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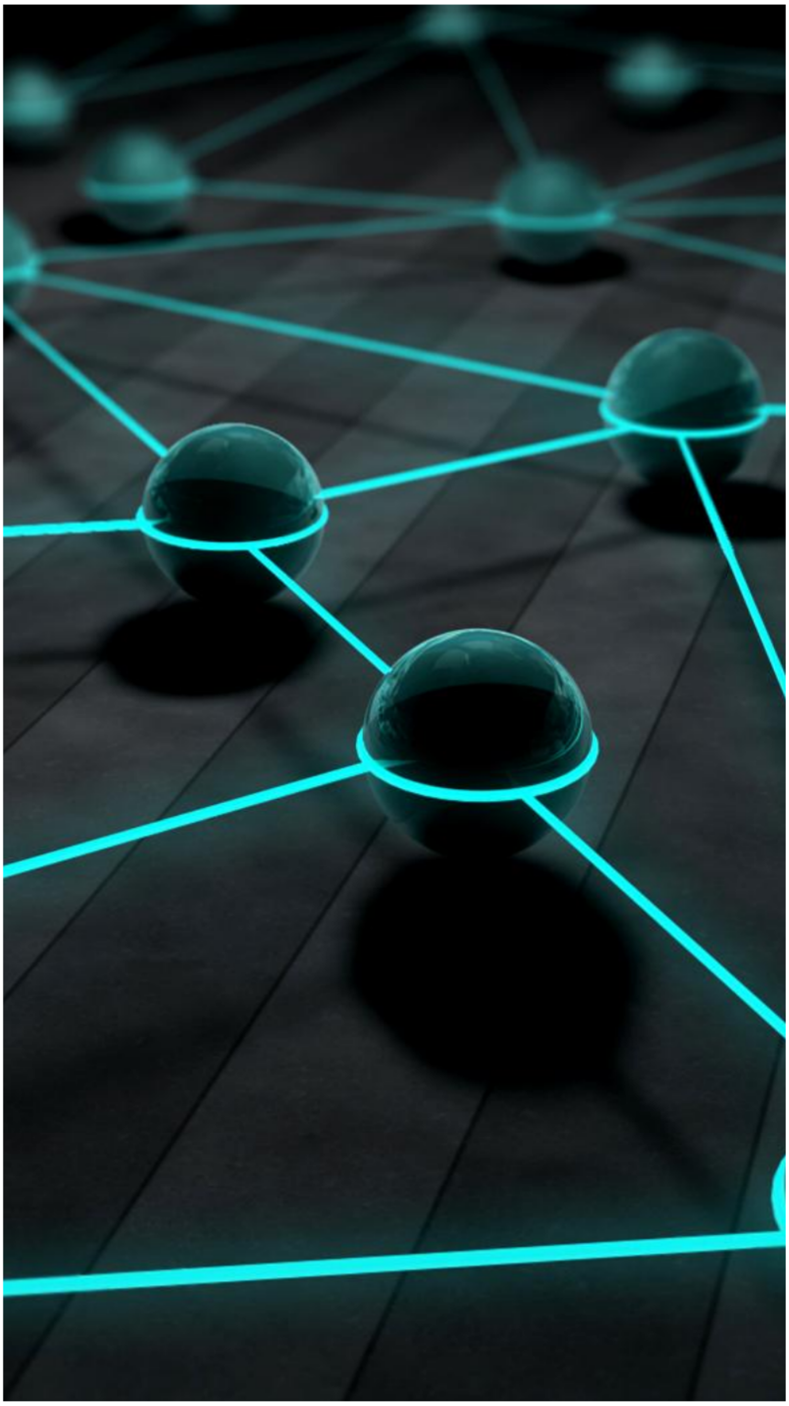

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URBAN ENERGY MODELLING APPROACHES: A LITERATURE REVIEW

Ayse Zelal Tugrul

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DESIGN AND SIZING OF STANDALONE SOLAR POWER GENERATION FOR A MEDIUM RESIDENCE IN KANO STATE

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Abstract

Energy is one of the prime mover of mankind and need of the energy is always increasing at the same time the sources of energy are depleting with respect to time. Because of these reasons, energy expert thinks of other sources of energy that are sustainable, among which solar energy is the freely renewable energy source and it is abundant in nature. This paper tend to design a stand-alone solar energy generation for a medium house in Kano state Nigeria, the results of the research revealed that a 300W solar PV array capacity of 30 modules, 22 (140Ah, 12V) batteries and 4 (90A, 202-253V) voltage regulator are needed to supply the electrical load of the house. The overall cost estimate of the system was ₦886,032 which is relatively high when compared to that of fossil fuel generator used by the house but the payback period of the system is estimated to be 2 years 4 months, which is obviously much shorter than the lifespan of the selected PV modules which is 30 years.

Keywords: *Battery Bank, Electrical Energy Load, Inverter, Solar PV Module, Voltage Regulator*

1. Introduction

Due to the high demand of electricity and power fluctuation in most countries in Africa especially Nigeria. Nevertheless, recently around December 2015, the United Nations Framework Convention on climate Change (UNFCCC) Europe led by Paris came up with a Paris Agreement for the world in which countries would devise means and strategies to help curtail global warming to well below 2^{o}C by 2030 [1]. One hundred and ninety five countries have signed and agreed to this and Nigeria on 22nd September, 2016 [2]. Scientists and Engineers are always conducting researches on alternative source of generating electricity with consideration of the sustainability of these sources. Solar energy is one of the most promising sources of electricity especially in the northern states of Nigeria due to it's abundant in nature at that states.

Sunlight is converted in electricity by a means of solar photovoltaic (PV) cell when the light emitted to PV cell that made from silicon [3, 4]. The power generation by solar cell, the change of temperature and radiation which effect in values of power generation [5, 6].

About 1.4 billion people around the world still do not have access to the regular electricity. Almost 85% of the people without electricity live in rural, semi-urban or remote rural areas of the sub-Saharan Africa and South Asia by estimate [7]. In Nigeria, residential electrification accounts for 57.3% of the total electricity generated in the Nation, while 26.1% and 16.6% account for commercial and industrial use [8].

Although the solar irradiation varies all through the year in Nigeria, it's recorded that the average daily solar irradiation per square meter in Nigeria is about 5.25kwh with an average estimated sunshine hour of 6.5 hours [9] and receives on the average 20MJ/m^2 per day of solar insolation depending on the time of the year and the location considered [9, 10].

There has been an energy policy in place in Nigeria since 2006, called the Renewable Energy Master Plan (REMP). The policy was implemented to increase the share of renewables to account for 10% of Nigerian total energy consumption by 2025. The plan includes an installed capacity target of 500MW by 2025. Nigeria's power minister has mentioned the ministry aims to boost the installed capacity of solar PV to 1 GW over the next 10 years [8].

2. Solar Energy Status and Policies in Nigeria

Solar energy is derived from the ultraviolet radiation given out by the sun from the outer space. It is the pivot of green plants sustenance is it energizes the process of photosynthesis through which green plants manufacture their food. It was claimed that Nigeria is capable of generating up to 600,000 MW of electricity from solar energy from only 1% of her land area [21]. Solar water heaters have been developed at the National Centre for Energy Research and Development (NCERD) situated at the University of Nigeria Nsukka [22]. Despite the expensive nature of solar power projects, the payback period is said to be not less than 5 years and the panel can last for as long as 25 years. Daily solar radiation is around 3.5kWh per m^2 in southern Nigeria and up to 7.0kWh per m^2 in northern Nigeria [23].

According to a Global Energy Network Institute report: If solar collectors/modules were used to cover 1% of Nigeria's land area, it would be possible to generate 1850 $\times 10^3$ GWh of solar electricity per year. This is over 100 times the current grid electricity consumption level in the country [24]. In a recent study [25], solar integration was classified into grid connected, off-grid hybrid and stand-alone systems. The study reveals that grid connected and off-grid hybrid solar project do not exist in Nigeria. Most of the solar systems projects are either stand-alone mini-grid or off-grid power applications. No comprehensive database exists about Nigerian solar energy applications and projects. Data from various websites and other sources are difficult to harmonize [26]. Although solar thermal power plants are developing on the global scene with some countries investing in the technology due to it benefits, Nigeria has no grid connected thermal power generation system [27]. There have been no solar energy integrated grid systems in the past in Nigeria. Nigeria aims to produce 9.74%, 18% and 20% of her consumed electricity from renewables by 2015, 2020 and 2030, respectively. Solar energy is expected to produce 1.26%, 6.92% and 15.27% of the electricity consumed in Nigeria by 2015, 2020 and 2030, respectively [26]. As of 2016, there was no data available to show that the 2015 solar energy targets were met. Over the long term, solar energy is expected to produce 76.36% of the total electricity consumed [28].

3. Design Method of the System

After interviewing the householder about the estimation of the house appliances load, the components of the system such as solar photovoltaic, battery bank, inverter, voltage regulator (charge Controller) and cable wires were properly designed and sized.

3.1 Appliances Loads Estimation

The house appliances load was presented in the Tab. 1 as:

Table 1. Electrical Energy Load of the House Appliances

S/N	Name	Quantity 'Q'	Power Rating 'P' (W)	Usage Hours 'T' (Hrs)	Total Power 'P_t' (W) P_t=Q*P	Total Energy 'E_t' (kWh/day) E_t=P_t*T
1	Fluorescents	50	20	6	1000	6
2	Television	5	140	5	700	3.5
3	DVD Player	5	40	5	200	1
4	Fans	10	100	6	1000	6
5	Laptop	3	40	3	120	0.36
6	Refrigerator	4	140	5	560	2.8
7	Pressing Iron	3	1000	2	3000	6
8	Accessories	4	200	3	800	2.4
	Total				**7380**	**28.06**

3.2 Design Assumptions

In design of an off-grid solar PV system, there are some assumptions and considerations which are employed in the design as:

A. Peak Solar Intensity at the earth surface is taken to be 1kW/m^2.
B. Inverter converts DC into AC power with efficiency of 90%.
C. The number of the autonomy days is taken to be 2days.
D. The maximum depth of discharging is assumed to be 50%.
E. The design system voltage is taken to 48V.
F. The safety factor of the module is taken to be 1.25.
G. The size of the wires and cables used in this design is considered based on National Electrical Code (NEC).

4. Selection and Sizing of System

4.1 Design and Sizing of Solar PV Module

Solar photovoltaic module is an electronic device used to convert energy from the sun to useful energy. Before selecting a photovoltaic module for the system, the power output and number of the module were designed and the Yingli 300Watt, 24V silicon-crystalline module is chosen in this design.

4.1.1 Power Output of Solar PV Module

The power output of the solar photovoltaic module (P_{pv}) can be obtained using the relation given by [11]:

$$P_{pv} = \frac{E_t \times PSI}{\eta_b \times K_{losses} \times H_{tilt}} \tag{1}$$

Where:
E_t is the total daily energy of the house load = 28.06kWh/day (From Tab. 1);
PSI is the Peak Solar Intensity at the earth surface = 1kW/m^2 [11];
η_b is the Efficiency of the System;
K_{losses} is the determination factor due losses on the system such as dust, change in temperature and
H_{tilt} is the average solar irradiance falling on the specific tilt angle which is 5.5m for Kano metropolis [13].
The efficiency of the system can be found using the relation given by [12] as:

$$\eta_b = \eta_{inverter} \eta_{connection\ losses} \tag{2}$$

Where:
$\eta_{inverter}$ is the efficiency of the inverter = 90% and
$\eta_{connection\ losses}$ is the efficiency of the system connection which is between the range 80-90% [12], and 85% is taken in this design.
The determination factor can determine using equation given by [11] as:

$$K_{losses} = t_{manuf.} F_{temp.} F_{dirt} \tag{3}$$

Where:
$t_{manuf.}$ is the manufacturer's tolerance = 97% ;
F_{dirt} is the de-rating due to dirt which is taken to be 90% since Kano metropolis is dirty and;
$F_{temp.}$ is the temperature de-rating factor which can be found using equation given by [14] as:

$$F_{temp.} = 1 - \left[\gamma(T_{cell,eff.} - T_{STC})\right] \tag{4}$$

Where:
γ is the power temperature coefficient = 0.48%/°C [11];
T_{STC} is the standard temperature of the collector = 25°C [11] and;
$T_{cell,\ effi.}$ is the average daily temperature which is given by [14] as:

$$T_{cell,eff.} = 25 + T_a \tag{5}$$

Where:
T_a is the ambient temperature = 27 ^{0}C.

4.1.2 Number of Modules

The photovoltaic modules were arranged in series and parallel connections.

A. Number of Modules in Series Connection

The number of modules in series connection can be found using relation given by [15] as:

$$N_{ms} = \frac{V_{system}}{V_{module}} \tag{6}$$

Where:

V_{module} is the nominal voltage of the module = 24V (Table A1) and;

V_{system} is the designed system voltage = 48V.

B. Number of Modules in Parallel Connection

The number of modules in parallel connection can be found using relation given by [15] as:

$$N_{mp} = \frac{P_{PV}}{N_{ms}P_{module}} \tag{7}$$

The number of modules of the system can be obtained by multiplying number of modules in series and that in parallel.

$$N_{mt} = N_{ms}N_{mp} \tag{8}$$

4.2 Design of Battery Bank

Battery bank is an essential component in smart grid design; it is where the solar irradiance absorbed by the solar photovoltaic modules being stored. The capacity of the battery bank can be obtained using the relation given by [16] as:

$$C_b = \frac{E_t N_c}{\eta_{inv.} V_n DOD_{max.}} \tag{9}$$

Where:

N_c is the number of the autonomy days = 2 days;

$\eta_{inv.}$ is the inverter efficiency = 90%;

V_n is the nominal battery voltage =12V (Table A2) and;

DOD_{max} is the maximum depth of discharging = 50%

The selected battery in this design was lead acid battery made from Hoppecke Solar Power with nominal voltage of 12V and capacity of 140Ah. The number of batteries used in this system can found using the equation given by [12] as:

$$N_{b_{requ}} = \frac{C_b}{C_{selected}} \tag{10}$$

Where:

$C_{selected}$ is the capacity of the selected battery

Like in solar PV modules, the batteries are also connected in series and parallel arrangement, the number of batteries connected in series can be obtained using the relation given as:

$$N_{b_{series}} = \frac{V_{system}}{V_{battery}} \tag{11}$$

Similarly, the number of batteries connected in parallel can be obtained using the relation given as:

$$N_{b_{parallel}} = \frac{N_{b_{requ}}}{N_{b_{series}}} \tag{12}$$

4.3 Design of the Inverter

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total power of appliances. The inverter must have the same nominal voltage as your battery. For stand-alone systems, the inverter must be large enough to handle the total amount of power that will be using at one time. The inverter size should be 25-30% bigger than total power of appliances [17].

4.4 Voltage Regulator Sizing

According to its function on controls the flow of current. A good voltage regulator must be able to withstand the maximum current produced by the array as well as the maximum load current. Sizing of the voltage regulator can be obtained by multiplying the short circuit current of the modules connected in parallel by a safety factor (f_{safe}). The result gives the rated current of the voltage regulator [18].

$$I_{rated} = N_{mp} I_{SC} f_{safe} \tag{13}$$

Where:
N_{mp} is the number of PV modules connected in parallel;
I_{SC} is the short circuit current of the module and;
f_{safe} is the safety factor which is usually taken to be 1.25 [16].

Number of voltage regulator required is given by equation (14):

$$N_{v_{reg}} = \frac{I_{rated}}{I_{selected}} \tag{14}$$

4.5 Sizing of System Cables and Wires

Selecting the correct size and type of wires and cables will enhance the performance and reliability of a photovoltaic system. Therefore, the National Electrical Code (NEC) was used in selecting cables and wires of this design [19].

5. Results and Discussion

5.1 Results

5.1.1 Design Output of Solar PV Module of the System

Table 2 presents the output parameters of the PV modules of the system as:

Table 2. The output parameters of the PV modules of the system

Input Parameters	Design Calculations	Output Parameters
E_t=28.06kWh/day; PSI=1kW/m^2; H_{tilt}=5.5m; $\eta_{inverter}$=90%; $\eta_{connection\ losses}$=85%; t_{man}=97%; F_{dirt}=90%; γ=0.48%/°C; T_{STC}=25°C and T_a=27°C.	From equation (2): $\eta_b = 0.90 \times 0.85 = 0.768$ From equation (5): $T_{cell,eff.} = 25 + 27 = 52℃$ From equation (4): $F_{temp.} = 1 - \left[\frac{0.48}{100}(52 - 27)\right] = 0.8704$ From equation (3): $K_{losses} = 0.97 \times 0.8704 \times 0.90 = 0.76$ From equation (1): $P_{pv} = \frac{28.06 \times 1}{0.768 \times 0.76 \times 5.5} = 8.74kWh/day$	$\therefore P_{pv} = 8.74kWh/day$
V_{system}=48V; V_{module}=24V and P_{module}=300W.	From equation (6): $N_{ms} = \frac{48}{24} = 2modules$ From equation (7): $N_{mp} = \frac{8.74 \times 10^3}{2 \times 300} = 14.57 \approx 15\ modules$ From equation (8): $N_{mt} = 2 \times 15 = 30\ modules$	$\therefore N_{ms} = 2\ modules$ $\therefore N_{mp} = 15\ modules$ $\therefore N_{mt} = 30\ modules$

5.1.2 Design Output of Solar Battery Bank of the System

Table 3 presents the output parameters of the solar battery bank of the system as:

Table 3. The output parameters of the solar battery bank of the system

Input Parameters	Design Calculations	Output Parameters
E_t=28.06kWh/day; V_n=12V; N_c=2days; DOD_{max}=50%; $\eta_{inverter}$=90% and $C_{selected}$=140Ah	From equation (9): $C_b = \frac{28.06 \times 10^3 \times 2}{0.50 \times 0.96 \times 12} = 9743Ah$ From equation (10): $N_{b_{requ}} = \frac{9743}{140} = 69.6 \approx 70\ batteries$	$\therefore C_b = 9743Ah$ and $N_{b_{requ}} = 70\ batteries$
V_{system}=48V and $V_{battery}$=12V	From equation (11): $N_{bseries} = \frac{48}{12} = 4\ batteries$ From equation (12): $N_{bparallel} = \frac{70}{4} = 17.5\ say\ 18\ batteries$	$\therefore N_{bs} = 4\ batteries$ $\therefore N_{bp} = 18\ batteries$

5.1.3 Design Output of Voltage Regulator of the System

Table 4. presents the output parameters of the voltage regulator of the system as:

Table 4. The output parameters of the voltage regulator of the system

Input Parameters	Design Calculations	Output Parameters
N_{mp}=25 modules; f_{safe}=1.25; I_{SC}=5.38A and $I_{selected}$=90A	From equation (13): $I_{rated} = 25 \times 9.6 \times 1.25 = 300A$ From equation (14): $N_{v_{reg}} = \frac{300}{90} = 3.33 \approx 4$	$\therefore I_{rated} = 300A$ and $N_{v_{reg}} = 4\ Regulators$

5.1.4 Cost Estimation and Analysis

a) Estimated Cost of the System

Table 5. presents the estimate cost of system’s components as

Table 5. The estimate cost of system’s components

Components	Model	Quantity	Unit Price (₦)	Overall Cost (₦)
Solar Modules	Yingli 300W, 24V (Silicon-crystalline Technology)	30	24,500	735,000
Battery	Hoppecke Solar.power 140Ah, 12V (Lead Acid Type)	22	4,000	88,000
Inverter	Latronics LS-3000W, 24V (d.c), 220V (a.c).	2	6,000	12,000
Voltage Regulator	Sunny Island 202-253V, 90A	4	3,500	14,000
Miscelleneous Cost				30,000
Total				879,000

The operating costs for solar PV installations are negligible, but the annual maintenance cost may amount to 0.5% to 1% of the capital cost of the system. Maintenance cost of the PV system is taken to be 0.8% of the capital cost of the system as:

$$Annual\ Maintenance\ Cost = 0.8\% \times Capital\ Cost = 0.8\% \times \text{₦}879{,}000 = \text{₦}7032$$

Therefore, the overall cost of the system can be found by adding the capital cost of the system with annual maintenance cost as given below:

$$Overall\ cost = capital\ cost + annual\ maintenance\ cost = \text{₦}879{,}000 + \text{₦}7032 = \text{₦}886{,}032$$

The house has a small generator used to charge the batteries of the system when there is no sun for a day.

The hours estimated was 3hours per day,

The total estimated hours used per annum were:

$$Total\ estimated\ hours\ per\ annum = 3 \times 365 = 1095 hours$$

The estimated fuel (Petrol) used for the generator was two litres per hour;

The total estimated fuel consumed by the generator per annum was:

$$Total\ estimated\ fuel\ consumed\ per\ annum = 1095 \times 2 = 2190 litres$$

The prevailing market price for a litre of petrol for running a generator in Nigeria was at the rate of ₦145 per litre [20].
The total cost fuel consumed by the generator per annum was:

$$Total\ estimated\ cost\ fuel\ consumed\ per\ annum = 2190 \times 145 = ₦317{,}550$$

For the generator to work properly it needs maintenance regularly, therefore the estimated maintenance cost of the generator was ₦15,000.

The total running cost of the generator per annum was:

$$total\ running\ cost = ₦317{,}550 + ₦15{,}000 = ₦332{,}550$$

The cost of purchased of the generator was ₦46,800;

Finally, the cost of the petrol consumed and the cost of generator for the first year was:

$$Total\ running\ cost\ and\ cost\ of\ the\ generator = ₦332{,}550 + ₦46{,}800 = ₦379{,}350$$

b) Payback Period of the System

The payback period of the system was equal to the ratio of the overall cost of the solar PV system to the total running cost of the fuel and cost of the generator.

$$Payback\ Period = \frac{Overall\ cost\ of\ the\ solar\ PV\ system}{total\ running\ cost\ fuel\ and\ cost\ of\ the\ generator\ for\ the\ 1st\ year} \qquad (15)$$

$$Payback\ Period = \frac{₦886{,}032}{₦379{,}350} = 2.34 years = 2 years\ 4 months$$

5.2 Discussion of the Results

The system was design and sizing the system components by considering the daily electrical energy demand for the house. The load was estimated as 28.06 kWh/ day based on the watt-hour rating of the appliances. The result of the estimated daily electrical energy demand was presented in Table 2.1. The stand-alone solar PV system was designed based on the estimated load.
The results as shown in Table 4.1 show that the house requires 30 solar PV which consist of series and parallel connections of the solar PV arrays of 2 modules and 15 modules respectively and Yingli mono-crystalline solar PV with output of 300W, 24V was selected in order to generate electrical energy 8.74kWh/day to the house.
For storage of energy for use when there is demand a storage battery bank has been designed and selected. From Table 4.2, the house requires 22 batteries of which 18 are connected in parallel while 4

batteries are connected in series. A battery bank with a capacity 140Ah manufactured by Hoppecke Solar Power was selected.

To safely charge the batteries and to maintain longer lifetime for them, the house requires a voltage regulators of capacity 90A. But the some of the appliances are AC current appliances, so the house requires inverters that convert its DC current to AC current. The number of the inverter required by the system is only one.

Finally, the capital cost of the system was ₦879,000 whereas the overall cost of the system was ₦886,032. It was observed that the modules, the batteries and the inverter are the most costly components of an off grid photovoltaic system (Table 4.4). Increasing the size of these components will increase the overall cost of the system. A cost estimate of the system provides the payback period of the system is estimated to be 2 years 4 months which is obviously much shorter than the lifespan of the solar PV modules which is 30 years (Table A1).

6. Conclusion and Recommendation

In this research work, the electrical energy demand of a house in a rural area of Kano state, Nigeria was estimated as 8.74 kWh/ day. System design, sizing and selection of the components were provided based on the estimated load. The results of the research revealed that a 300W solar PV array capacity of 30 modules, 22 (140Ah, 12V) batteries and 4 (90A, 202-253V) voltage regulator are needed to supply the electrical load of the house. The overall cost estimate of the system was ₦886,032 which is relatively high when compared to that of fossil fuel generator used by the house but the payback period of the system is estimated to be 2 years 4 months, which is obviously much shorter than the lifespan of the selected PV modules which is 30 years. The recommendation would be that the system can be made utility- interactive to enable the purchase of surplus solar energy from users.

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Appendix

Table A1: Solar PV Module Specification

Manufacturer	**Yingli**
Type	Silicon-Crystalline Technology
Rated Power (Watts)	300
Nominal Voltage (Volts)	24
Nominal Current (Amperes)	9.16
Short Circuit Current (Amperes)	9.6
Open Circuit Voltage (Volts)	40.1
Lifespan (years)	30

Table A2: Solar Battery Bank Specification

Manufacturer	**Hoppecke Solar.Power**
Battery Capacity (Ah)	140
Battery Type	Lead Acid
Nominal Battery Voltage (V)	12
Daily Amperes-Hours needed	1576

Table A3: Voltage Regulator Specification

Manufacturer	**Sunny Island**
Nominal Voltage (V)	Adjustable (202-253)
Maximum Continuous Power (W)	2200
Input Voltage Range (V)	(172.5-264.5)
Charge Controller Type	MPPT
Battery Capacity	(100-10000)Ah
Maximum Battery Charging Current (A)	90
Battery Voltage Range(V)	(16.8-31.5)
Charge Controller Efficiency	93%

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URBAN ENERGY MODELLING APPROACHES: A LITERATURE REVIEW

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Abstract
The energy efficiency of buildings at district and neighborhood level are limited availability, however there are multiple ways followed to evaluate the energy performance at the urban scale. The current methodologies on the energy efficiency strategies for the future cities are various depending on the project. The aim of this paper to provide an overview on two distinct energy modelling approaches: top-down and bottom-up. The paper is based on observations from the case studies following the top-down and bottom-up approaches. Each approach requires different level of information and analysis technique and provides different outcomes with various feasibility. The literature review provides several researches focusing on their targets, strengths and shortcomings.

Key words*: Urban modelling; Bottom-up; Top-down; Building energy consumption*

1. Introduction

Buildings, as the keystones of cities, have an important role for the sustainable development. According to European Commission, buildings are responsible for 40% of global energy consumption [1]. Even though the majority of the performance analyses are on single-building energy strategies, it is crucial to widen the energy saving strategies from building to building stock at a neighborhood and district scale in order to reduce greenhouse gas emissions (GHG) and global energy consumptions.

There are multiple ways followed to evaluate the energy performance at the urban scale. Each methodology requires different level of input data to calculate or simulate the energy efficiency of the buildings. In fact, both inductive and deductive attitudes, either start from detecting and categorizing the group of building to be analyzed or defining the benchmarking to be followed for evaluation of analyses results. The building stock, building archetype and energy benchmarking are important terms and necessary indicators on building and district scale energy efficiency analyses. The building stocks are defined in the category of reference buildings or defined archetypes with the aim of determination of the building energy demand. Building archetypes are the theoretical buildings classified based on their similar attributes, so as to be modeled as a building stock. This approach is especially important for analyzing of the existing buildings as groups and also implementation of several energy scenarios for district retrofits and future energy projects in urban scale [2]. The energy benchmarking models are the tools derived from the energy efficiency indicators to evaluate the usage of energy in a more efficient way for targeted buildings. Energy rating systems, energy policies are considered to qualify and improve the energy efficiency of buildings such as BREEAM (Building Research Establishment's Environmental Assessment Method), the Leadership in Energy and Environmental Design (LEED) [3], Green Building Rating System, 2000-Watt Society Benchmark. They are generated through comparison with standards such as climate conditions, historical energy uses, and following the researches [4]. For instance, a study outlines an energy benchmark for schools in England to determine their energy use intensity by classifying as 'good practice' and 'typical' performance [5].

This paper provides an overview for two main approaches; top-down and bottom-up, so as to analyze the building energy consumption at urban level. The current studies about district level energy efficiency have different phases and follow varied approaches. The district level energy analyze steps for the top-down and bottom-up approaches can be classified under the three main steps with a different order for each approach, to obtain a robust analysis.

- Data collection and investigation: The relevant data and input parameters are collected to be process at the further steps. The corresponding data is gathered for assessing the benchmarks and the energy policies. The relevant information such as site maps, building data, historical archives, are used to estimate the past, current or future energy performance of buildings.
- Identification of variables and modelling: The identification and classification of collected data are variable processes based upon the existing building information. In order to conduct the analysis through modelling, determination of each archetype is required.
- Broadening the model scope at district and neighborhood scale: Each unit of archetypes determines the energy consumption by lightening, cooling and heating demands etc. By using the archetypes, the building stocks are created to estimate the overall energy consumption. The detailing of each archetypes has a crucial role on estimation of an extensive urban energy consumption analyses of the building stock.

Even though both approaches follow similar steps as mentioned above, each of them requires different level of detail of information, uses different modelling techniques and follows different policies and data to estimate the energy consumption at urban scale. A literature review allows to have an exhaustive overview on building and district energy modelling. This paper intends to analyse several researches followed top-down and bottom-up approaches, focusing on their purposes, strengths or shortcomings. After a brief explanation of the each approach, the researches analysed in the context of top-down and bottom-up models separately. The paper concludes with a comparison of the approaches.

2. Modelling Approaches

In general, both top-down and bottom-up approaches are implied to improve the processing of information in methodical way for the different types of fields such as software development, architecture, management etc. This paper mainly presents the implementation of these two approaches for the purpose of the reduction of energy consumption and carbon emission of cities, in the fields of engineering and architectural. Depending on the available data, each building stock model follows a different approach. The top-down models start by analyzing the energy demands of a region and process by dividing them into smaller building stocks [6]. But this approach is challenging when the number of buildings are too much in the region or when the focus is on a specific neighborhood. Unlike the top-down approach, the bottom-up approach requires a building level information to obtain the overall consumption of the focused area. The aim of this section is to outline the descriptions of the top-down and bottom-up modelling approaches over the case studies and previous researches in an effort to better understanding of each technique.

2.1. Overview of the top-down approach

The top-down approach is a deductive method as it is understood from the name of the approach. Swan and Ugursal et al. defines the residential sector as an energy sink in the case of top-down approach, which means determination of energy consumption in the sector is not degraded on account of the individual end-uses [7]. The selection of the approach is conducted by the available input data. In this approach, mainly the long-term changes and historical data including climate conditions, population etc. are considered. So that, the drawback of this approach comes from the absence of the up-to-date data or information of the future changes.

2.1.1 The top-down model

The top-down approach can be used to derive energy benchmarking. As it is shortly described before, benchmarks are an effective way of describing an energy performance of a group of buildings with reference to the building stock.

An example of benchmarking based upon the top-down approach is studied in central Argentina [8]. The study examined 15 school building in Santa Rosa. The top-down approach is implemented to predict the energy consumption of the sampled school buildings and then the comparisons of the energy performances and GHG emissions are made with the other schools in northern hemisphere to obtain the performance benchmarks and regional standards. Similar approach was used to analyse the effect of energy management through a regression analysis [9]. The top-down approaches appraise the overall energy consumptions and energy savings at the national or regional level.

In Europe, Odyssee is a database includes energy saving studies based on top-down approach. The database tool provides also comparison facility between the selected countries. It includes the databases from all EU countries as well as Norway, Switzerland and Serbia [10].
Another example study follows the top-down approach is the annual delivered energy, price, and temperature (ADEPT) with the aim of controlling the household delivered energy and benchmarking the performance of domestic energy sector. The model uses multiple linear regression based on two variables that are temperature and energy price. The study is important for detection of the changes in the energy prices [11].

With the aim of investigation of available energy data and visualisation of environmental performance of the buildings in Goteborg, an energy model has been developed by Tornber and Thuvander [12]. The model uses Geographic Information Systems (GIS) to visualize the energy data related a building stock and follows the top-down approach to estimate the energy use of the stock. The study does not provide the energy consumption of individual buildings.
Saha and Stephenson [13], developed a model for residential buildings in New Zealand by utilizing national level data in order to achieve an energy efficient environment.

The top-down population-based approach is used for a representative study of seasonal diurnal anthropogenic heating profiles of six US cities. [14], [15]. But since the diurnal data for energy survey was obtained from the historical data as is the case of top-down approach, the analysis was limited to change in building technologies and human behaviours.

2.2. Overview of the bottom-up approach

The bottom-up approach is an inductive method depending on the input data used. It is based on the calculation of the individual energy consumptions of particular end-uses and then the total sum of them to represent region.

Swan and Ugursal [7], showed that the bottom-up approach can be divided into two groups; the statistical approach and engineering approach. The statistical approach is based on the historical data. The analyses are made to define the relationship between end-uses and energy consumption. The engineering approach defines the energy consumption of end-uses according to usage of engineering systems. Unlike the top-down approach, the calculation of the energy consumption of buildings does not fully depend on the historical data. But since the amount of the information is more detailed than the information required for the top-down approach, the calculations of bottom-up models can be more challenging. Hence, the bottom-up approach models can be classified in micro-scale studies, the top-down approach studies can be involved in the macro-scale ones considering the level of detail of input data. The bottom-up models generally start with analysing of the energy consumption of a single or a couple of buildings, after the results are extrapolated to the building stock level. Since the bottom-up models analyse individual building in detail, the approach allows to be traced and examined the effects of new technological changes on building stock as they do not rely on historical data alone.

2.2.1 The bottom-up model

A study follows the bottom-up statistical approach for energy retrofit of building that is important for carbon mitigation and energy savings at city scale. The energy retrofit based on Geographical Information System (GIS) is implemented in Rotterdam for approximately 300,000 dwellings by using a multiple linear model to estimate the natural gas and electricity consumption of the city. For the study, the bottom-up engineering approach provided a fast and simple way of the prediction of the energy consumption at a large scale [16].

Protopapadaki et al. [17] examined the dynamic behavior of a building stock in Belgium. The research provides a comparison of the two typologies to determine the effects of the different identifications of dwellings in the building stock and the results of those variations on the model outcome. The results of the typologies show the significant difference in the case of comparison of the dwellings. The study emphasizes the importance of the sufficiency of the provided database for a bottom-up approach model.

Despite the fact that, many studies focus on energy savings and GHG reduction by retrofitting of building stocks, it is required to consider the LCA of a building stock to obtain a comprehensive assessment. LCA allows to estimate the energy efficiency of a building within its lifecycle including from production, transportation and installation to the material for retrofitting [18]. A case study in Luxemburg is developed a data model for life cycle environmental assessment of a building stock retrofitting by following the bottom-up approach. An elaborative archetype technique is used by the utilization of geospatial data and a spatio-temporal database. The study provides a base for retrofitting measurements at urban scale also gives the local authorities the opportunity to simulate different retrofitting scenarios on the building stock [19].

Fonseca and Schlueter [20], developed a new hybrid model with the integration of GIS for the city of Zug in Switzerland, that collects the data from local archetypes as input data for a dynamic energy model. The paper is an example for the integration of two subcategories of the bottom-up approach, that are statistical and analytical methods. The database of detailed archetypes is provided from the combination of these two methods. In this study, 172 building archetypes are grouped into sixteen occupancy types, six construction periods and six renovation period. Addition to analyzing the current energy performance of the archetypes, the model provides a dynamic urban zoning analysis for the urban planners in the case of an urban transformation by creating different urban scenarios for any possible urban development. For this study, 10 different scenarios were implemented and the potential energy consumptions for each scenario were calculated for the implemented zone.

The Urban Modeling Interface (UMI) is an urban modelling platform, developed by Sustainable Design Lab at MIT with the aim of the environmental performance of the neighborhoods and cities respecting building energy, daylighting and outdoor comfort, and walkability with the bottom-up approach [21].

Wang et al. [22], presented a building stock modelling based on bottom-up modelling approach for the buildings in Switzerland. The CESAR modelling tool was used to simulate three types of districts. The bottom-up approach is used to evaluate the future building performance and climate change scenarios. The results were discussed in this paper based upon the introduced transformation scenarios and their efficiency on achieving targets for primary energy and GHG emissions until 2050.

3. Comparison Of The Top-Down And Bottom-Up Approaches

Depending on the available data and the project scale, the top-down and bottom-up approaches represent many similarities and differences in terms of required information as input data and the results as output data [7].

The studies are analyzed in this paper for the top-down approach generally based on benchmarking. As it is also seen from the studies mentioned above, the top-down approach uses the historical data as input for the analyses which ensure an easily improvable large-scale project. But at the same time, the top-down model relies on antecedent information and does not provide the possible chances or future technologies.

The bottom-up models analyzed in this paper are based on energy analysis and modelling. The reason is that, the energy models require a detailed analyse process and technical information unlike the top-down approach which utilizes macro level parameters. Energy bills or surveys can be others source of the bottom-up models to evaluate the energy consumption of district buildings. Determination of the effects of future implication scenarios or technological changes requires the usage of bottom-up model.

Detailed information issue is one of the main distinctions between two approaches which has both negative and positive effects. While requiring more detailed information provides more reliable results, but also at it can be challenging in the case of lacking adequate information. Moreover, relying on the historical data can be seen as a negative feature for the projects were renovated in the recent past or planning to be renovated in the future. There are also some models are introduced as a mixed model arising from the integration of the bottom-up and top-down models [23], [24]. The models incorporate the macroeconomic parameters with future technological changes [25].

All in all, it can be deduced that the combination of the two modelling approaches can become a very important tool in the case of need an alteration only for the particular buildings by taking advantage of bottom-up model and using the rest of the avaible data comes from the top-down model without having any change.

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