand[9].

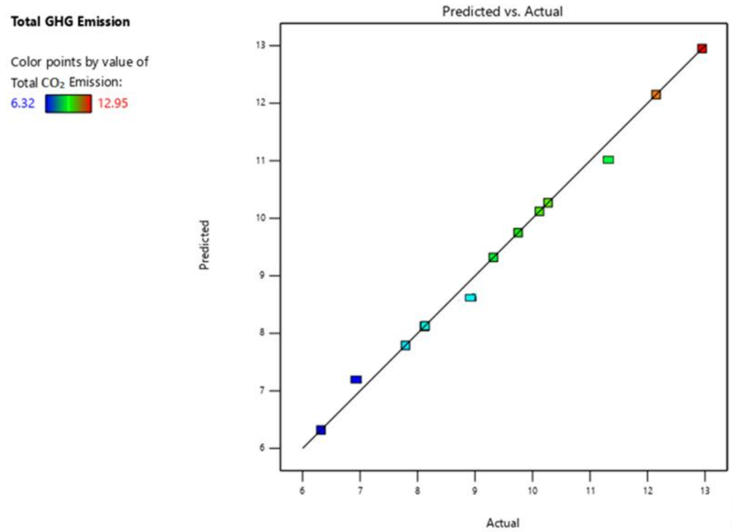

Figure 3: Plot of Predicted Versus Actual CO_2 Emission of Household

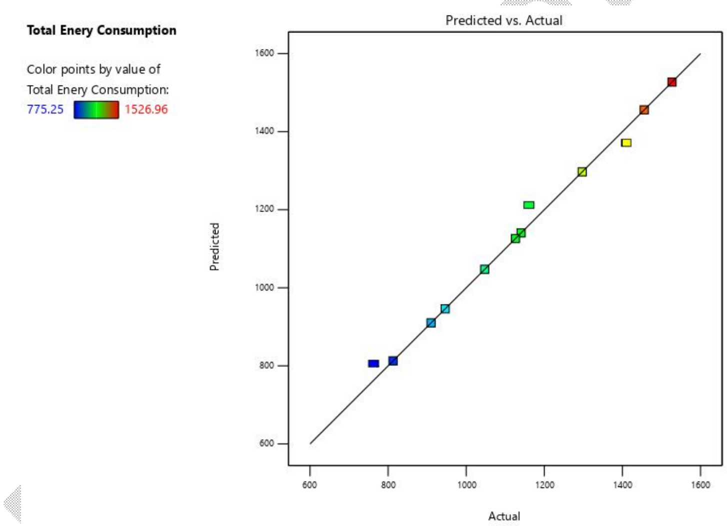

Figure 4: Plot of Predicted Versus Actual Energy Consumption of Household

4.0 CONCLUSION

The study revealed that the electricity from power generator is responsible for more than half of the total monthly energy consumption of the households. This implies that electricity from power generator is mostly utilized by the respective households.The study also revealed that electricity and cooking fuel are the major sources of CO_2 emission of the households.The high emission due to the electricity usage in the households can be reduced by gradually replacing inefficient gadgets with energy efficient ones. For the emission from cooking fuels, it can be reduced by use of alternative fuels (like briquettes) which are efficient and environmentally friendly.As with similar assessments, this is somewhat an underestimation since not all sources of emission and energy consumption were considered.

The Significance F which is one of the measures of the adequacy of the CO_2 emission and energy demand models shows to be very low ($\leq$ 0.0001) , and this is a perfect fit for the models. Also, the high R-Squared value obtained shows consistency and that the process parameters explained 99.8% and 98% of the variance of the CO_2emission and the energy demand models. Therefore, the developed models canbe used in predicting the CO_2 emission and the energy demand of a household in Makurdi, Benue State Nigeria.

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