On the Bio-inspired Computational framework for exploring the production and management of sustainable energy - IEEE

Olugbenga Oluwagbemi
Johns Hopkins University

Folakemi Oluwagbemi
Covenant University Ota Ogun State, Nigeria

Olaitan O. Afolabi
Elizade University

Olaoluwa Bamiduro
Federal University Lokoja

Eighth IEEE International Conference on Innovative Computing Technology INTECH 2018, UK Centre for Carnival Arts, next to Postgraduate Centre, University of Bedfordhshire, Luton, , 3 St Mary's Rd, Luton LU1 3JA, near London, UK

On the Bio-inspired Computational framework for exploring the production and management of sustainable energy

*[1]Olugbenga Oluwagbemi
Department of Mathematical Sciences, Stellenbosch University, Stellenbosch, South Africa
olugbenga.oluwagbemi@fulbrightmail.org

[2]Folakemi Oluwagbemi
Department of Information Technology
Salem University
Lokoja, Nigeria
folakemi.majek@gmail.com

[4]Olaoluwa Bamiduro,
Department of Computer Science
Federal University Lokoja
Lokoja, Nigeria
olaoluwab48@gmail.com

[3]Olaitan Afolabi
Department of Information and Communication Technology, Faculty of Engineering, Elizade University, Ilara Mokin, Ondo State, Nigeria
olaitanmails@yahoo.co.uk

***Abstract*— In this paper, we proposed and designed a bio-inspired integrated cost-effective computational framework for generating and managing sustainable energy from biologically-related sources. The objective is to maximize the utilization of natural and biological sources of energy, for energy production among developing countries.**

First, we studied previously known sources of clean and sustainable energy. Second, we conducted a comparative study among these previously known energy sources. We conclude that these previously known energy sources are expensive and have the tendency to exhibit unimpressive performances in their distribution and management. In order to guarantee excellent performance and at a relatively cheaper rate, we proposed and designed a bio-inspired computational framework of integrated energy sources and bio-solar cells, to provide energy for local communities in developing countries. Third, we simulated an intelligent energy distribution management system for a typical residential unit within the proposed prototype of the bio-inspired computational framework. We provided justification that our framework has better potentials in terms of management, than existing energy sources.

***Keywords*— Biocomputing, computational framework, energy, electricity, bio-solar cells, developing countries**

I. Introduction

Energy plays a very significant role in the day-to-day activity of the human life. It is interesting to note that there are different kinds of energy sources. The different sources of energy include biomass [1, 2, 8, 9, 10, 11], biofuel, fossil fuel, solar [6, 7, 12]. Others include: nuclear power [13, 14, 15], hydroelectric [16, 17, 18, 19], geothermal [20, 21, 22], solar [23, 24] and others such as wind, and wave. Studies have shown over the years that it is possible to generate energy from biomass [3]. It has been proven that world crop residue can help generate biofuel [4]. In fact, Hoogwijk and colleagues [5] conducted a study where they were able to project the technical and geographical potential inherent in energy crops to generate biomass energy between the years 2050 – 2100. They analyzed these potentials as an alternative source of electricity and energy, given different land-use scenario. From their study [5], they envisaged that the geographical potential of land that have been excluded from agricultural purposes, is the most likely greatest contributor. They also predicted that, land that have been excluded from agricultural purposes, will have a geographical potential, of a range of130 EJyr-1 to 410 EJyr-1 for the year 2050. In a similar fashion, the predicted geographical potential of excluded lands for year 2100 ranged from 240 to 850 EJ yr−1. The researchers discovered significant potentials in former Soviet Union, eastern Asia and the southern America. They stated that these geographical potentials can be converted into electricity. It is thus evident that energy can be produced from biomass, which is one of the renewable sources of energies [8]. Peter McKendry, in his works [8, 9], provided an overview of how energy can be generated from biomass. Biomass, by gasification, can also be converted into fuels [10, 11, and 12].

One of the problems common among many developing countries, is the epileptic nature of electricity supply and distribution. This problem generates a ripple effect, by negatively affecting all sectors of such nations' economy. The aim of this research is the proposal of a computational framework, for exploring and adopting biologically-related energy sources. Our focus will be on the application of knowledge to the computational integration of biomass, bio-solar cells and biofuel, as hybrid sources of energy. The objectives of this research are: (i) to conduct literature search and comparative analysis on different energy types (ii) to propose a prototype of a bio-inspired computational framework (iii) to simulate an intelligent energy distribution management system, for a typical residential unit, within the proposed prototype of the bio-inspired computational framework (iv) to discuss the benefits that accrue to the implementation of the proposed framework (v) to demonstrate how this integrated energy sources will solve the existing electricity challenge in developing countries.

The structure of the paper is as follows: comparative description of energy sources is the subject of section 2. This is followed by the section on the description of the proposed bio-inspired computational framework. The demonstration of the simulation of an intelligent energy distribution management system for the framework, is the subject of section 4. Section 5 depicts the simulation results. Section 6 focuses on discussion of results and benefits of implementing the proposed framework. Section 6, also discussed how to adapt these energy sources to provide and manage electricity distribution for remote communities in developing countries. Recommendations is the subject of section 7.

II. Review and comparative description of Energy sources

There are different kinds of sources of clean and sustainable energy. Many literatures have been published to proffer solutions to societal energy needs. In the literature review section of this article, we shall be focusing on the solar, biomass and the bio-fuel sources of energy. We review some of them in our study. Solar energy is a very important source of energy [23, 24]. In a review conducted by Mekhilef and colleagues [25], solar energy conversion was identified as a source of generating heat and producing electricity. Various uses and applications of solar thermal energy were identified. In their work, they specifically focused on the utilization of solar energy in industries and industrial applications, that are solar-energy compatible [25]. The world cumulative solar energy capacity, as at 2009, was estimated to be 22928.9 MW [26]. Solangi and colleagues reviewed different solar energy policies around the world. From their study, they discovered that the most beneficial solar energy policies around the world are the FIT, RPS and incentives [26]. In another study, Mills [27], discussed advances and funding for different solar energy technologies in Europe, Australia and the USA. He also made suggestions for effective support. He further estimated that in the next fifty years (around 2054), the market for solar energy would have greatly increased in order to achieve climate goals. He also suggested that significant storage be installed in order to enhance the market of solar energy [27].

Biomass energy is another source of energy that can be converted to electricity [31]. Energy can be generated from biomass in three major ways [32] namely through; thermo-chemical conversion processes, photo-biological conversion processes, and biochemical conversion processes (anaerobic digestion and fermentation processes [33]). These are conversion processes for biomass [11]. These and other types of energy have been enumerated in Table 1.

We took the literature review a step further, by conducting an extensive tabular comparative analysis among different energy sources, by focusing on their respective merits, demerits, applications and references (See Table 1). From Table 1, based on the demerit of each energy source, we conclude that these energy types are expensive and have the tendency to exhibit unimpressive performances.

II. Proposed Bio-inspired Computational framework

Computational frameworks are essential platforms for solving real-life problems. Some computational frameworks have been previously developed and applied to address other problem domains [78]; [79] [80]. Biomass, biofuel and solar sources of energy are biologically-related clean energy sources. In this section, we describe the various components of our proposed computational framework.

(i) Biomass represents the entirety of organisms or organic matter, with respect to its volume or its quantity. Biomass is a biologically-related source of energy. Biomass [32] has been discussed in the literature review section. In figure 1, there exists a biomass energy plant. Biomass is an energy source that can be tapped, converted [11, 33] and stored in energy banks within this proposed framework.

(ii) Bio-Solar Panel [62]: This novel infrastructure integrates cyanobacteria (blue-green algae) into the building of bio-solar cells in order to continually generate and produce clean energy. Cyanobacteria inhabit terrestrial and aquatic habitats. The mechanism of the bio-solar panel is such that it consistently generates electricity from photosynthesis and respiratory activities of the cyanobacteria. The bio-solar cells can be connected in a matrix-like pattern which could be a 7 by 7 (7 X 7 composition) matrix formation or 10 by 10 (10 X 10 composition) or 1000 by 1000 (1000 X 1000 composition) matrix composition or even matrix patterns of very high dimension. It was estimated in the work of Wei and colleagues [62, 63] that a typical solar panel made up of 60 cells (6 X 10) configuration generated about 200Watts of electrical power.

Photosynthesis process in cyanobacteria is governed by the general photosynthesis equation:

$$\underset{Carbondioxide}{6CO_2} + \underset{Water}{6H_2O} \xrightarrow{Light} \underset{Sugar}{C_6H_{12}O_6} + \underset{Oxygen}{6O_2}$$

…..Equation 1

Cyanobacteria undergo the Calvin cycle, which is a light independent chemical reaction, that reduces Adenosine Triphosphate ((ATP) useful in cellular energy transfer)), and NADPH (the reduced form of Nicotinamide adenine dinucleotide phosphate (NADP+)), to form more carbohydrates such as glucose. Atmospheric carbondioxide is also integrated into RuBP (Ribulose BisPhosphate) [64, 65]. Respiratory processes also occur in cyanobacteria. The light-independent reaction for cyanobacteria is depicted through the Calvin cycle [66, 67] as shown in Equation 2.

$$3CO_2 + 6NADPH + 5H_2O + 9ATP \rightarrow$$
$$glyceraldehyde - 3 - phosphate(G3P) +$$
$$2H^+ + 6NADP^+ + 9ADP + 8P_i$$

………Equation 2

$$(where P_i = inorganic phosphate)$$

The process involves the capturing of CO_2 from the atmosphere, and then newly created NADPH are used, and three carbon sugars are released to ultimately form starch and sucrose.

The bio-solar panel within the proposed bio-inspired computational framework is an infrastructure that absorbs rays and sunlight energy from the sun, thus storing and converting energy from the sun into useful forms. This energy becomes transferred to and stored in an energy banks (See Figure 1), through an energy conversion [6, 23, 26] and storage mechanism [29, 30]. With these features, this infrastructure can be self-sustaining.

(iii) Biofuel energy plant: This facility is the biofuel infrastructure from which energy can be generated, tapped and stored into energy banks. It should be noted that biofuel can be produced from biomass [32, 33].

(iv) Energy Conversion and storage mechanism: These are the mechanisms for converting biomass [11, 32, and 33], biofuel [32] and solar energy into a storable form. Here, the converted energy is stored in energy banks.

(v) Energy banks/reservoirs: These a repository for accommodation and long-term storage of energy obtained from biofuel, biomass and solar sources. Biomass and bio-fuel energy can be stored in dedicated energy banks [68, 69]. Energy generated from bio-solar cells can be stored in fuel cells, super batteries, specialized energy banks and super capacitors [70, 71, 72, 73, and 74].

(vi) Computers and software: These represent an intelligent electricity management system. This will involve the development of a smart electricity distribution and cloud computing infrastructure [75]. Here, the advantage of using computer systems is to help automate the process of electricity distribution and management. The computer systems will help to contribute to the control and management of the energy system. Furthermore, the software that will be used for managing and distributing energy will be resident on such systems. Hardware and servers will complement such computer systems. They will help to effectively and efficiently channel electricity, which in turn, can be distributed to the local communities in need of electricity. The cost of these computer systems in terms of energy consumption will be minimal. The output decisions for this computer systems will be to depict the amount of energy allocated to each household within a local community, the amount of energy consumed by each household, and the reserved energy left in the energy banks.

(vii) Servers and Hardware: These are the equipment and servers that will ensure effective communication and transmission of electricity to appropriate quarters.

(viii) Electricity distribution switch box and controller: The computers and software communicate with hardware to distribute electricity through the switch box to communities where the electricity is needed.

(ix) A small community powered by electricity: In this proposed computational framework, we used a sample or prototype of just ten (10) houses within a small community (See Figure 1).

This computational framework provides a platform to store, manage, and distribute energy. Natural and biological sources of energy, that have been tapped, and converted, into useful forms, are managed by the computational framework, for electricity generation, to rural communities.

III. Simulation of an Intelligent Energy Distribution Management System

Simulation and modeling play important roles in the process of problem-solving. They have been applied at solving different types of problems [81][82] [83][84].

For the purpose of our experimentation, we performed two (2) separate simulations. First, we used a simulation software known as the MATLAB-Simulink simulation tool to depict the use of bio-solar cells systems in connection with a utility grid, via a boost converter, and voltage source controller. The function of the boost converter is to increase the natural voltage generated by the PV array, in order to increase both the efficiency and rate at which the PV arrays generate electricity. It also ensures a backup storage of energy in the battery. We included a Maximum Power Point Tracking (MPPT) in the boost converter, in order to extract maximum available power from a PV module. The voltage produced by the boost converter is converted by the voltage source converter to 250+/- AC so that loads in residential units can be powered up (See Figure 4 and 5). We also used Window SDK7.1 in Simulink as a C compiler. The compiler was included in Matlab, by using mex-setup in the Matlab command window, after we successfully installed the SDK7.1.

Second, we implemented the second simulation by using a Proteus Design Suite (PDS) software (developed by Labcenter Electronics; https://www.labcenter.com/pcb/#tuning), and by embedding the Arduino library into it. A Proteus Design Suite software is a design suite that can be used for electronic design automation and microcontroller simulation.

In our experiment, the Arduino library was actually incorporated into the library folder of the program file in the Labcenter electronics folder. The compiled C++ codes written in the Arduino IDE (See Figure 2), helps the Arduino board to the control the board (See Figure 3).

The Proteus Design Suite (PDS) was redesigned to consist of simulation of a 5V battery, a potentiometer, Relays, a 16 by 2 Liquid Crystal Display (LCD), Lamps, Arduino Uno board (See Figure 4). We used LCDs because this is just a prototype. The LCD helps to display the value and readings of the battery. Pin4 of the LCD was connected to pin 12 of the Arduino board. Pin 6 was connected to Pin 11, Pin 13 was connected to Pin 5, and pin 14 was connected to pin 4. The battery was connected to the Arduino board to power the board, and turn on appliances. Relays were used for automatic switching on and off of circuits. The lamps served as loads and were connected to the relay. Potentiometer helped to measure the voltage in the battery. We adopted and focused on voltage because this is just a prototype. The implementation of the real system will focus on energy with Megawatts (MWh) units.

In summary, the minimum hardware requirements for our implementation include: A personal computer, Processor: multiprocessor, Hard disk: 500GB or higher. Ram: 4GB or higher. The software requirements for this implementation include: Windows operating system 7/8/10, Microsoft Visual Studio 2010, .Net Framework 4.5, Windows SDK 7.1, C++ programming language compiler, Arduino Library for Proteus. The simulation software are Matlab-Simulink

R2013a or higher and the Proteus Design Suite simulation software 8.0 or higher.

IV. Results of Simulation

The results produced by the simulations, were in form of graphs, digital measurements, and display graphics. The average value of voltage obtained from the PV array with respect to changes in the sun's irradiance is depicted by the Pmean graph. The V graph shows the amount of voltage being produced after it has been converted by the voltage source converter. The ratio of the pulse width to the pulse period is depicted by the duty cycle graph. The intensity of the sunlight that hits the bio-solar panels is depicted by the irradiance of the sun. Changes in the irradiance affect the amount of voltage the bio-solar panels can produce (See Figure 6, 7, 8, 9 and 10).

V. Discussion

A. *Discussion of the results of the simulation*

In Figure 7, the output depicted in the Proteus Design Suite (PDS) software, shows when the voltage in the battery is higher than the first preset level. In Figure 8, the output depicted in the Proteus Design Suite (PDS) software, revealed when the voltage in the battery is lower than the first preset level. For Figure 9, the voltage in the battery is lower than the second preset level. In Figure 10, the Proteus Design Suite (PDS) software display showed that the voltage in the battery is lower than the third preset level. An analogy of this output is described as follows:

In order to have a proper understanding of this output, there is a need to provide a vivid description of the scenario. For instance, in a residential unit, assuming we have a battery that is capable to storing 50V from the bio-solar panel, and it needs to supply voltage to appliances within a residential unit. Let us assume that there are three (3) appliances within the residential unit namely; bulb (6V), standing fan (10V), and TV (25V). We set bulb at high priority because if someone enters a residential apartment at night, the person requires light to see in order to switch on the fan and then the TV.

The general scenario is when the intelligent energy management and distribution system checks if the amount of voltage present in the battery is capable of powering all the appliances within the residential unit. If it has the capability, then the battery powers all appliances.

First scenario, if our first preset level is 40V, this implies that the amount of voltage that can be allowed out of the bio-solar powered battery is close to 40V because the battery needs some voltage to maintain its reserved state. Therefore, with our first preset level at 40V, we assume that the intelligent system turns on the Fan (10V) at medium priority, turns on the bulb(6V) at highest priority, and because the battery needs some voltage for its reserved state, it will not have sufficient voltage to power the TV(which requires 25V). Thus the TV is automatically turned off and set as lowest priority.

Second scenario, if our second preset level is 30V, this implies that the amount of voltage that can be supplied by the bio-solar powered battery is close to 30V since the battery still needs some voltage to support its reserved state. Thus, with our second preset level at 30V, we assume that the intelligent system turns on the bulb (6V) at highest priority, since our battery cannot power the TV (25V) – lowest priority due to insufficient voltage, the TV will be turned off. The intelligent system will also turn off the fan (10V)- medium priority, because the battery needs some voltage to sustain its reserved state.

Third scenario, if our third preset level is 20V, this implies that the voltage that can be generated by the bio-solar powered battery is close to 20V because the battery needs voltage to sustain its reserved state. With a third preset level of 20V, we assume that our intelligent system turns off all appliances and displays RESERVE on the Liquid Crystal Display (LCD).

B. *Benefits of the proposed Bio-inspired computational framework*

Some of the benefits of the proposed framework are as follows: (i) It will help supply well optimized energy to appliances within residential units of small communities (ii) The energy will be well managed using Information Technology and Computational equipments (iii) Energy generated can be stored and later utilized (so there is no wastage of resources) (iv) The computers, hardware, server are also powered by energy from the energy banks (v) It will help solve the problem of dwindling electricity supply currently experienced in many local communities in Africa and other developing nations.

This technology, if fully implemented, can be applied to support Research and Development (R&D) on a small scale. This technology will also be able to support education, and proffer solution to the existing electricity challenge among small communities in developing countries. It will act as an alternative energy source to provide better services. The evidence from the simulation experiments, in this research, provides justification, that it is possible in real-life, to implement this bio-inspired computational framework.

VI. Recommendations

This proposed bio-inspired computational framework should be constructed in a secured environment. Adequate monitoring and security should be provided for the framework, after it has been implemented. The constructed prototype should be weather-proof – it should be built in a secured facility. Storm, excessive heat, or other adverse weather conditions should not be able to affect it. The constructed prototype should be well-tested. Mobile applications can be integrated and used to activate the monitoring of energy distribution and management.

Government of developing nations, Non-Governmental Organizations (NGOs) and relevant international scientific research bodies, should fund research in this direction, in order to solve existing electricity management challenges among developing countries.

VII. Conclusion

We proposed a bio-inspired computational framework for managing and supplying energy to residential units. We implemented a simulation of a sub-set of this framework. This framework, if fully implemented real-life, in Africa and other developing countries, will benefit local communities that have dwindling electricity supplies. Appliances will be well-managed.

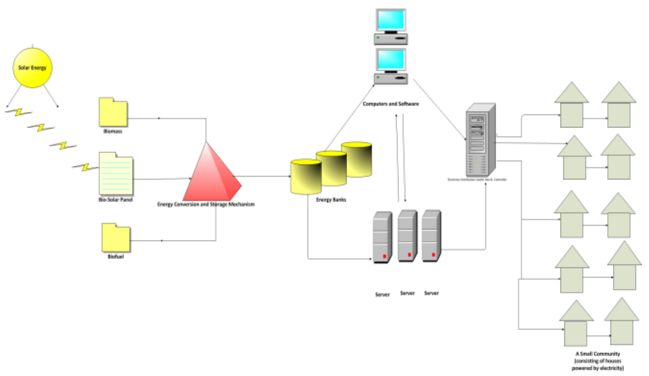

Figure 1: Schematic depiction of the proposed bio-inspired computational framework

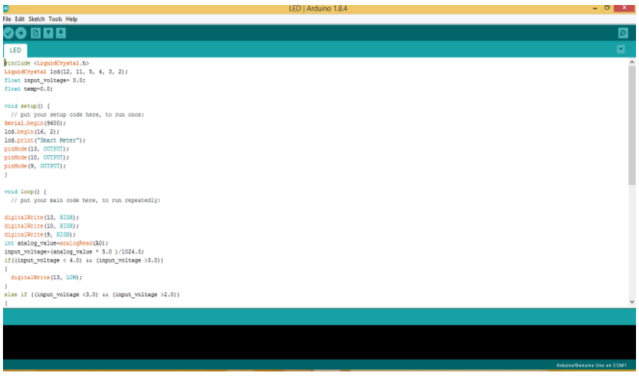

Figure 2: Screenshot of the Arduino code written and compiled in the Arduino IDE. The Arduino code written in C++ controls the Arduino board. This enables the intelligent load shedding operation based on priorities set by each user.

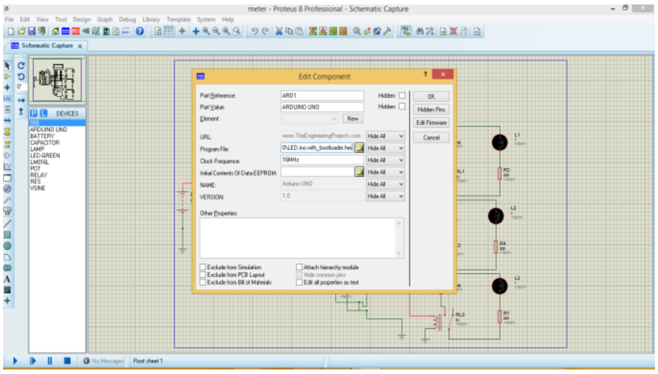

Figure 3: screenshot of how the code is included into the Arduino board on Proteus. After the code has been compiled in the Arduino IDE, it is included in the Arduino board under the program file section like this.

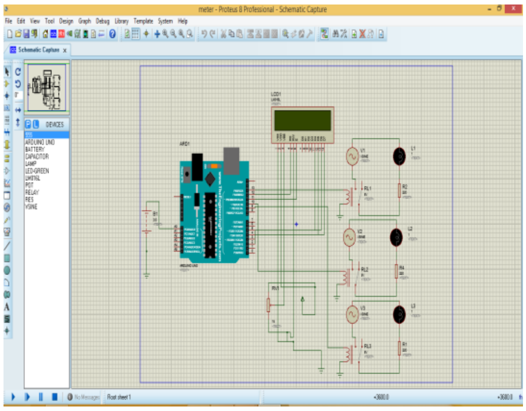

Figure 4: User interface design in Proteus

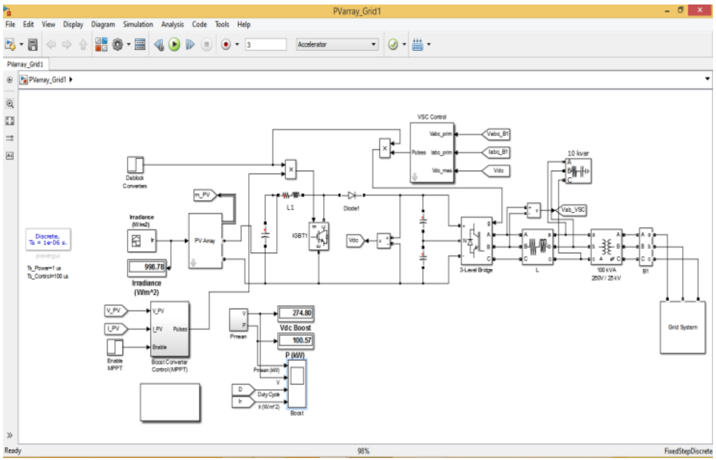

Figure 5: User interface design in Simulink

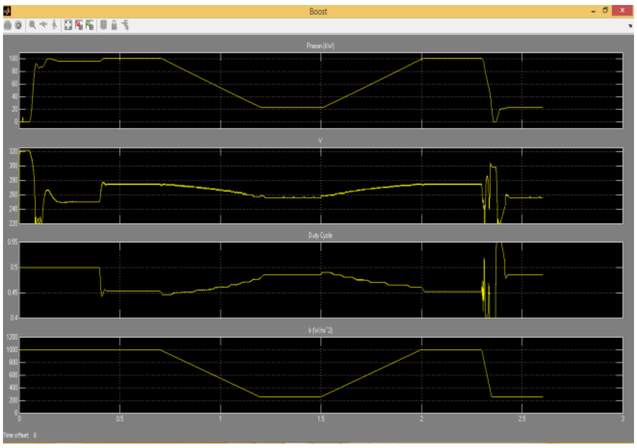

Figure 6: graph output in Simulink

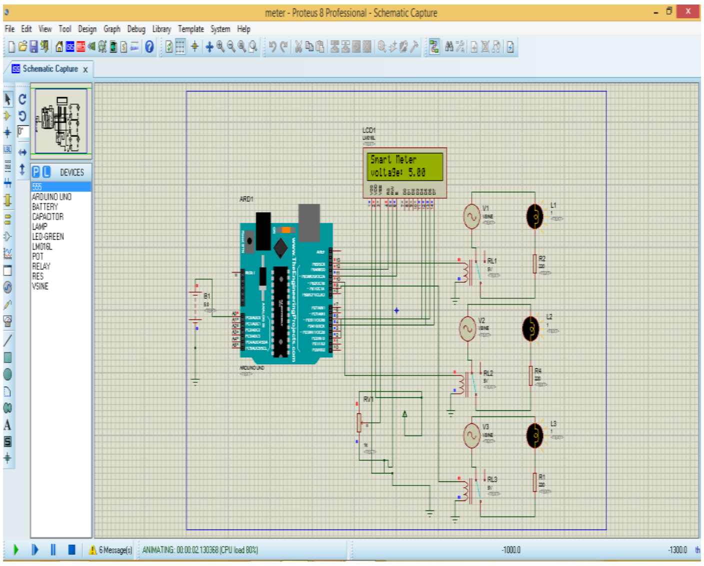

Figure7: Output in Proteus Design Suite when the voltage in the battery is higher than the first preset level

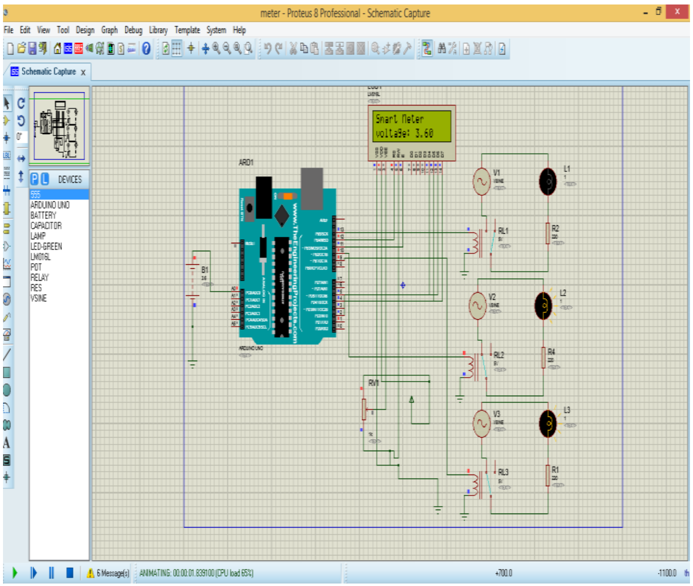

Figure 8: output display in Proteus Design Suite(PDS) when the voltage in the battery is lower than the first preset level

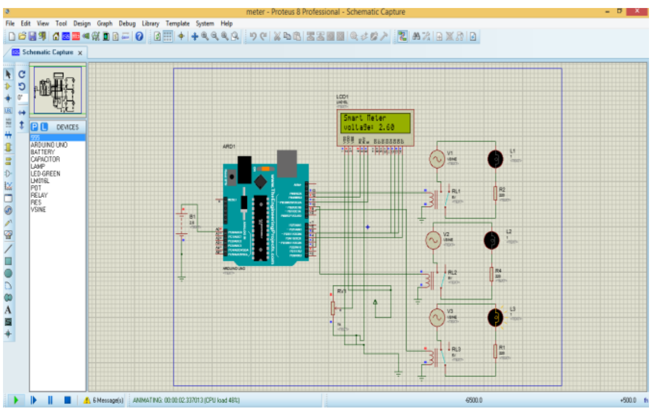

Figure9: output display in Proteus Design Suite(PDS), when the voltage in the battery is lower than the second preset level.

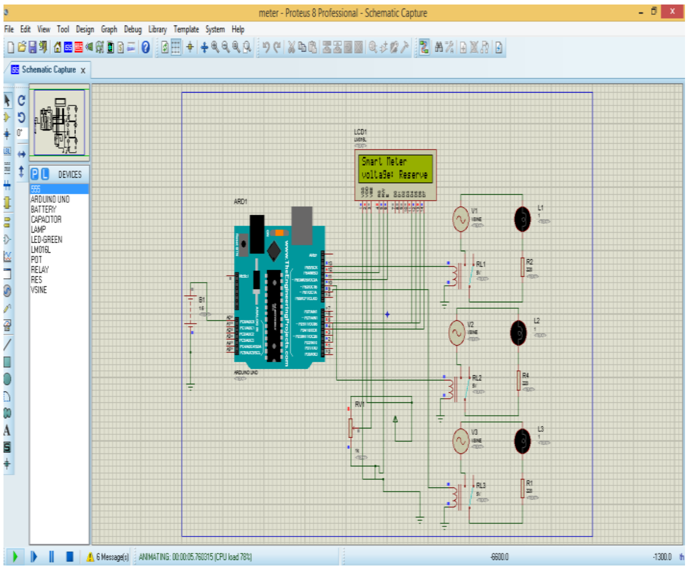

Figure10: output display in Proteus Design Suite(PDS), when the voltage in the battery is lower than the third preset level.

ACKNOWLEDGMENT

We want to thank the INTECH Conference Committee 2018 for granting us a 40% scholarship waiver for the registration fee for this conference.

We also thank Stellenbosch University for providing part support for the payment of our registration/publication fee for the INTECH 2018 conference.

We want to thank the TORPF Foundation for partially supporting this research in kind, through the provision of computers, internet and other resources at the early stages of the research.

AUTHOR CONTRIBUTION:

OO conceived the research. OO, FO and AO contributed to the literature survey. OO and BO conducted the experiments and contributed to the implementations. OO wrote the manuscript. All authors approved the final manuscript

REFERENCES

[1] C.B. Field, J. Elliott Campbell, David B. Lobell, "Biomass energy: the scale of the potential resource", Trends in Ecology and Evolution, 2008, vol. 23(2), pp.65–72

[2] M. Hoogwijk, A. Faaij, R. van den Broek, Göran Berndes, D. Gielen, W. Turkenburg, "Exploration of the ranges of the global potential of biomass for energy". Biomass and Bioenergy, 2003, vol. 25(2), pp.119–133.

[3] V Dornburg, APC Faaij.(2001). Efficiency and economy of wood-firedbiomass energy systems in relation to scale regarding heat and power generation using combustion and gasification, - Biomass and Bioenergy, 2001

[4] R. Lal. (2005). World crop residues production and implications of its use as a biofuel. Environment International 31(4): 575–584.

[5] M. Hoogwijk, A. Faaij, B. Eickhout, B. de Vries, W. Turkenburg. "Potential of biomass energy out to 2100, for four IPCC SRES land-usescenarios". Biomass and Bioenergy 2005, vol. 29(4), pp. 225–257

[6] JAMES BARBER, (2006). Biological solar energy. Philosophical Transactions of the Royal Society A (2007) 365, 1007–1023.

[7] Nathan S. Lewis and Daniel G. Nocera.(2006). Powering the planet: Chemical challenges in solar energy utilization, Proceedings of the National Academy of Sciences 103 (43):15729–15735

[8] Peter McKendry(2007). Energy production from biomass (part 1): overview of biomass, Bioresource Technology 83(1):37–46.

[9] Peter McKendry.(2002). Energy production from biomass (part 2): conversion technologies, Bioresource Technology 83(1):47–54

[10] Peter McKendry. (2002). Energy production from biomass (part 3): gasification technologies. Bioresource Technology 83(1):55–63.

[11] M.M. Küçük, A. Demirbaş (1997). Biomass conversion processes, Energy Conversion and Management 38(2): 151–165.

[12] Ayhan Demirbaş.(2001). Biomass resource facilities and biomass conversion processing for fuels and chemicals, Energy Conversion and Management 42(11):1357–1378.

[13] Haefele, W. (1990). Energy from nuclear power. Scientific American 263, 136 - 144 (1990) ; doi:10.1038/scientificamerican0990-136

[14] C.D. Bowman, E.D. Arthur, P.W. Lisowski, G.P. Lawrence, R.J. Jensen, J.L. Anderson, B. Blind, M. Cappiello, J.W. Davidson, T.R. England, L.N. Engel, R.C. Haight, H.G. Hughes III, J.R. Ireland, R.A. Krakowski, R.J. LaBauve, B.C. Letellier, R.T. Perry, G.J. Russell, K.P. Staudhammer,... G. Versamis, (1992).

[15] Nuclear energy generation and waste transmutation using an accelerator-driven intense thermal neutron source, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 320(1–2):336-367.

[16] Benjamin K. Sovacool. (2008). Valuing the greenhouse gas emissions from nuclear power: A critical survey, Energy Policy 36(8):2950–2963.

[17] Rosa, L.P.; Schaeffer, R.(1994).Greenhouse gas emissions from hydroelectric reservoirs, Ambio; ISSN 0044-7447; Worldcat; CODEN AMBOCX; v. 23(2); p. 164-165

[18] Rudd, J.W.M.; Hecky, R.E.; Harris, R.; Kelly, C.A.(1993).Are hydroelectric reservoirs significant sources of greenhouse gases?, Ambio; ISSN 0044-7447; Worldcat; CODEN AMBOCX; v. 22(4); p. 246-248.

[19] N. V. Arvanitidits and J. Rosing, "Composite Representation of a Multireservoir Hydroelectric Power System," in IEEE Transactions on Power Apparatus and Systems, vol. PAS-89, no. 2, pp. 319-326, Feb. 1970; doi: 10.1109/TPAS.1970.292595

[20] Berkes, F.(1981). Some environmental and social impacts of the James Bay hydroelectric project, Canada, : J. Environ. Manage.; (United States); Journal Volume: 12:2

[21] Ruggero Bertani, (2012). Geothermal power generation in the world 2005–2010 update report, Geothermics 41:1–29.

[22] DiPippo, R.(1980). Geothermal energy as a source of electricity. A worldwide survey of the design and operation of geothermal power plants, Technical Report; Report Number(s): DOE/RA/28320-1

[23] Milora, S.L., Tester, J.W., (1976). Geothermal energy as a source of electric power. Thermodynamic and economicdesign criteria, Massachusetts Institute of Technology,Cambridge, MA; OSTI Identifier: 7310742.

[24] T.R. Cook, D.K. Dogutan, S.Y. Reece, Y. Surendranath, T.S. Teets, and D. G. Nocera. (2010). Solar Energy Supply and Storage for the Legacy and Nonlegacy Worlds, Chemical Reviews, 2010, 110 (11), pp 6474–6502.

[25] Nathan S. Lewis. (2007). Toward Cost-Effective Solar Energy Use, Science 315 (5813):798-801; DOI: 10.1126/science.1137014.

[26] S. Mekhilef, R. Saidur, A. Safari, (2011). A review on solar energy use in industries, Renewable and Sustainable Energy Reviews 15(4):1777–1790.

[27] K.H. Solangi, M.R. Islam, R. Saidur, N.A. Rahim, H. Fayaz, (2011). A review on global solar energy policy, Renewable and Sustainable Energy Reviews 15 (2011) 2149–2163.

[28] D. Mills, (2004). Advances in solar thermal electricity technology, Solar Energy 76 (2004) 19–31.

[29] Various,2000. Karapanagiotis N. (Ed.),Environmental impacts from the use of solar energy technologies. THERMIE.

[30] Furkan Dincer (2011). The analysis on photovoltaic electricity generation status, potential and policies of the leading countries in solar energy, Renewable and Sustainable Energy Reviews 15 (2011) 713–720.

[31] Marcel Suri, Thomas A. Huld, Ewan D. Dunlop, Heinz A. Ossenbrink.(2007). Potential of solar electricity generation in the European Union member states and candidate countries, Solar Energy 81 (2007) 1295–1305.

[32] Ayhan Demirbas.(2002).Electricity from Biomass and Hydroelectric Development Projects in Turkey, Energy Exploration & Exploitation 20(4):325-335.

[33] A.V. Bridgwater (2003). Renewable fuels and chemicals by thermal processing of biomass, Chemical Engineering Journal 91 (2003) 87–102.

[34] Sergio Canzana Capareda (2003)Biomass Energy Conversion, Chapter 10: Sustainable Growth and Applications in Renewable Energy Sources, pp.209-226.

[35] Clemens Posten, Georg Schaub (2009). Microalgae and terrestrial biomass as source for fuels—A process view, Journal of Biotechnology 142(1):64–69.

[36] John C. Clifton-brown, Paul F. Stampfl, Michael B. Jones(2004). Miscanthus biomass production for energy in Europe and its potential contribution to decreasing fossil fuel carbon emissions, Global Change Biology 10(4):509–518.

[37] S. Czernik and A. V. Bridgwater. (2004). Overview of Applications of Biomass Fast Pyrolysis Oil, Energy & Fuels 2004, 18, 590-598.

[38] Enrico Barbier (2002). Geothermal energy technology and current status: an overview, Renewable and Sustainable Energy Reviews 6(1–2):3–65.

[39] Ingvar B. Fridleifsson, (2003). Status of geothermal energy amongst the world's energy sources, Geothermics 32(4–6):379–388.

[40] Ingvar B Fridleifsson .(2001). Geothermal energy for the benefit of the people, Renewable and Sustainable Energy Reviews 5(3): 299–312.

[41] John W Lund, Derek H Freeston (2001). World-wide direct uses of geothermal energy 2000, Geothermics 30(1):29–68.

[42] John W. Lund, Derek H. Freeston, Tonya L. Boyd,(2005). Direct application of geothermal energy: 2005 Worldwide review, Geothermics 34(6):691–727.

[43] J. Sigurvinsson, C. Mansilla , B. Arnason, A. Bontemps, A. Marechal , T.I. Sigfusson , F. Werkoff. (2006). Heat transfer problems for the production of hydrogen from geothermal energy, Energy Conversion and Management 47 (2006) 3543–3551.

[44] F.W. Geels, B. Verhees(2011). Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986), Technological Forecasting & Social Change 78 (2011) 910–930.

[45] Ralph E.H. Sims,Hans-Holger Rogner,Ken Gregory,(2003). Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation, Energy Policy 31 (2003) 1315–1326.

[46] Christopher Graves, Sune D. Ebbesen, Mogens Mogensen, Klaus S. Lackner,(2011). Sustainable hydrocarbon fuels by recycling CO2 and H2O with renewable or nuclear energy, Renewable and Sustainable Energy Reviews 15(1):1–23.

[47] Benjamin K. Sovacool, (2010). A Critical Evaluation of Nuclear Power and Renewable Electricity in Asia. Journal of Contemporary Asia 40(3):393–400; doi:10.1080/00472331003798350.

[48] Benjamin K. Sovacool, (2009). The Accidental Century - Prominent Energy Accidents in the Last 100 Years Archived August 21, 2012, at the Wayback Machine.

[49] http://www.forbes.com/sites/jamesconca/2012/06/10/energys-deathprint-a-price-always-paid/ with and without Chernobyl's total predicted, by the Linear no-threshold, cancer deaths included.

[50] Nuclear Power Prevents More Deaths Than It Causes | Chemical & Engineering News". Cen.acs.org. (Retrieved 2014-01-24).

[51] Kharecha, P. A.; Hansen, J. E. (2013). "Prevented Mortality and Greenhouse Gas Emissions from Historical and ProjectedNuclear Power". Environmental Science & Technology. 47 (9): 4889. Bibcode:2013EnST..47.4889K. doi:10.1021/es3051197.

[52] Sovacool, B. K. (2008). The costs of failure: A preliminary assessment of major energy accidents, 1907–2007". Energy Policy 36 (5): 1802–1820. doi:10.1016/j.enpol.2008.01.040.

[53] Dennis Normile (2012). Is Nuclear Power Good for You? Science 337 (6093): 395. doi:10.1126/science.337.6093.395-b.

[54] Richard Schiffman (2013). "Two years on, America hasn't learned lessons of Fukushima nuclear disaster". The Guardian. London.

[55] Martin Fackler (2011-06-01). Report Finds Japan Underestimated Tsunami Danger. The New York Times.

[56] Andrew C. Revkin (2012). Nuclear Risk and Fear, from Hiroshima to Fukushima. The New York Times.

[57] Frank N. von Hippel (September–October 2011).The radiological and psychological consequences of the Fukushima Daiichi accident. Bulletin of the Atomic Scientists. 67 (5): 27–36. doi:10.1177/0096340211421588.

[58] Arifumi Hasegawa, Koichi Tanigawa, Akira Ohtsuru, Hirooki Yabe, Masaharu Maeda, Jun Shigemura, et al., (2015). Health effects of radiation and other health problems in the aftermath of nuclear accidents, with an emphasis on Fukushima, The Lancet 2015.

[59] Henrik Lund, (2005). Large-scale integration of wind power into different energy systems, Energy 30(13):2402–2412.

[60] G.M. Joselin Herbert, S. Iniyan, E. Sreevalsan, S. Rajapandian, (2007). A review of wind energy technologies, Renewable and Sustainable Energy Reviews 11(6):1117–1145.

[61] Aynur Ucar, Figen Balo., (2009). Evaluation of wind energy potential and electricity generation at six locations in Turkey, Applied Energy 86 (2009) 1864–1872.

[62] Eftichios Koutroulis and Kostas Kalaitzakis, (2006). Design of a Maximum Power Tracking System for Wind-Energy-Conversion Applications, IEEE Transactions on Industrial Electronics 53(2):486-494.

[63] Xuejian Wei, Hankeun Lee, Seokheun Choi.(2016). Biopower generation in a microfluidic bio-solar panel. Sensors and Actuators B: Chemical, 2016; 228: 151 DOI: 10.1016/j.snb.2015.12.103.

[64] Seokheun Choi. (2015). Microscale microbial fuel cells: Advances and challenges, Biosensors and Bioelectronics 69:(8–25)

[65] Reece J, Urry L, Cain M, Wasserman S, Minorsky P, Jackson R. Biology (International ed.). Upper Saddle River, NJ: Pearson Education. pp. 235, 244. ISBN 0-321-73975-2.

[66] Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson, (2014), Campbell Biology, (10th Edition), | Benjamin Cummings | 1504 pp | ISBN-13: 9780133447002.

[67] Bassham J, Benson A, Calvin M (1950). "The path of carbon in photosynthesis" (PDF). J Biol Chem. 185 (2): 781–7. doi:10.2172/910351. PMID 14774424.

[68] Campbell, Neil A.; Brad Williamson; Robin J. Heyden (2006). Biology: Exploring Life. Boston, Massachusetts: Pearson Prentice Hall. ISBN 0-13-250882-6.

[69] A. Jirapornanan, (2010). Study of smart grid for Thailand and identification of the required research and development,PICMET 2010 Technology Management for Global Economic Growth,Phuket, pp. 1-6.;

[70] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5603365&isnumber=5602021

[71] U. Kwhannet ; N. Sinsuphun ; U. Leeton ; T. Kulworawanichpong. (2010). Impact of energy storage in micro-grid systems with DGs, IEEE Power System Technology (POWERCON), 2010 International Conference on, 24-28 Oct. 2010.

[72] Prabhu, Rahul R. (13 January 2013). "Stationary Fuel Cells Market size to reach 350,000 Shipments by 2022". Renew India Campaign. Retrieved 2013-01-14.

[73] BioSolar Plans to Lower the Cost of Solar Power With Energy Storage Technology.(2015). http://finance.yahoo.com/news/biosolar-plans-lower-cost-solar-080100079.html (Accessed: 19-01-2017)

[74] BioSolar Teams With UCSB to Develop a Low Cost Supercapacitor for Solar EnergyStorage, (2014); http://finance.yahoo.com/news/biosolar-teams-ucsb-develop-low-070100705.html; (Accessed: 19-01-2017)

[75] BioSolar Sets Record with Low Cost Energy Storage Supercapacitor, (2014); http://www.biosolar.com/view_news.php?id=103&PHPSESSID=cc64e396e966b618f344bc0f6bca5310; (Accessed: 19-01-2017)

[76] Michelle Rasmussen, Alexander Shrier and Shelley D. Minteer (2013). High performance thylakoid bio-solar cell using laccase enzymatic biocathodes, Phys. Chem. Chem. Phys., 2013, 15, 9062—9065.

[77] Dragan S. Markovic, Dejan Zivkovic, Irina Branovic, Ranko Popovic, Dragan Cvetkovic (2013), Smart power grid and cloud computing, Renewable and Sustainable Energy Reviews 24:566–577.

[78] J.O Daramola, V.C. Osamor, and O.O Oluwagbemi (2008) A Grid based framework For Pervasive HealthCare Using Wireless Sensors Networks: A Case for Developing Nations, Asian Journal of Information Technology, 7(6):260 – 267.

[79] Oluwagbemi, O.O. (2012), Development of a prototype hybrid-grid-based computing framework for accessing bioinformatics databases and resources, Scientific Research and Essays 7(7): 730-739;

[80] Oluwagbemi O. and Clarance YS, (2012), Computational Predictive Framework towards the Control and Reduction of Malaria incidences in Africa, Egyptian Computer Science Journal ECS, 36 (2): 1-17.

[81] Oluwagbemi O, Ogeh D,, Adewumi A, Fatumo S (2016), Computational and Mathematical Modeling: Applicability to Infectious Disease Control in Africa – Asian Journal of Scientific Research 9(3):88-105.

[82] Oluwagbemi O. (2012), Promoting public health and safety: A predictive modeling software analysis on perceived road fatality contributory factors, IEEE African Journal of Computing and ICTs 5(5): 23-36.

[83] Oluwagbemi O.O, (2010) Reducing Road-Traffic Accidents on African Roads through a Computer Simulation Programming Approach, Australian Journal of Basic and Applied Sciences, 4(8): 3016-3024.

[84] Oluwagbemi O, Adewumi A and Akindun F.(2013), Insights from computational modeling and simulation towards promoting public health among African countries, ICT4 Africa International Conference, , Zimbabwe, pages 1-13; Available online at: http://www.ictforafrica.org/attachments/section/4/ict4africa2013_submission_29.pdf

Table 1. Comparative depiction of previously known sources of clean and sustainable energy

Energy sources	Merits	demerits	applications	References
Solar energy	improves energy stability, increases energy sustainability, enhances system efficiency, conversion reduction; Renewable energy, reduced negative environmental impact, reduces the emissions of greenhouse gases and preveents toxic gas emissions, (SO2,particulates); reclamation of degraded land; reduces the required transmission lines of electricity grids; and improves the quality of water resources; Job creation; provision of energy market; used to generate electricity; cheaper than other energy sources	Solar energy conversion equipment are expensive; unfavorable geographical and climatic variability; uneven seasonal distribution of solar energy resource;	Producing energy and electricity in industries, educational institutions, research institutions, homes, government parastatals.	[25][26][27][28][29][30]
Biomass & bio-fuels energy	Used to generate electricity; Less pollution emission; more economic benefits; provision of more jobs; clean energy; no harmful emissions; cheap and readily available renewable energy; decresases fossil fuel carbon emissions; cheaper than other energy sources	Expensive preliminary setup cost; requires large land mass.	Production of bio-fuels, gasification, industrial energy productions, residential electricity generation; bio-oils used to produce chemicals and fertilizers, bio-oils that can be used to operate engines, turbines and boilers	[3,4,5,8,9,10,11,12] [31,34,35,36]
geothermal energy	Used to generate electricity; cost-competitive with other energy sources; reduces the emission of greenhouse gases.	Heat transfer problem;	Space heating; industrial processes; greenhouses heating, aquaculture pond heating, district heating, bathing and swimming pool heating; agricultural drying, snow melting; raceway heating	[37][38][39][40][41][42]
nuclear energy	Used to generate electricity; used for powering industrial processes;	Nuclear accidents leads to death; cancer infection; Evacuation as a result of nuclear attacks, accidents can lead to chronic depression; psychosomatic medical problems; in worst cases, suicide. Very expensive to set up; requires advanced expertise	used for powering industrial processes; used for supplying electricity to large cities;	[43][44][45] [46][47][48] [49][50][51] [52][53][54] [55][56][57]
hydroelectric energy	Used to generate electricity; used for powering industrial processes;	Expensive to setup; Large water body is essential;	used for powering industrial processes; used for supplying electricity to large cities;	[16, 17, 18, 19]
wind energy	Used to generate electricity; used for powering industrial processes;	Expensive to setup; Windy environment is essential	used for powering industrial processes; used for supplying electricity to large cities;	[58, 59, 60, 61]