PERFORMANCE EVALUATION OF ENERGY-SAVING BULBS IN SELECTED NIGERIAN LOCATIONS WITH ARTIFICIAL NEURAL NETWORK MODELLING

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Abstract

The performance evaluation of energy-saving bulbs in the Nigerian market is crucial in assisting energy auditing, which is beneficial to producers and consumers of electricity. Specifically, the high-power bills issued monthly by Electricity Distribution Company in most parts of Nigeria have made Nigerians in our various domestic homes embrace the latest lighting technology that consumes less energy.In this study, lighting system data were obtained from twenty-four households from different geographical zones in Nigeria. The performance evaluation of compact fluorescent light(CFL) bulbs was investigated and the observation was predicted with artificial neural networks (ANN) to enhance informed policy formulation and decision-makingResults showed that CFL bulbs givehigh-quality light that is cost-effective and environmentally friendly. ANN predicted the observation with high accuracies.

Keywords:Energy-saving,technology, artificial neural networks, compact fluorescent light, cost-effectful, environmentally friendly

1.0 Introduction

In accordancewith the International Energy Agency (IEA) report, annualper capital electricity consumption was 140 kWh in 2015, or roughly 12 kWh per capital per month. By the year 2030, Nigeria's population is expected to increase in population which will invariablylead to significant energy demand. Therefore, there is a necessity for saving energy. Over the past four decades, meeting the electricity demand of the population has been a major policy goal for Nigeria but this has remained unachievable for several reasons such as poor energy supply infrastructure, and poor lighting system policy among others; therefore, the sparingly available electricity should be efficiently utilized by the energy-saving appliances (Perez-Lombard,2008). An important area of consideration to minimize electric wastage is the lighting system appliances in various households. This is the consequence of the preference of the citizens to light up their facilities throughout the day as a result of negligence and throughout the night for security consciousness.

Technologicaladvancement has brought about innovations in lighting systemsby improving the quality of light and energy saving of the bulbs in the lighting system.This lighting system plays a vital role in the economic growth and security of Nigeria. The early generation of lighting systems were incandescent bulbs, fluorescent bulbs, and halogen lamps. Recently, the improvedlighting system Compact Fluorescent Lamp (CFL) was introduced and had been in existence since the early 1980s (Elphick et al., 2010).CFLs are commonly referred toas energy-saving lamps because they convert a higher percentage of consumed electricity into light. CFLs consume 2 to 2.5 times lesser energy for the same lumen (brightness) output as the other types and may last up to twice as long as other bulbs (Olaniyan, 2018).

The predictive estimator is an important condition for monitoring, decision making, and policy formulation. The nature of the lighting-related investigation suggests that historical data will be generated; therefore, historical predictive modelling could be the best representation of the observation. A number of historical modelling method exists; however, the artificial intelligent methods are specifically useful for quick investigation, analysis, implementation, and use. They are easily built into soft sensors. Artificial intelligence (AI) approaches such as Artificial Neural Networks (ANN) is a structural relation between nodes and layers linked together for process modelling. ANN is an effectivecomputing technology (Okwonko*et al*., 2021; Kaveh *et al*., 2018; Harsh *et al*., 2016), due to itshigh efficiency in complex and non-linear processes, and simulating variables. ANN model is formed using experimental data under consideration and predicts the data with high accuracy. The merit of the ANNmodelling approach over mathematical modelling includes the real-time preservative measurement, non-sensitivity to poor data quality; and reduced assumptions (Onwude*et al.,* 2016). ANN modelling can process incomplete information through perception (Buragohain, 2009), and modelled several inputs and outputs together in a single structure (Wang *et al.,* 2020). It can combine other variable points not tested and predict their output with high accuracy, thus saving the cost and time that could be used for the optimization of the process (Adeyi*et al.,* 2020).

The specific aim of this study was to investigate the performance evaluation of CFL bulbs and predict the observation with ANN to enhance informed policy formulation and decision-making in selected Nigerian localities.

2.0 Materials and methods

2.1 *Materials*

Mostly utilized bulbs in Nigeria as confirmed by various sellers include Torch AKT MODI NOMI and Goodman; and are therefore used for the performance evaluation in this study. Torch (11, 15, 40 watts), Tico (18, 20, 26 watts), Osram (12, 15, 23 watts), Goodman (11, 15, 26 watts),MODI (11 and 26 watts), AKT (9, 15 and 26 watts), and Spring Lamp (9, 13 and 18 watts) were purchased at SilvoElectrical Stores Enterprises, Muritala Road, Ilorin, Nigeria, and Jezico Electrics Limited, Taiwo Road, Ilorin, Nigeria.

Twenty-four (24) households were randomly selected from a state in each of the six geopolitical zones using an official roster of households provided by the National Bureau of Statistics to yield 144 households with 682 residents. Table 1 identifies the specific localities from which households were drawn. Table 2 presents the list of lighting appliances used in the selected households.

Table 1:households' localities

		Number of Selected Households	
Zone	**State**	**Rural**	**Urban**
North Central	Plateau	12	12
North East	Gombe	12	12
North West	Kaduna	12	12
South West	Oyo	12	12
South East	Enugu	12	12
South-South	Cross River	12	12
Total number of households		**144**	

Table 2:lighting appliances used in the selected households

		Power Rating (Watts)			
Category	**Appliances**	**Range**	**Mean**	**Mode**	**Median**
Lighting	Incandescent Lamps	60 -100	80	80	80
	Fluorescent Lamps	9 – 18	10	9	9
	Compact Fluorescent Lamps (CFL)	3 – 85	11	5	8

Data sources: Konga Online; US Department of Energy; Wholesale solar Inc. (www.wholesalesolar.com); mean, mode, and median are taken as the midpoint of the range.

2.2 Methods

The effect of the types of CFL, CFL usage time, and CFL wattage on the bulb lamination, bulb temperature, and current utilized was investigated as the representative of the performance evaluation. Bulbs of different wattages were experimented with using a varying voltage, which ranges from 160 – 280-volt at 10-volt incremental intervals over a period. The light meter was used to measure the brightness of the bulbs at each voltage input interval, and thermometers were used to measure the temperature of the bulb at each voltage input interval. Astopwatch was employed to determine and monitor the duration of time at each interval.

2.3 *ANN experimental modelling*

ANN is made up of simple units of interconnected neurons thatare used for data approximation, classification, and pattern recognition among others. The neuron relationship guides against failure. The associated inputs and outputs in the structure of ANNare scalar. Its operation starts when the input move through the neuron and the neuron multiplyits strength by its weight to form a product. The weighted inputs areadded individually to the bias which is the equation constant. The parameters of ANN are self-adjusting during thetraining until a desirable behaviour is achieved. The selection of appropriate topology is crucial to ANN model accuracy.

In this study, the optimum topology was investigated by considering correlation coefficient (R)and root mean square error (RMSE). The closer the R to unity,and the closer the RMSE to zero value; the more accurate the model is. The ANN simulation was run in triplicate and the mean is reported here as the result. Prior to modelling, the experimental data were normalization enhance simulation accuracy and speed in accordance with the method of Kavehet al., (2018) using Eqn. 1

$$X_n = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

where,$X_n$depicts the normalized value of the specific experimental data, $X_i$depicts the value of each experimental data,X_{max} depicts the maximum value for the specific experimental data, andX_{min} depicts the minimum value of the specific experimental data.The data were partitioned into training, testing, and validation data in conformity with the basic requirement for ANN modelling.

3.0 Results and Discussions

3.1 Results of Experimented CFL Bulbs

CFLbulbs of five different types wereutilized for the investigation and the reports are summarized in Table 3 – 17.

Table 3:**40 watts/equivalent watt is 200W for incandescent**
6years lamp life Lifetime: -8000 hours
Wide range of input voltage: - 170V – 240V

	Luminance x100 (Lux)			**Temperature (° c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	95	94	103	28.9	30.9	30.7	0.155	48.0
170	111	124	102	30.8	28.7	29.9	0.160	48.0
180	146	150	140	28.9	28.9	29.0	0.157	48.0
190	139	142	142	29.2	30.5	34.2	0.157	48.0
200	153	148	166	31.6	34.3	30.8	0.156	48.0
210	163	166	166	32.7	30.4	35.8	0.160	48.3
220	177	174	176	31.0	34.6	31.0	0.161	48.3
230	180	171	170	32.8	30.6	33.9	0.160	48.3
240	210	205	224	31.7	32.2	33.6	0.161	48.3
250	232	229	221	31.2	33.8	31.5	0.173	48.3
260	218	223	221	32.9	31.6	34.7	0.161	48.3
270	225	238	234	28.8	30.7	33.1	0.170	48.3
280	240	235	248	33.0	35.6	32.7	0.171	48.3

Table 4: 18 watts/equivalent watt is 90W for incandescent
6years lamp life Lifetime: - 8000 hours
Wide range of input voltage: -170V – 250V Best efficiency from 220V – 240V

	Luminance x100 (Lux)			**Temperature (° c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	42	49	67	28.4	31.2	30.0	0.087	48.0
170	54	64	81	30.8	28.9	29.8	0.092	48.0
180	98	97	100	28.5	29.1	28.9	0.092	48.0
190	101	111	114	29.4	30.4	33.9	0.092	48.0
200	113	100	111	31.5	33.5	30.9	0.092	48.0
210	110	113	102	32.4	30.6	34.1	0.097	48.3
220	101	100	104	30.7	33.4	31.3	0.097	48.3
230	117	108	118	29.4	30.9	30.0	0.095	48.3
240	116	122	120	31.9	31.4	33.3	0.095	48.3
250	125	118	125	30.8	33.5	31.0	0.099	48.3
260	127	123	135	32.8	31.5	34.7	0.100	48.3
270	148	145	143	29.1	30.6	33.2	0.103	48.3
280	146	154	160	32.2	35.6	31.8	0.106	48.3

Table 5: 15 watts/equivalent watt is 75W for incandescent

6years lamp life Lifetime: - 8000 hours

Wide range of input voltage: -170V – 250V Best efficiency from 220V – 240V

	Luminance x100 (Lux)			Temperature (° c)			Observation	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	84	74	72	28.4	29.3	29.9	0.082	48.0
170	91	94	89	30.7	29.2	29.9	0.087	48.0
180	97	105	131	28.4	29.0	28.9	0.085	48.0
190	116	128	120	29.3	30.4	33.1	0.084	48.0
200	140	119	126	31.5	32.8	30.8	0.083	48.0
210	129	138	124	32.4	30.6	33.4	0.086	48.3
220	148	142	152	30.9	32.2	31.1	0.086	48.3
230	136	144	139	29.3	30.3	30.0	0.085	48.3
240	146	152	148	32.3	31.0	33.0	0.086	48.3
250	170	185	177	30.7	33.4	31.0	0.090	48.3
260	168	173	167	32.4	31.4	34.0	0.086	48.3
270	171	178	173	29.3	30.3	32.3	0.093	48.3
280	178	185	175	32.1	35.5	31.1	0.091	48.3

Table 6: 11 watts/equivalent watt is 55W for incandescent

6years lamp life Lifetime: - 8000 hours

Wide range of input voltage: - 170V – 250V Best efficiency from 220V – 240V

	Luminance x100 (Lux)			Temperature (° c)			Observation	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	14	21	31	28.4	30.3	29.8	0.064	48.0
170	36	42	41	30.8	29.5	30.3	0.064	48.0
180	42	42	47	28.2	29.1	28.6	0.064	48.0
190	54	57	55	29.4	30.3	32.3	0.064	48.0
200	55	53	52	31.7	32.4	30.1	0.063	48.0
210	56	56	53	32.0	30.7	32.9	0.067	48.3
220	56	63	65	31.8	31.5	30.7	0.066	48.3
230	66	61	67	29.1	30.3	30.1	0.065	48.3
240	65	64	65	32.0	30.9	32.9	0.067	48.3
250	70	69	71	30.6	33.4	30.8	0.070	48.3
260	75	73	69	32.5	31.3	33.9	0.067	48.3
270	79	76	77	29.7	30.0	32.3	0.072	48.3
280	78	77	76	32.2	35.4	31.3	0.071	48.3

Table 7: AKT bulbs of 9 watts/save energy of 80% more than the normal bulb
Live longer than 3 years to 5.5hours per day calculated ignition
Input voltage range: - 220V – 240V/50 – 60Hz

	Luminance x100 (Lux)			**Temperature (^{o} c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	42	55	41	32.1	33.0	32.8	0.039	48.34
170	50	47	51	33.6	34.4	34.0	0.040	48.34
180	51	59	58	28.5	33.7	29.5	0.039	50.86
190	60	62	71	31.8	29.8	32.0	0.039	49.93
200	64	62	61	28.0	31.7	32.6	0.040	49.93
210	73	74	83	33.4	30.4	33.8	0.040	50.52
220	81	77	75	33.4	33.1	30.7	0.040	50.52
230	77	79	83	32.8	30.5	33.9	0.041	50.52
240	75	74	80	28.7	36.0	30.0	0.044	50.52
250	85	84	93	34.1	31.5	34.2	0.044	50.52
260	85	90	86	33.9	35.9	35.0	0.042	50.52
270	89	86	84	28.7	34.2	31.4	0.046	48.33
280	114	103	103	34.5	31.3	37.0	0.045	48.34

Table 8: AKT bulbs of 15 watts/save energy of 80% more than the normal bulb
Live longer than 3 years to 5.5hours per day calculated ignition
Input voltage range: - 220V – 240V/50 – 60Hz

	Luminance x100 (Lux)			**Temperature (^{o} c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	123	140	153	32.0	34.5	34.1	0.076	48.34
170	136	129	140	34.1	34.0	34.2	0.078	48.34
180	152	141	140	28.9	34.8	30.8	0.076	50.86
190	151	169	166	32.5	30.1	32.0	0.074	49.93
200	171	173	183	28.3	31.8	33.8	0.075	49.93
210	197	190	198	33.5	30.9	35.0	0.076	50.52
220	197	192	189	32.9	33.2	30.9	0.077	50.52
230	194	195	190	32.8	30.9	35.2	0.076	50.52
240	194	207	206	29.1	30.4	32.5	0.083	50.52
250	216	214	218	34.0	31.5	34.2	0.088	50.52
260	216	221	211	34.1	35.5	35.1	0.083	50.52
270	201	230	233	29.2	34.7	32.3	0.093	48.33
280	245	246	242	34.6	31.4	39.7	0.091	48.34

Table 9: AKT bulbs of 26 watts/save energy of 80% more than the normal bulb

Live longer than 3 years to 5.5hours per day calculated ignition

Input voltage range: - 220V – 240V/50 – 60H_z

	Luminance x100 (Lux)			Temperature (° c)			Observation	
Voltage Input (V)	At start-up	After 30 mins	After 1 hour	At start-up	After 30 mins	After 1 hour	Current (A)	Frequency (Hz)
160	234	257	243	31.7	34.7	34.3	0.126	48.34
170	361	259	288	34.1	34.0	34.3	0.129	48.34
180	372	290	298	29.0	35.5	31.0	0.132	50.86
190	305	304	292	33.0	30.6	31.6	0.126	49.93
200	267	301	293	29.8	33.8	32.5	0.126	49.93
210	308	309	300	33.2	31.0	34.4	0.129	50.52
220	302	300	299	33.3	34.1	31.3	0.131	50.52
230	310	321	320	32.7	34.1	34.5	0.133	50.52
240	331	346	334	29.4	37.3	32.0	0.147	50.52
250	350	357	375	33.5	33.2	34.8	0.144	50.52
260	390	403	395	33.9	36.4	35.2	0.140	50.52
270	378	404	401	31.4	35.1	33.3	0.157	48.33
280	411	422	427	34.7	31.9	39.7	0.150	48.34

Table 10: 40 watts/equivalent watt is 200W for incandescent

6years lamp life   Lifetime: - 8000 hours

Wide range of input voltage: - 170V – 240V Best efficiency from 220V – 240V

	Luminance x100 (Lux)			Temperature (° c)			Observation	
Voltage Input (V)	At start-up	After 30 mins	After 1 hour	At start-up	After 30 mins	After 1 hour	Current (A)	Frequency (Hz)
160	154	145	147	31.2	34.6	34.0	0.167	48.34
170	161	159	187	33.0	34.6	34.3	0.182	48.34
180	187	190	185	29.2	35.1	31.3	0.184	50.86
190	186	198	206	31.8	31.4	32.7	0.175	49.93
200	174	173	195	30.1	33.3	32.5	0.180	49.93
210	196	200	205	32.4	31.3	32.5	0.176	50.52
220	205	211	201	33.7	33.4	32.2	0.179	50.52
230	207	204	211	32.3	31.7	33.5	0.181	50.52
240	207	222	227	29.8	37.9	30.9	0.196	50.52
250	229	230	244	33.3	34.0	34.8	0.201	50.52
260	246	243	241	33.4	35.1	34.9	0.190	50.52
270	237	251	245	32.0	35.3	34.0	0.213	48.33
280	281	276	258	35.2	32.6	39.6	0.211	48.34

Table 11: Goodman bulbs of26 watts/equivalent to 8 Incandescent bulbs
Saving energy by 80% compared with the incandescent bulb
6times longer service life; use standard socket types; instant on; low heat emission
Lifetime: - 8000 hours   Temperature: - 5– 40ºc
Input voltage range: - 220V – 240V/50 – 60Hz

	Luminance x100 (Lux)			Temperature (º c)			Observation	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	337	320	322	29.7	30.2	35.7	0.155	48.34
170	351	362	369	29.9	31.7	35.3	0.154	48.34
180	360	376	377	33.2	37.0	32.8	0.157	48.34
190	373	378	380	33.7	32.0	31.7	0.155	48.34
200	388	392	421	35.2	37.8	31.9	0.159	48.34
210	412	428	419	28.5	35.7	32.1	0.152	48.34
220	457	449	446	32.5	33.6	34.2	0.152	48.34
230	460	478	467	33.7	30.8	37.7	0.157	48.34
240	481	486	484	35.2	37.4	34.5	0.158	48.34
250	490	477	471	36.1	34.0	36.1	0.157	48.34
260	524	516	530	35.4	37.7	34.6	0.163	48.34
270	534	532	533	27.8	32.0	38.4	0.165	48.34
280	540	560	539	35.0	37.7	33.8	0.172	48.34

Table 12:Goodman bulbs of 15 watts/equivalent to 8 Incandescent bulbs
Saving energy by 80% compared with the incandescent bulb
6times longer service life; use standard socket types; instant on; low heat emission
Lifetime: - 8000 hours   Input voltage range: - 220V – 240V/50 – 60Hz
Temperature: -   5 – 40ºc

	Luminance x100 (Lux)			Temperature (º c)			Observation	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	106	112	104	29.2	30.3	30.5	0.080	48.34
170	111	113	116	30.6	32.2	35.5	0.081	48.34
180	115	227	121	33.6	36.8	34.6	0.081	48.34
190	123	126	129	33.9	31.6	32.5	0.081	48.34
200	125	132	152	34.2	37.2	32.5	0.083	48.34
210	138	140	134	28.2	34.6	30.6	0.082	48.34
220	143	153	163	32.8	33.1	33.9	0.079	48.34
230	160	162	164	33.9	30.3	36.7	0.082	48.34
240	163	163	162	35.2	37.1	35.1	0.083	48.34
250	165	168	164	35.4	33.6	35.7	0.083	48.34

260	170	167	173	35.3	37.3	34.0	0.085	48.34
270	164	171	172	28.2	31.5	38.2	0.086	48.34
280	180	191	193	34.8	37.3	33.3	0.090	48.34

Table 13: Goodman bulbs of 11 watts/equivalent to 8 Incandescent bulbs
Saving energy by 80% compared with the incandescent bulb
6times longer service life; use standard socket types; instant on; low heat emission
Lifetime: - 8000 hours Input voltage range: - 220V – 240V/50 – 60Hz
Temperature: - 5 – 40ºc

	Luminance x100 (Lux)			**Temperature (º c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	95	109	119	29.2	30.4	34.9	0.064	48.34
170	120	124	121	31.0	30.2	35.0	0.065	48.34
180	128	121	129	34.0	36.3	32.6	0.066	48.34
190	140	143	149	33.8	31.7	32.5	0.066	48.34
200	143	144	143	34.9	36.3	32.6	0.068	48.34
210	149	146	144	28.2	34.3	32.5	0.067	48.34
220	147	140	152	32.8	33.2	33.8	0.066	48.34
230	149	154	162	33.8	29.8	36.4	0.068	48.34
240	169	163	170	35.7	36.9	33.6	0.069	48.34
250	175	174	171	35.9	33.4	35.8	0.068	48.34
260	185	182	184	35.6	36.7	33.9	0.070	48.34
270	180	183	182	28.7	31.1	36.7	0.071	48.34
280	182	181	182	36.1	36.9	32.7	0.073	48.34

Table 14: Modi bulbs of 18 watts/power consumption 20% of the incandescent lamp
Life time: - 8000 hours Voltage: - 220V – 240V/50 – 60Hz Current: - 0.14A (0.15A)

	Luminance x100 (Lux)			**Temperature (º c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	63	58	52	29.1	30.9	29.7	0.051	48.34
170	50	58	62	30.0	29.6	30.0	0.051	48.34
180	58	60	72	30.6	29.7	30.0	0.052	48.34
190	61	68	56	30.3	31.2	30.8	0.053	48.34
200	61	62	52	31.0	30.6	30.4	0.056	50.82
210	77	83	86	28.4	32.3	31.7	0.054	49.29
220	92	91	87	31.8	32.9	32.6	0.055	50.34
230	90	94	100	32.3	32.8	31.6	0.056	49.96
240	103	96	98	32.5	32.7	35.1	0.056	50.73
250	102	103	100	33.4	33.6	33.8	0.055	48.34
260	102	101	102	33.7	33.3	32.9	0.056	48.34
270	108	106	105	33.1	31.5	32.4	0.056	48.34

280	103	107	104	32.8	32.0	32.6	0.057	48.34

Table 15: Modi bulbs 26 watts/power consumption is about 20% of the incandescent lamp

Life time: -8000 hours Voltage: - 220V – 240V/50 – 60Hz Current: - 0.21A

	Luminance x100 (Lux)			**Temperature (° c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	80	84	86	29.6	31.1	29.9	0.100	48.34
170	77	88	86	30.2	30.1	30.3	0.100	48.34
180	92	91	93	30.9	30.0	30.1	0.100	48.34
190	98	93	87	31.1	30.8	31.0	0.100	48.34
200	93	96	100	31.3	30.8	30.9	0.098	50.82
210	103	107	107	29.3	32.8	31.9	0.098	49.29
220	113	123	120	32.1	34.3	32.3	0.100	50.34
230	121	126	125	31.1	32.8	32.4	0.103	49.96
240	127	129	126	32.5	32.6	33.7	0.114	50.73
250	128	127	126	33.5	34.1	33.9	0.112	48.34
260	136	142	140	33.8	32.7	32.8	0.114	48.34
270	146	142	144	33.0	32.0	32.3	0.117	48.34
280	150	151	150	33.4	34.0	33.8	0.119	48.34

Table 16: Nomi bulbs of 15 watts/save energy 4 times than the normal bulb
Lumen is 8 times than normal bulb, life is 8 times longer than normal bulb

Lamp life: -6 years Lifetime: - 6000 hours Voltage: - 220V – 240V/50 – 60Hz

Low voltage start-up: - 150V

	Luminance x100 (Lux)			**Temperature (° c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	87	82	74	29.4	30.9	30.0	0.059	48.34
170	51	50	68	30.0	29.8	30.3	0.058	48.34
180	76	60	62	30.9	29.9	30.0	0.057	48.34
190	70	68	85	30.6	31.0	30.9	0.057	48.34
200	75	73	71	31.1	30.6	30.5	0.059	50.82
210	115	132	131	28.9	32.7	31.7	0.060	49.29
220	130	137	131	31.8	32.7	32.3	0.058	50.34
230	135	140	139	32,3	32.8	32.0	0.059	49.96
240	147	147	152	32.6	32.8	34.8	0.058	50.73
250	150	160	157	33.5	33.7	33.7	0.058	48.34
260	164	173	170	33,5	33.5	32.8	0.058	48.34

270	177	180	185	33.0	32.4	32.3	0.059	48.34
280	187	185	189	32.4	32.9	33.0	0.061	48.34

Table 17: Nomi of 26 watts/save energy 4 times than the normal bulb

Lumen is 8 times than normal bulb, life is 8 times longer than normal bulb

Lamp life: - 6 years Lifetime: - 6000 hours Voltage: - 220V – 240V/50 – 60Hz

Low voltage start-up: - 150V

	Luminance x100 (Lux)			**Temperature (^{o} c)**			**Observation**	
Voltage Input (V)	**At start-up**	**After 30 mins**	**After 1 hour**	**At start-up**	**After 30 mins**	**After 1 hour**	**Current (A)**	**Frequency (Hz)**
160	82	81	76	28.8	30.6	29.7	0.065	48.34
170	89	82	92	30.0	29.5	29.8	0.063	48.34
180	98	104	105	30.5	29.6	29.9	0.064	48.34
190	111	103	115	30.3	31.4	30.8	0.063	48.34
200	124	109	114	31.0	30.8	30.0	0.065	50.82
210	120	128	124	27.7	32.2	31,4	0.064	49.29
220	125	139	140	31.7	33.2	32.2	0.067	50.34
230	162	156	152	34.0	32.7	31.8	0.064	49.96
240	160	163	156	32.4	33.0	35.3	0.065	50.73
250	164	165	170	33.3	33.8	33.7	0.064	48.34
260	173	170	174	33.3	32.6	32.8	0.063	48.34
270	180	182	183	31.4	31.4	32.5	0.064	48.34
280	203	202	207	32.3	32.4	32.3	0.065	48.34

It can be inferred that the brightness of the CFL bulbs is directly proportional to the input voltage, that is, the brightness increases with an increase in its voltage input. In addition, the brightness of the CFL bulbs increase as the wattage of the bulb varies increasingly.Moreover, there is expected fluctuation of current, which results in the sharp falls experienced in the different CFL bulbs, being used. As the luminance of the CFL bulb is been an experiment, the temperature is also noticed. It is evident that the temperature increases with an increase in input voltage, which results in the generation of more heat as the wattage of the CFL bulb, varies. In addition, there is continuous variability of both increase (rising) and decrease (falling) of temperature apparently visible in all of the wattage, which falls at almost the same period.

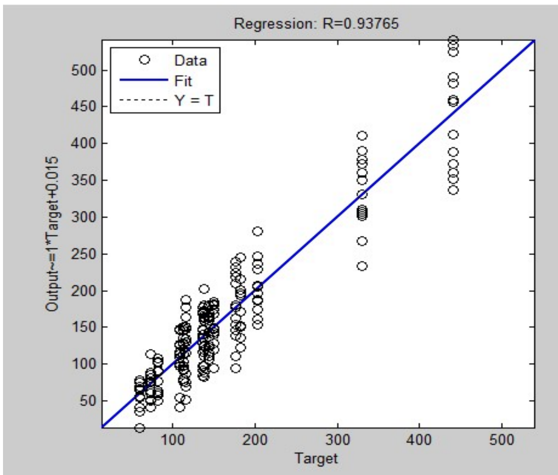
3.2 ANN simulation

The simulation was performed by considering the effect of each applied ANN topology on the efficiency of the model formed. Table 5 showed that for the bulb illumination model, topology 3-1-10-1 had the least epoch number while topology 3-1-8-1 had the highest model accuracy. In the case of the effect of bulb type, usage time, and bulb wattage on the bulb temperature, the least epoch number was found at topology 3-1-6-1 while the highest model accuracy was found at topology 3-1-2-1. In addition, the model for current utilized had the least epoch number at topology 3-1-7-1 while the highest model accuracy occurred at topology 3-1-1-1. Usually, a topology with the least epoch number is desirable because it signifies that little computer memory was utilized during modelling which in turn reduces the computational cost both in model development and utilization while the model with a high R value is also desirable for accurate prediction.

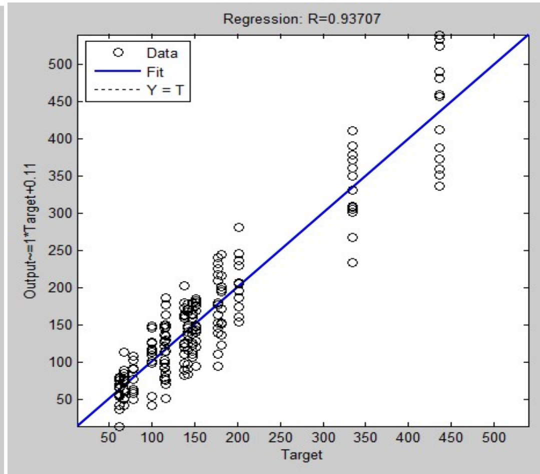
Table 18: ANN simulation

S/N	Performance indicator	Topology	Epoch No	R
1	Bulb Illumination	3-1-1-1	24	0.9135
2	Bulb Illumination	3-1-2-1	15	0.9165
3	Bulb Illumination	3-1-3-1	15	0.9007
4	Bulb Illumination	3-1-4-1	11	0.9095
5	Bulb Illumination	3-1-5-1	13	0.8798
6	Bulb Illumination	3-1-6-1	42	0.9213
7	Bulb Illumination	3-1-7-1	20	0.8732
8	Bulb Illumination	3-1-8-1	11	0.9376
9	Bulb Illumination	3-1-9-1	15	0.7681
10	Bulb Illumination	3-1-10-1 14		0.9085
11	Bulb temperature	3-1-1-1	10	0.8899
12	Bulb temperature	3-1-2-1	25	0.9370
13	Bulb temperature	3-1-3-1	11	0.7029
14	Bulb temperature	3-1-4-1	13	0.9188
15	Bulb temperature	3-1-5-1	13	0.7123
16	Bulb temperature	3-1-6-1	8	0.7618
17	Bulb temperature	3-1-7-1	13	0.9126
18	Bulb temperature	3-1-8-1	11	0.8930
19	Bulb temperature	3-1-9-1	9	0.8920
20	Bulb temperature	3-1-10-1 18		0.9260
21	Current utilized	3-1-1-1	18	0.9345
22	Current utilized	3-1-2-1	15	0.8505
23	Current utilized	3-1-3-1	20	0.8485
24	Current utilized	3-1-4-1	10	0.8924
25	Current utilized	3-1-5-1	11	0.8842
26	Current utilized	3-1-6-1	9	0.9124
27	Current utilized	3-1-7-1	6	0.8449
28	Current utilized	3-1-8-1	8	0.9023
29	Current utilized	3-1-9-1	9	0.8089
30	Current utilized	3-1-10-1 51		0.9002

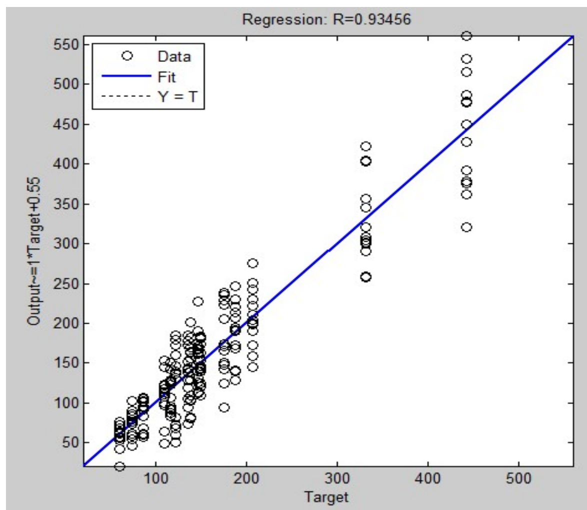
The graphical representation of the best topology prediction of bulb illumination, bulb temperature and current utilized is represented in Fig. 5.



(a)



(b)



(c)

Figure 6: ANN (a) bulb type, (b) bulb temperatureand (c) current utilized

The efficiency of the best ANN topology in Fig. 6 (b) shows a strong relationship between the experimental and simulated data as observed from the cluster of data around the regression lines. This shows that little difference existed between the experimental and ANN simulated data.

4.0 Conclusion

This investigation presented a performance evaluation of Compact Fluorescent Lamp (CFL). In the analysis, it was observed that:

1. Despite subjecting the CFL bulbs to a very high voltage input which is far above the range of voltage supplied to our communities, all the CFL bulbs been used still stood the test of time without failure at which any further increase in voltage input above 290 V might lead to its failure.
2. CFL is a better option for adoption due to its high efficacy and longer lifetime.
3. Lumen output of CFL bulbs should be considered and not their watts when consumers are choosing/purchasing their household CFL bulbs.
4. The replacement of earlier mentioned bulbs with energy-saving bulbs (CFL) is useful for the consumer as well as for the utility.
5. ANN model was accurate in modelling the observation

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